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DECISION SCIENCES INSTITUTE
A Blockchain-Based Deep Learning Neural Network

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ABSTRACT

This research proposes a blockchain-based deep learning neural network. The proposed deep learning neural network uses blocks in the blockchain as neurons to learn and memorize knowledge. The blockchain-based deep learning neural network is shared and distributed on the Internet and it is also a constantly adapted learner with more blocks being added on the blockchain. There are many advantages of applying blockchain in the deep learning architecture, for example, it is more secure, constantly learning from doing, shared and distributed memories, and specialized in a specific knowledge domain.

KEYWORDS: Blockchain, Deep Learning, Biological Neural Network, Artificial Neural Network, Artificial Intelligence

INTRODUCTION

The rises of blockchain technologies and the bloom of cryptocurrencies (Tapscott & Tapscott, 2016) have been attracting more and more interests and investment in the business community. Blockchain has not only the potential to disrupt the existing business processes in finance, but also in many other areas (Nofer *et al.* 2017). “Blockchain is emerging as a game changing technology in many industries.” (Salviotti *et al.* 2018)

Similarly, widely adopted artificial intelligence (AI) (e.g., machine learning) and robotic technologies have been greatly changing the business landscape and our daily life. In addition, advancement in AI and automation is replacing many jobs in many industry sectors. McKinsey Global Institute’s report (2017) predicts that by 2030, AI and automation may displace 400 million to 800 million people who need to switch job categories and learn new skills.

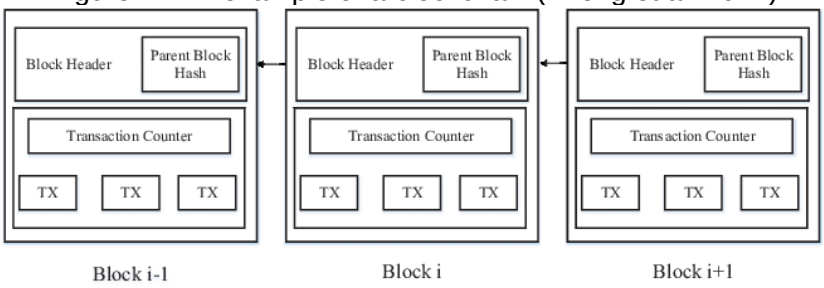
By investigating blockchain and AI together, this research proposes a new deep learning architecture aiming to explore new algorithm and application of AI in the business community. Deep learning is a type of machine learning, which is also one of the most important disciplines in AI. This paper is organized as follows. We introduce blockchain, deep learning and neural network first, and then propose a blockchain-based deep learning neural network followed by discussing its academic and practical implications.

BLOCKCHAIN

Blockchain is a binary tree data structure in which two sibling tree nodes are linked to its parent node. This binary tree structure is called “Merkle tree” (Merkle 1988) and a tree node is a data object called “block” in the blockchain. A “block” consists of a block header and a block data set. The block data consists a large number of messages (e.g., bank account transactions) and the summarized information of the entire Merkle tree up to the current tree node. This summarized Merkle tree node information is hashed/encrypted. The block header consists of the current

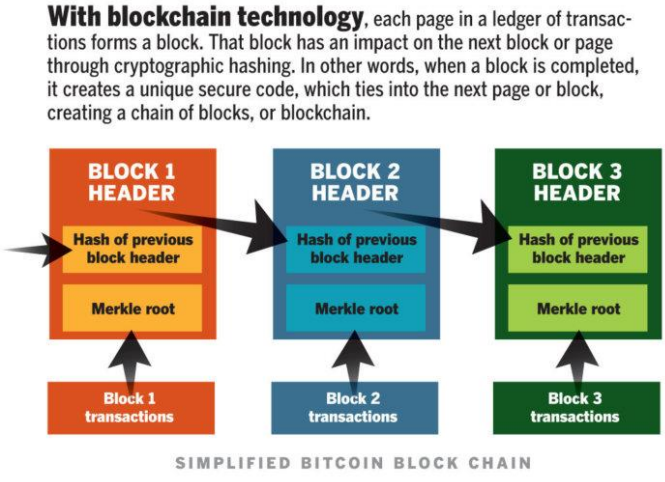
Merkle tree node's summary information and the hash value of the preceding (parent's) block header (Fill and Härer 2018). Accordingly, all the blocks in the Markle tree are linked and forms so-call blockchain as shown below.

Figure 1: An example of a blockchain (Zheng et al. 2017)



The blockchain or the Merkle tree is a peer-to-peer distributed and shared data management system on the Internet in that a block can be stored anywhere - at any IP address or on a computer on the Internet. Each block (e.g., on a computer) in the blockchain can keep a copy of the entire blockchain. The following diagram illustrates a business application of blockchain, a distributed shared transaction ledge system. When a new transaction gets into the blockchain in which a block represents a company, the block "executes algorithms to evaluate and verify the history of the individual blockchain block that is proposed." (Hassell 2016). If this transaction is verified to be valid in terms of the transaction history and signature, the transaction is added to the block. The new transaction is then broadcasted to the entire network in which all copies of this blockchain are updated. The blockchain has many advantages, for example, the information is transparent and any changes can be seen by all owners of the blockchain, it is more secure due to high degree encryption, the information is distributed and shared without concerns of data lost, etc.

Figure 2: An example of blockchain application (Hassell 2016)

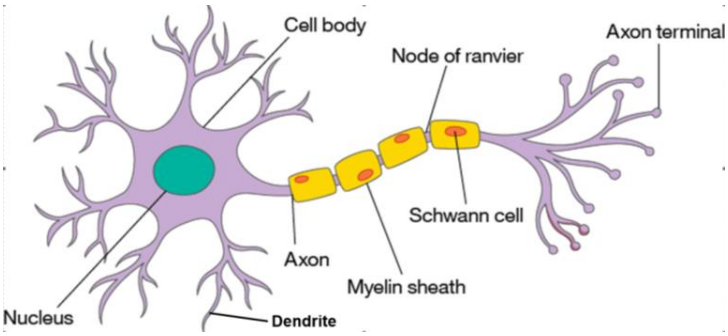


DEEP LEARNING AND ARTIFCIAL NEURAL NETWORKS

Before we discuss the deep learning algorithm, we introduce human neural networks and artificial neural networks.

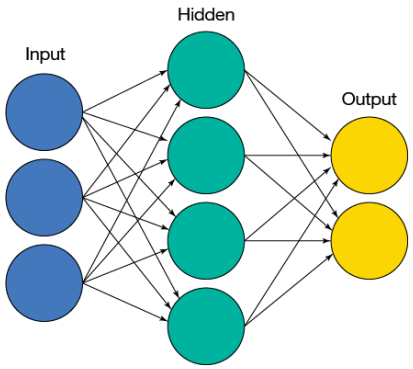
Biological neural networks like human brains store and process information through a huge number of neurons shown in Figure 3. A neuron is a nerve cell that receives and processes information through electrical and chemical signals. In a neuron cell, the dendrites receive signals, the cell body processes them, and the axon sends outputs (processed input signals) to other neurons. All neurons are connected in a nonlinear manner forming a network.

Figure 3: Neuron – a major components of biological neural network (Kienzler 2017)



An artificial neural network is a mathematical model that simulates the biological neural network. The artificial neural network consists of several layers: input layer, output layer and hidden layers. There can be many hidden layers. Each layer has many nodes which mimic biological neurons. A node consists a mathematical function which takes the input signals from the nodes in the previous layer. When the input signal strength is above a threshold value, the function is activated and generates an output signal sent to the nodes in the next layer. Accordingly, the function in a node is called activation function. See a simplified artificial neural network model in Figure 4.

Figure 4: Artificial Neural Network (Kienzler 2017)



Although the artificial neural network models the biological neural network, there are some major differences between them. In addition, we are still in the very early stage in understanding biological neural networks or human intelligence. Compared to biological neutral network, artificial neural network is much simpler, for example, the biological neural network has much more neurons (e.g., 10^{11} neurons) than artificial neural network has (up to 10^{8} nodes) and the connections among neurons are nonlinear rather than layers, which means biological neural networks are much more complicated and more effective (e.g., more intelligence). The

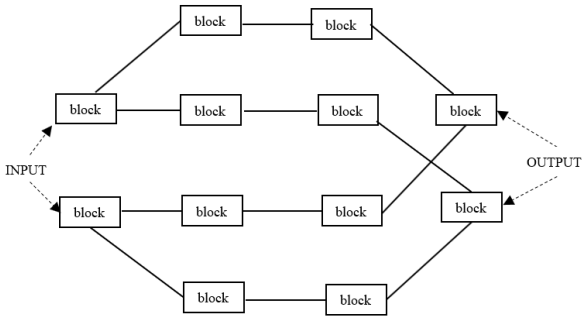
biological neural network memorizes information in the connection parts between neurons which are called synapses. Memory recall requires many neurons and synapses to work together and they can be much more complicated than we currently know. Instead, the artificial neural network memory information (e.g., knowledge) in the weight of the link between two nodes, which is much simpler than the biological neural network. Thank to the model computer operation capability, today's artificial neural network has much faster operations (i.e., logic and arithmetic operations) and much more storage capability than biological neural network. As a result, the artificial neural network can use big data to train itself and achieve so-called deep learning.

Deep learning is one type of artificial intelligence (AI) models that use large data set to train a model to make it smarter. Most deep learnings are built upon artificial neural networks that have deep architecture or many hidden layers. Deep learning is becoming one of the most promised AI methods and has been widely used in all industry sectors. For example, automated driving is one of the most disruptive technology in IT and auto industries. The core technology in automated driving is the application of deep learning that automatically detect objects such as stop signs, traffic lights, moving vehicles, pedestrians, etc. The deep learning uses a large amount of data to train the automated driving software before the vehicle gets on the road. By using more and more real time driving data or road experience, the deep learning software is constantly learning and improving its self-driving skills.

BLOCKCHAIN-BASED DEEP LEARNING NUERAL NETWORK

By applying the blockchain technology in the deep learning method, we propose a blockchain-based deep learning neural network as shown below.

Figure 5: Blockchain-based Deep Learning Neural Network



Compared with the layer-based neural network, the blockchain-based neural network has many advantages.

- The blockchain is a nonlinear tree structure and thus the knowledge is stored in many different blocks over the Internet. This memory mechanism is closer to the biological neural network than the traditional layer-based neural network. We expect the blockchain-based deep learning architecture to be more intelligent and efficient.
- It is more adapted in the real-time learning environment. Learning process occurs at any time when new blocks and/or new transaction data is added to the blockchain. As a result, this AI technique is a purely learning from doing.
- It integrates real-time business processes in the decision making so that it provides fast decision support.

- It is specialized in a specific knowledge domain and can be a good "decision maker".
- It is shared and distributed - knowledge can be accessed anywhere at any time globally.
- It is more secure.

ACADEMIC AND PRACTICAL IMPLICATIONS

The proposed blockchain-based deep learning neural network has great academic and practical implications. In academia, the proposed deep learning architecture explores a new algorithm/technique for machine learning. It has many advantages than the traditional layer-based neural network as discussed above. In practice, this new deep learning architecture integrates business processes and decision-making processes from self-learning – learning from doing and thus it would greatly improve decision-making performance by using real-time data. In sum, the blockchain-based deep learning architecture is a fast and smart AI that constantly learns from doing using real-time business data.

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DECISION SCIENCES INSTITUTE
A Causative Analytic Approaches for Improving Graduation and Retention Rates

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ABSTRACT

Six-year graduation rates have attracted the attention of educational researches and policy makers for decades. However, the graduation rate has not improved much during that time. Retention rates are a good predictor of graduation rates. This study explores the use of causative analytics for identifying the true magnitude of factors affecting retention. The study assesses the actual effect size that on campus living and math preparation have on dropping out of a business college. A detailed discussion of issues that need to be addressed when exploring the magnitude of factors at different stages in a student's program is provided.

KEYWORDS: Graduation Rates, Retention Rates, Causative Analytics, Inverse Probability Weighting

INTRODUCTION

Student success, retention and graduation has been a focal point of public debate (Elton, 1988; Keams, 1998; Dill, 1999; Alexander, 2000; Kitagawa, 2003; Huisman, 2004; Bailey, 2006). According to the most recent statistics, only between 30% to 40% of students graduate within four years from a four–year program, and about 60% students graduate within six years in the United States (ACT, 2014). The stakeholders, educational researchers and policymakers have made countless efforts to identify the factors that can affect retention and graduation rates. While "earlier attempts by states to measure institutional effectiveness have generally been met with passive resistance and benign neglect by academics" (Alexander, 2000), the above-inflation rise of tuition and the growth of student loan debts have created an urgency for change (Jackson, 1975; Shin, 2006; Hemelt, 2011; Shenand, 2009). Additionally, with the drastic budget reductions for public universities, faculty members have been asked to serve increasing numbers of students. Increasing retention and graduation rates could be beneficial for both the students and the universities. The students would pay tuition for a shorter time and thus could earn money earlier to pay off their debts, and the universities could save considerable money when fewer students take up resources. Because of the significant role graduation rates play in the evaluation of universities, they merit an in-depth analysis. While there is no silver bullet that guarantees an increase in graduation rates, analytics is suitable for providing necessary insights into how university administrators can increase retention and graduation rates. The objective of this article is to explore the use of causative analytics in an academic institution with the aim of identifying the true effects size of factors affecting retention rates.

The remainder of the paper is organized as follows. Section 2 reviews the literature about retention rates and graduation rates to provide the domain knowledge for our analytics case that

is necessary in the application of analytics in order to avoid the misinterpretation of results. Section 3 introduces and clarifies the differences and importance of causative analytics. Section 4 contains two subsections; the first subsection applies logistic regression to conduct an initial approach in order to gain insights into the data of identifying key factors on campus living status and math preparation that affect graduation rates and retention rates at different stages. Additionally, we compare results between naïve estimate and logistic regression. The second subsection applies inverse probability weighting for identifying the true effect size of on campus living and math preparation on retention. Section 5 closes with recommendations regarding the application of causative analytics in academics to increase retention and graduation rates.

LITERATURE REVIEW

Despite the massive literature examining the factors effecting student retention and graduation rates (rankings, e.g., U.S. News & World Report), very few assessments of campus retention initiatives exist and evidence is thus scarce as to whether these initiatives are effective (Hossler, 2008). This is partly due to the slow adoption of advanced data management systems by universities. However, as new low-cost analytics solutions have become available in recent years, there has been a growing interest in using analytics to gain better and timely insight into what affects student retention and to allow for the tracking of the effects of new initiatives (Pirani, 2005). The use of descriptive analytics has focused on analyzing the admission process and pre-college factors and their impact on graduation rates. Predictive analytics can be used to identify students at risk of dropping out of university and can therefore allow for advising students in time to increase student retention and subsequent graduation rates (Campbell, 2007). Prescriptive analytics compromises the understanding from descriptive and predictive analytics for allowing corrective actions to be taken for making the decisions. As new technologies are adopted and available data grows larger, more complex models can be used to monitor and assess student success. Despite the numerous empirical studies testing models, explaining retention and graduation rates, and studying methods to improve them, graduation rates at public colleges are still very low. There has been little work done on using data collected by colleges to provide a more effective management of retention and graduation rates. While universities collect and store information about students' performance and demographics and students' background, administrators struggle with how to use the data to improve graduation rates. Therefore, understanding the capabilities of analytical methods and knowing how to apply them to student data is a crucial step toward developing an effective program to increase graduation rates. When using analytics for improving retention and graduation rates, it is important to distinguish between pre-college factors and in-college factors that affect graduation rates throughout college. While pre-college factors are used for selective admission, in-college factors are time dependent, measuring the student's progress towards graduation.

Pre-college factors include academic factors such as High School GPA and ACT assessment scores as well as non-academic factors such as socioeconomic status, self-confidence, achievement motivation, and academic goal orientation which attempt to measure personal traits. Academic factors have been shown to be important for college success and have been widely adopted for selective admission (Schnell, 2003; DesJardins, 2003). In this study, the pre-college factors include student demographic information, academic factors and some non-academic factors. In-college factors are significant keys for effecting the performance after the students enrolled in college, and the factors might vary with the students' performance over time. First-year retention rates have received special attention because it is critical for college success (Hossler, 2008). Moreover, there are some researches that focus on examining specific strategies to

increase first-year retention (Schnell, 2003). In this study, in-college factors contain the grades in core courses and semester-based cumulative GPA.

ANALYTICS

While the objective of descriptive analytics is to gain insight into possible relationships between factors that affect a variable of interest such as graduation, predictive analytics is used to make predictions regarding individual observations. Predictive modeling is therefore different from explanatory modeling (Shmueli, 2010). In explanatory modeling the objective is to determine whether certain factors such as pre-college preparation measured by the high school GPA or SAT/ACT explain college success. In contrast to statistical hypothesis testing where "significance" and thus associated "p" values are important criteria for concluding that a relationship between dependent and independent variables exists, predictive modeling does not concern itself with these issues. The objective of causal analytics is to obtain estimates from observational data that are unbiased. While inferential statistics is only concerned with whether a factor is statistically significant, causative analytics is trying to identify the true effect size of key factors that affect an outcome such as graduation rates.

This article focuses on applying causative analytics using data from the E. J. Ourso College of Business at LSU to assess the actual effect size of on campus living and mathematics preparation on retention and graduation rates. As mentioned above, predictive analytics and prescriptive analytics do not make any causal claims nor do they suggest which factors affect the target. All that is important is that the model is able to predict the outcome. In many cases this is sufficient for the practical application at hand. However, there are many situations where one is interested in what factors cause the target to change and how much they will change the target. For instance, when predicting what student is likely to drop out it may be of interest to know what factors have a large effect. If living on campus makes a big different, in graduation rates then university administrators could plan for more on-campus housing. But, one needs to know that living on campus causes an increase in graduation rates before investing in significant resources. Thus, having good predictions for individual students is not enough. Much of statistics has focused on statistical significance instead of practical significance.

MODELS AND RESULTS

College success requires different models for different points in time. This study covers outcomes from two perspectives, it measures 4-year graduation rate and retention rate at different stages. It focuses on applying causative analytics using data to explore the true effect size of on campus living for improving retention and graduation rates. A model evaluating 4-year graduation was developed using data with 5,582 students who entered college between 2006 and 2011 and would have graduated between 2010 and 2015 if they had graduated within four years. In order to have a more timely model for decision making, two models were developed for assessing dropout rate at different semesters using a data set with 9,913 students who entered college between 2006 and 2015. The data consisted of precollege information collected on all freshmen and in-college information about programs, courses taken and grades. The data include the demographics, high school GPA and ACT test results, whether students will live on campus or not, information about the type of high school, distance between home and campus, whether they are Pell grant recipients, the number of college credits they have taken and the intended major they want to enroll in. Three models were built based on different points in time. For the first and second semester models, all pre-college factors and the additional in-college factors are included for the respective semester models. Since there are too many courses a student can take as electives,

we only included individual grades from required courses in the first and second semester that exhibited some confounding that affect the power of dropout with specific factors. The student information and the course table were put into a data warehouse, a quality check was performed, and missing information was identified. In this study, two treatments are evaluated; the first treatment is on/off campus living, and the second is mathematical preparation. The status of on campus living is determined when the students enroll the university. We have examined the effect size of on-campus living status on the dropout after the first and second semester. The effect of mathematical course preparation is also measured by the dropout after the first and second semester.

Naïve Estimate & Logistic Regression

As a baseline model, logistic regression was used on 75% of the data (training set) to identify factors that are highly statistically significant. Logistic regression has the advantage of providing an interpretation, namely the odds ratios. As Table 1 shows, the precollege factors Gender, HSGPA, ACT, CAMPUS and Distance are statistically significant at the 0.05 level.

Table 1 shows that academic qualifications such as ACT and high school GPAs, while important predictors for 4-year graduation, are less important factors for affecting return to the college after the second semester. For the third model, grades in college are the most important factors affecting the dropout after the first semester, specifically, failures of passing courses such as Algebra (MATH1021), Calculus (MATH1431), Information Systems (ISDS1102), Economics (ECON2000) and first-semester GPA. Both cumulative GPA at the end of the first semester and at the end of the second semester are statistically significant for dropout after the first and second semester, respectively. Generally, the statistical significance of pre-college factors decline as more in-college information becomes available. However, Math preparation is the foundation of other courses, passing courses Algebra(MATH1021) and Calculus (MATH1431) are very crucial for student further success.

Table 1. Logistic Regression Results of Factors for Predicting 4-Year Graduation and Retention

Information Including up	Pre-College Information		1nd Semester		First Year	
Predict	4-Year Graduation		Returning 2rd Semester		Returning 2nd Year	
Term	P-value	Significance	P-value	Significance	P-value	Significance
Gender	<.0001	***	<.0001	***	0.0587	*
HSGPA	<.0001	***	<.0001	***	0.0527	*
ACT	<.0001	***	0.0269	**	0.1326	
CAMPUS	<.0001	***	0.8575		0.1103	
Distance	0.0143	**	0.048	**	0.2602	
Race	0.1795		0.058	*	0.0326	**
Hsenrl	0.1084		0.4648		0.9617	
Hstype	0.2747		0.3316		0.6585	
Pelican	0.1422		0.0595	*	0.0164	**
Greek			0.0019	***	<.0001	***
ISDS1102			<.0001	***	<.0001	***
Math1021			0.0086	***	0.828	

Math1431			0.0007	***	<.0001	***
Econ2000			<.0001	***	<.0001	***
LSUGPA_1st			<.0001	***		
CURR1			<.0001	***	0.211	
ISDS2000					0.025	**
ACCT2001					<.0001	***
LSUGPA_2st					<.0001	***
Level of statistical significance (*** at p<0.005, ** at p<0.05, * at p<0.1) Estimates based on 75% of data.						

Because the study focuses on examine the true effect size of on campus living and math preparations, the logistic regression provides an important step by identifying key performance indicators. Additionally, the logistic regression model also has the added benefit of providing odds ratios which are depicted in Table 2. For instance, living on campus in the first semester increases the odds of a student graduating in 4 years by 66% compared to the odds of a student who does not live on campus in the first semester. This indicate that students who live on campus in the first semester are more likely to graduate in 4 years than students who did not live on campus in the first semester. Moreover, with the comparison of effect size between naïve estimate and logistic regression, the average treatment effect for on campus status holds the same trend in table 2. However, the average treatment effect for math preparation does not hold the same trend in table 3. To the extent of native estimate, logistic regression only adjusts for covariates, but it does not completely provide the causal estimates, and this is the reason why we need to do further study for exploring the true effect size.

Table 2. Average Treatment Effect for On Campus Status (Naïve vs. Logistic Regression)

	Naïve Estimate		Logistic Regression	
	Estimate (Percentage Points)	Stand Error	Estimate (Percentage Points)	Stand Error
Four-Year Graduation	14.7	0.015	1.66	0.035
First Semester	1.2	0.005	1.28	0.067
Second Semester	4.1	0.009	1.49	0.051

Table 3. Average Treatment Effect for Math Preparation (Naïve vs. Logistic Regression)

		Math 1021		Math 1431	
		Naïve Estimate (Percentage Point for Estimate)	Odds Ratio	Naïve Estimate (Percentage Point for Estimate)	Odds Ratio
First Semester Dropout	Estimate	8.3	1.68	4.4	2.38
	Stand Error	0.009	0.09	0.005	0.098
	Estimate	45.4	1.9	25.4	1.97

Second Semester Dropout	Stand Error	0.024	0.11	0.001	0.071

Causative Analytics - Inverse Probability Weighting

Inverse probability weighting is a common method used by researchers to identify causal estimates. Inverse probability weighting is helpful for bias reduction under various situation (Mansournia & Altman, 2016). Additionally, it is often used to overcome the selection bias in multiple disciplines (Hernan & Robin, 2010). In this study, we will employ inverse probability weighting for comparing the actual effect size for on/off campus living and math preparation at different semesters. Inverse Probability weighting applies the conditional probability of treatment given the covariates, in order to create the pseudo population by weighting each individual in the population by the inverse of the conditional probability of receiving the treatment level that one indeed received. In another word, the entire process for inverse probability weighting is trying to double the population, in order to achieve the conditional exchangeability between treatment group and control group in each of strata. The hypothetical population that is twice as large as the original population is known as the pseudo-population (Hernan & Robin, 2010).

As mentioned in the previous section, there are many confounders. Although the effect size of on campus living on retention rate is estimated at different times, the in-college factors cannot be treated as confounders because the on-campus status is decided when the students enter the university. Therefore, only the pre-college factors are treated as confounders in different models for measuring the effect size of on campus living on the retention rate.

Table 4. Average Treatment Effect for on/off campus (Naïve Estimate vs. Inverse Probability Weighting)

	Naïve Estimate		Inverse Probability Weighting	
	Estimate	Stand Error	Estimate	Stand Error
Four-Year Graduation	0.147	0.015	0.118	0.014
First Semester	0.012	0.005	0.009	0.005
Second Semester	0.041	0.009	0.032	0.009

Table 4 shows lower results from Inverse Probability Weighting. If a student decides to live on campus, there is a 1.0 percentage point increase in staying in college after the first semester, and there is around 3.2 percentage point increase of staying in college after the second semester. These estimates are causal provided there are no other unknown confounders. Additionally, the campus living status takes heavier effect on graduation rate. If a student decides to live on campus there is about an 11.8 percentage point increase in graduation within 4 years.

The causal effect of math preparation is also examined. In this study, the effect of grades in Algebra and Calculus is evaluated by semesters. The grades of two courses have eight different levels (P(Pass), A, B, C, D, W, F, NT (not taken)). A student who has a grade of P, A, B, C are passing the course while (D, W, F, NT) indicate no passing. When assessing effect size of math preparation, the in-college factors are potential confounders as well and are added in the model for reducing bias. The additional confounders are the grades in required courses. Classes' grades in different classes may be correlated because better students tend to have better grades.

Table 5. Average Treatment Effect for math preparation (Naïve Estimate vs. Inverse Probability Weighting)

		Math 1021		Math 1431	
		Naïve Estimate	Inverse Probability Weighting	Naïve Estimate	Inverse Probability Weighting
First Semester Dropout	Estimate	0.083	0.125	0.044	0.095
	Stand Error	0.009	0.034	0.005	0.022
Second Semester Dropout	Estimate	0.455	0.200	0.254	0.080
	Stand Error	0.024	0.062	0.001	0.029

Table 5 also shows that the causal estimate is larger than the naïve estimate. For instance, there is 12.5 percentage point increase in retention after the first semester and a 20-percentage point increase in retention after the second semester. However, for the second semester the causal estimates are smaller than the naïve estimates. This is due to the second semester having only students that remain in college and the true effect of math performance is smaller than for the first semester.

DISCUSSION AND IMPLICATIONS

This study contributes to an understanding of the important of specific factors that improve retention rates and graduation rates. While logistic regression allows for a more straightforward interpretation because of the estimated odds ratios, the results can be misleading when researchers rely only on p-values, which provide statistical significance and odds ratio for explaining and are not a metrics for identifying true effect size of specific factors. This study applies causal inference method – Inverse probability weighting to identify two factors that have a large effect on 4-year graduate rate and first and second semester retention. There are several findings. First, living on campus does improve the retention rate after the first and second semester and 4-year graduation. And there is a higher affect on 4-year graduation compared to the first and second semester retention. Second, mathematics preparation is a crucial factor affecting retention after the first and second semester. Specifically, the results indicate that students who have not passed algebra in by the second semester have a 20 percentage point higher dropout rate than students who pass algebra. This result should lead to policy changes regarding suggested courses taken in high school. High school councilors should advise their students that they must be well prepared in mathematics in high school if they intend to study business in college.

This paper contains several limitations that influence the potential generalization of its findings. First, the average effect is only a causal effect if there are no other unknown confounders. Although we have made attempts to control for some known confounders when considering the effect of on-campus living, there may be other unknown confounders such as family background and family income. However, applying the causal analytics could help researchers to approach the true effect size of specific key performance indicators.

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A Comparison of Dispatching Heuristics to Schedule Jobs in a No-wait Flow Shop to Minimize Total Earliness and Tardiness

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ABSTRACT

This paper considers the problem of scheduling jobs in a no-wait flow shop with the objective of minimizing total earliness and tardiness. Several dispatching heuristics that have been used previously for other environments were modified for use in no-wait flow shops. These heuristics were tested under a variety of conditions. It was found that two of the heuristics consistently perform best.

KEYWORDS: Scheduling; Heuristics; No-Wait Flow Shop; Earliness and Tardiness

INTRODUCTION

Scheduling problems with the objective of minimizing total earliness and tardiness have gained increased attention during the past four decades. A key reason for this is the adaption of supply chain management in which customers and suppliers have tried to have better coordination in their operations. This causes the early and tardy delivery of products to be viewed as poor quality service. Early deliveries result in unnecessary inventory that requires space, cash and resources needed to maintain and manage the inventory. Lost sales and the loss of customer good will are penalties that are the result of tardy delivery of products. This paper addresses this trend by considering an objective that sums the penalties for earliness and tardiness for a set of jobs to be processed in a no-wait flow shop.

A flow shop is a production shop which consists of two or more machines. In a flow shop each of the jobs to be processed uses the machines in the same order. In a no-wait flow shop once a job starts processing it must continue through the flow shop without any intermediate waiting. In some cases the nature of the product is such that the no-wait restriction is a requirement. In many cases organizations are adopting a lean production philosophy and want to minimize waste by not having any waiting between the machines. When jobs do not have to wait between the machines there is no in-process inventory and space is not wasted.

The objective in this problem is non-regular, therefore the insertion of idle time into a schedule could help to reduce the earliness of some jobs and thus improve the objective. In a no-wait flow shop there could be idle time on any of the machines but if additional idle time (unforced idle time) was to be used in the no-wait flow shop environment it would have to occur on the first machine because the storage of jobs is not allowed in between the intermediate stages. There are production environments, however, where the insertion of unforced idle time may not be productive. (Korman, 1994; Landis, 1993) provide specific examples of the undesirability of unforced idle time. For instance, idle time should be avoided when the capacity of the shop is limited when compared with the demand. Also, idle time should not be inserted when the machine has a high operating cost, and / or when starting a new production run involves high

setup costs or times. In this research only schedules without unforced inserted idle time are considered.

LITERATURE REVIEW

Research that is relevant to our problem is scheduling with earliness and tardiness penalties, scheduling flow shops with earliness and tardiness penalties and scheduling in a no-wait flow shop with these penalties.

Literature Review of Earliness and Tardiness

Many papers have been published that consider earliness and tardiness penalties. The first comprehensive survey that covered the early papers dealing with early/tardy scheduling was provided by (Baker and Scudder, 1990). (Hoogeveen, 2005) provides a survey of multicriteria scheduling which includes more recent research on problems with earliness and tardiness penalties. The single machine environment has the greatest amount of research early/tardy objective. (Valente, 2009) summarized more recent research for single machine environments with no idle time and an early/tardy objective. (Kanet and Sridharan, 2000) reviewed scheduling models when inserted idle time is allowed. Several of the papers consider how idle time can be inserted optimally in a given sequence for the single-machine problem. (Fry et al., 1987) were the first to address this problem. They formulated the problem as a linear program. Special characteristics of the problem were used by (Davis and Kanet, 1993) and (Yano and Kim, 1991) to develop more efficient timetabling procedures. Branch-and-bound procedures were developed by (Davis and Kanet, 1993; Kim and Yano, 1994; and Schaller, 2007) for the single-machine problem for finding an optimal sequence and schedule. Dominance conditions were developed for the single-machine problem with inserted idle time by (Kim and Yano, 1994; Szwarc, 1993; and Schaller, 2007) in order to eliminate partial sequences within a branch-and-bound algorithm.

Literature Review of Flow Shop Earliness and Tardiness

We know of nine papers that investigate flow shop environments with objectives that consider earliness and tardiness costs. In none of these cases was the flow shop a no-wait flow shop.

(Zegordi et al., 1995; and Rajendran, 1999) were the earliest papers. (Zegordi et al., 1995) considered a permutation flow shop with the objective of minimizing the sum of weighted earliness and tardiness and presented a simulated annealing algorithm for the problem. (Rajendran, 1999) considered scheduling a kanban flow shop with the objective of minimizing the sum of weighted flowtime, weighted tardiness and weighted earliness of the kanban containers and presented heuristics for the problem.

An optimal procedure was presented by (Moslehi et al., 2009) for minimizing the sum of maximum earliness and tardiness in a two-machine flow shop. The problem of scheduling a permutation flow shop with earliness and tardiness penalties when all the jobs have a common due date was investigated by (Chandra et al., 2009). Branch-and-bound algorithms were presented by (Madhushini et al., 2009) for a variety of objectives including minimizing earliness and tardiness.

A genetic algorithm was proposed by (Schaller and Valente, 2013b) and was compared with five other neighborhood search and metaheuristics for a permutation flow shop to minimize total earliness and tardiness. A variable neighborhood search heuristic was developed by (M'Hallah ,2014; and Fernandez-Viagas et al., 2016) developed a constructive heuristic and local

searches for the problem (Schaller and Valente, 2013b) investigated. (Schaller and Valente, 2013a) incorporated family setups into the permutation flow shop problem to minimize total earliness and tardiness. Several metaheuristics were compared for this problem and it was found a genetic algorithm worked best.

Literature Review of No-Wait Flow Shops

To the best of our knowledge there have been no papers that have addressed the problem of minimizing total earliness and tardiness in a no-wait flow shop. However, there has been a great deal of research on scheduling problems in the no-wait flow shop environment. A review of early work was provided by (Hall and Sriskandarajah, 1996). Much of the research dealt with objectives that were measures of efficiency such as minimizing makespan or flowtime. Recent research with an objective of minimizing makespan includes (Pan et al., 2008; and Laha and Chakraborty, 2009). For the flowtime objective, (Framinan et al., 2010 and Gao et al., 2011) are recent examples. There has been increased research in recent years on objectives that measure the shop's ability to meet due dates and include tardiness in the objective. Minimizing total tardiness is similar to our objective but does not penalize the early completion of jobs. (Aldowaisan and Allahverdi, 2012; Liu et al., 2013; and Ding et al., 2015) are recent examples of research for minimizing total tardiness in no-wait flow shops.

THEORETICAL DEVELOPMENT/MODEL

Formally, suppose there is a set of n jobs to be processed in a no-wait flow shop with M machines. Let d_j be the due date of job j $(j = 1, \ldots, n)$. Let p_{jm} and C_{jm} represent the processing time and completion time of job j $(j = 1, \ldots, n)$ on machine m $(m = 1, \ldots, M)$. The earliness of job j, E_j, is defined as: $E_j = max\{d_j - C_{jM}, 0\}$, for $j = 1,\ldots, n$ and the tardiness of job j, T_j, is defined as: $T_j = max\{C_{jM} - d_j, 0\}$, for $j = 1,\ldots, n$. The objective function, Z, can be expressed as:

$$Z = \sum_{j=1}^{n} E_j + T_j. \quad (1)$$

In this paper we only consider no-wait flow shops. A permutation flow shop is a flow shop in which the order the jobs are processed remains the same on each machine. Therefore no-wait flow shops are also permutation flow shops so a solution is defined by determining the sequence of processing the jobs that need be processed in the flow shop. Also, for each pair of jobs it can be determined how much idle time is needed on the first machine between the finish time, on the first machine, of the job sequenced first and the start time, on the first machine, of the job sequenced second. This time is the same regardless of where the pair of jobs appears in the sequence so it can be calculated before sequencing jobs. Once a start time for a job is determined, its completion time on the final machine is easy to determine as we only need to add the sum of the job's processing times to its start time. We refer to this time as the delay or offset time and use OS_{jk} to denote the offset time needed on the first machine if job j is sequenced immediately after job k for job j not to wait at any of the machines. A dummy job 0 is used to take into consideration that a job may be first in a sequence and $OS_{j0} = 0$ for j = 1, …, n. For a given sequence of jobs in which the job to be sequenced in position j is denoted as $[j]$, the completion time of job $[j]$ on machine M will determine the earliness or tardiness of the job in position j of the sequence. The completion time:

$$C_{[j]M} = C_{[j-1]1} + OS_{[j][j-1]} + \sum_{m=1}^{M} p_{[j]m} \text{ , where } C_{[0]1} = 0 \quad (2)$$

To calculate the offset time between a pair of jobs j and k when job j is to immediately follow job k (OS_{jk}) we can use the following.

$$OS_{jk} = \max_{m=1,\ldots,M-1} \{\sum_{l=1}^{m} p_{kl+1} - \sum_{l=1}^{m} p_{jl}\} \quad (3)$$

DISPATCHING HEURISTICS TESTED

Several heuristics were tested for the problem. All of the heuristics tested are either variants of heuristics used in other environments or were motivated by heuristics used in other environments but were modified for the no-wait flow shop environment.

In the heuristics that follow let S be the current partial schedule and $C_{jM}(S)$ be the completion time of job $j \notin S$ if j is scheduled at the end of S. Let $s_j(S)$ be the slack of job $j \notin S$ if j is scheduled at the end of S, where $s_j(S) = d_j - C_{jM}(S)$. Additionally, let $t_1(S)$ be the current availability time of machine 1 under schedule S. This is the time the last job in schedule S completes its processing on the first machine. For convenience, the current time on the first machine will also be denoted by t, so $t = t_1(S)$. Finally, let $P_j(S) = C_{jM}(S) - t$ be the total time (total processing time plus any idle time on the first machine between the completion of the preceding job and start of job j on the first machine) between the completion of the last job in the schedule S on the first machine and finish of job $j \notin S$ on the final machine if j is scheduled at the end of S.

Simple Dispatching Heuristics

Four simple dispatching heuristics are considered: earliest due date (EDD), modified due date (MDD), minimum slack rule (SLK), and minimum slack per work (SLK/P).

The earliest due date (EDD) rule was first proposed by Jackson (1955). This rule schedules the jobs in non-decreasing order of their due dates d_j.

In the modified due date (MDD) heuristic (Baker and Bertrand, 1982; Vepsalainen and Morton, 1987), at each iteration we select the job with the minimum value of the modified due date.

$$MDD_j(S) = \max\{d_j, C_{jM}(S)\} \quad (4)$$

The minimum slack (SLK) rule (Panwalkar & Iskander, 1977; Vepsalainen & Morton, 1987) chooses, at each iteration, the job with the minimum slack:

$$s_j(S) = d_j - C_{jM}(S) \quad (5)$$

The minimum slack per required time (SLK/P) (Panwalkar & Iskander, 1977; Vepsalainen & Morton, 1987) selects, at each iteration, the job with the minimum value of the ratio:

$$SLK/P_j(S) = s_j(S)/P_j(S) \quad (6)$$

Dispatch Rules with More Advanced Indexes

In this section we present dispatching rules that utilize priority indexes that consider a variety conditions that may be present. The indexes in these rules have multiple branches to allow for flexibility to respond to conditions.

LIN-ET Rules (LIN1 and LIN2)

The first two rules are based on the LIN–ET procedure proposed in (Ow & Morton, 1989) for the weighted single machine problem. These rules, which will be denoted by LIN1 and LIN2, choose, the job to be selected for the iteration, the job with the largest value of the following priority indexes:

$$LIN1_j(S) = \begin{cases} \frac{1}{P_j(S)} & if \quad s_j(S) \leq 0 \\ \frac{1}{P_j(S)} - \frac{s_j(S)}{slk\_thr} \times \frac{2}{P_j(S)} & if \quad 0 < s_j(S) < slk\_thr \\ -\frac{1}{P_j(S)} & if \quad s_j(S) \geq slk\_thr \end{cases} \tag{7}$$

and

$$LIN2_j(S) = \begin{cases} \frac{1}{P_j(S)} & if \quad s_j(S) \leq 0 \\ \frac{1}{P_j(S)} - s_j(S) \times \left(\frac{1}{slk\_thr \times P_j(S)} + \frac{1}{P_j(S)} \right) & if \quad 0 < s_j(S) < slk\_thr, \\ -\frac{s_j(S)}{P_j(S)} & if \quad s_j(S) \geq slk\_thr \end{cases} \tag{8}$$

where slk_thr, which stands for “slack threshold”, is a parameter meant to represent a value such that slacks which are greater or equal to that value are considered large.

In the first branch of the priority index, identical in both heuristics, a job is late or on time if scheduled next. When one or more such jobs exist, LIN1 and LIN2 select the job using a shortest time rule, in line with various heuristics for earliness and tardiness problems (Kenneth R. Baker, 1974; Ow & Morton, 1989; Smith, 1956). Here the shortest time refers to a job’s cumulative processing time plus the idle time on the first machine to ensure the job does not have to wait between machines.

In the third branch, the job has a large slack, and is quite early. If all jobs are quite early, LIN1 chooses the job using a longest time rule, again in line with several heuristics for early/tardy problems (Ow & Morton, 1989; Valente, 2007; Valente & Alves, 2005). LIN2, on the other hand, selects the job with the minimum slack per required time. Finally, the middle branch performs a linear interpolation between the priority values corresponding to $s_j(S) = 0$ and $s_j(S) = slk\_thr$. Such an interpolation was first performed in the LIN–ET procedure (Ow & Morton, 1989).

The slk_thr parameter is calculated as follows. At each iteration, representing a partial schedule S with k jobs, the slack threshold is set equal to

$$slk\_thr = w * (C_{\max}^{LB} (S) - t), \quad (9)$$

where $C_{\max}^{LB} (S)$ is a lower bound on the completion time of the last job on the final machine (makespan), given the current schedule S, and $0 \leq w \leq 1$ is a user-defined parameter. To calculate this lower bound we first obtain a lower bound on the completion of processing on the first machine of the unscheduled jobs and then add to this time the minimum cumulative processing time on machines two through M. To find the lower bound for completion on the first machine we sum the processing times on the first machine of the unscheduled jobs and add this to t ($t + \sum_{j \notin S} p_{[j]1}$). This lower bound is weak because the offset times of the unscheduled jobs is not included. To strengthen this lower bound we find the lowest offset time for each unscheduled job if it is not scheduled next ($\min\{OS_{j \notin S, l \notin S}\}$ and sum the n – k – 1 of these times and add to this the minimum offset time among the unscheduled jobs if scheduled next. The lower bound on the offset times is then added to the lower bound above to obtain a lower bound on the completion time on the first machine. We then add the minimum among the unscheduled jobs of the cumulative processing time for machines two through M to obtain a lower bound on the makespan.

The procedures formed using these indexes are referred to as LIN1 and LIN2 in this paper.

A heuristic based on Fernandez-Viagas et al. (2016)'s Constructive Heuristic

A constructive heuristic for permutation flow shops when waiting is allowed between machines was developed by Fernandez-Viagas et al. (2016). In this heuristic a sequence is built from the beginning to the end by adding one job at a time to a partial sequence. An index is used to select the next job to be added to the partial sequence. During an iteration of the procedure the problem is classified according to the due dates of the jobs that remain to be sequenced into one of three cases: 1) tight due dates, 2) loose due dates, 3) due dates that are not tight or loose. Based on this classification the index used to select the next job changes.

To help define the classifications, if k jobs have been scheduled (kth iteration) let NT_k be the number of jobs from the unscheduled set (n – k) that would be tardy if scheduled next. Let NE_k be the number of jobs from the unscheduled set that would have an earliness that is greater than (n – k) * c if scheduled next, where c is a user defined parameter. The classifications are as follows. 1) Tight due dates – if the fraction of tardy jobs is greater than a, where a is a user defined parameter:

$$NT_k/(n - k) \geq a \quad (10)$$

2) Loose due dates – this case is divided into two subcases:
Subcase A) if there are at least four jobs still to be scheduled (n – k > 3), all the unscheduled jobs will be early if scheduled next, and $NE_k = n - k$.
Subcase B) there are at least four jobs still to be scheduled (n – k > 3), all the unscheduled jobs will be early if scheduled next, and:

$$b * (n - k) \leq NE_k < n - k \quad (11)$$

where b is a user defined parameter.
3) If the above criteria are not met than the due dates are not tight or loose.

Let EI_{jk} be the index for job j if scheduled next. Each time a job is to be selected, the job with the lowest index among the unscheduled jobs is selected. Let E_{jk} equal the earliness of job j if scheduled next. In the original Fernandez-Viagas et al. 2016 heuristic a variable is used to calculate the weighted idle time of the candidate jobs. We modify this heuristic by using the idle time on the first machine for each unscheduled job if scheduled next. Let IT_{jk} be the idle time on the first machine of the candidate jobs if scheduled next (in the $k+1^{st}$ position):

$$IT_{jk} = OS_{j[k]} \tag{12}$$

The indexes are:
1) Tight due dates.

$$EI_{jk} = (n - k - 2)/4 * IT_{jk} + C_{jM} \tag{13}$$

2) Loose due dates
Subcase A) Extremely loose due dates.

$$EI_{jk} = -(n - k - 2)/4 * IT_{jk} - C_{jM} \tag{14}$$

Subcase B) Moderately loose due dates.

$$EI_{jk} = -(n - k - 2)/4 * IT_{jk} - C_{jM} + E_{jk} \tag{15}$$

3) Due dates are not tight or loose. $EI_{jk} = E_{jk}$.

The procedure formed using this index is referred to as FV in this paper

COMPUTATIONAL TEST

The proposed algorithms are tested on randomly generated problems of various sizes in terms of the number of jobs and number of machines and under various conditions of due date range and tightness.

Data and Performance Measures

The dispatching heuristic procedures described in section three were tested on problems of various sizes in terms of the number of jobs and number of machines for nine sets of distributions of due date range and tightness. Each problem set consists of 10 problems. The problems within a problem set have the same number of jobs and machines, and the due dates for the jobs are generated using the same distribution. Eight levels of number of jobs (*n*) to be scheduled were tested: *n = 15, 20, 25, 30, 40, 50, 75* and *100*. Three levels of number of machines (*M*) were tested: *M = 5, 10* and *20*. The processing times of the jobs for each machine were generated using a uniform distribution over the integers 1 and 100. The due dates for the jobs were also randomly generated using a uniform distribution over the integers *MS (1 – r –*

R/2) and *MS (1 – r + R/2)*, where *MS* is an estimated makespan found for the problem using the makespan lower bound proposed in Taillard (1993), and *R* and *r* are two parameters called due date range and tardiness factors. Three levels of due date range (*R*) were tested: *R = 0.2, 0.6* and *1.0* and three levels of due date tightness (*r*) were tested: *r = 0.0, 0.2* and *0.4*. These levels of *R* and *r* result in nine sets of due date parameters for each *n* and *M* combination.

A second set of 10 problems for each of the sets of parameters described above were created to use in preliminary tests to determine the parameter w for the LIN1 and LIN2 procedures. This parameter is multiplied by the estimated makespan to create the slack threshold (*slk_thr*). Based on these experiments a value of w = 0.6 was selected for LIN1 and w = 0.5 was selected for LIN2. The values selected for the FV procedure were a = 0.90, b = 0.75, and c = 300.

The procedures were coded in Turbo Pascal and were tested on a Dell Inspiron 1525 GHz Lap Top computer. The measure of performance used to evaluate the dispatching procedures for the problems is percentage deviation (*% Dev*) of the total earliness and tardiness of the solution generated by each procedure from the total earliness and tardiness generated by the EDD procedure.

$$\% \ Dev = [(Z_h - Z_{EDD})/ Z_{EDD}] * 100 \quad (16)$$

where Z_{EDD} = the total earliness and tardiness of the solutions generated by the EDD procedure, and Z_h = the total earliness and tardiness of the solutions generated by the dispatching heuristic procedures (MDD, LIN1, LIN2, SLK, SLKP, FV). The EDD procedure would always have a % Dev equal to 0.00 so it is omitted. The results of this test are described in the next section.

Results of the Test

Tables 1, 2 and 3 show the *% Dev* for each procedure for each level of number of jobs to be sequenced (*n*) as well as the averages across all the levels of jobs. Table 1 shows the results for *M =5*, table 2, for *M = 10* and table 3, for *M = 20*.

Table 1. % deviation from the EDD solution for *M = 5*.

	Procedure					
n	MDD	LIN1	LIN2	SLK	SLKP	FV
15	-13.72	-13.96	-8.61	14.08	6.17	-1.42
20	-16.17	-16.94	-13.48	14.48	1.16	-4.44
25	-18.21	-19.38	-15.74	15.55	0.76	-4.86
30	-18.30	-19.66	-16.41	15.19	-2.28	-4.38
40	-19.93	-22.91	-19.93	13.33	-6.35	-9.12
50	-22.08	-24.32	-20.32	14.00	-7.25	-9.06
75	-23.03	-27.18	-22.25	13.33	-10.84	-10.82
100	-23.28	-27.61	-22.32	13.70	-11.74	-11.27
Ave.	-19.34	-21.50	-17.38	14.21	-3.80	-6.92

Table 2. % deviation from the EDD solution for *M = 10*.						
	Procedure					
n	MDD	LIN1	LIN2	SLK	SLKP	FV
15	-21.67	-20.12	-15.83	18.25	8.35	-7.34
20	-20.83	-19.00	-16.34	18.23	5.26	-10.33
25	-24.37	-22.62	-19.84	18.55	2.51	-12.23
30	-25.63	-22.90	-19.93	19.64	0.00	-14.03
40	-26.83	-25.17	-21.93	17.91	-3.09	-17.07
50	-27.67	-26.66	-22.76	19.53	-4.96	-17.53
75	-29.77	-26.36	-26.36	18.39	-10.96	-20.15
100	-30.95	-31.79	-27.33	17.93	-13.36	-22.24
Ave.	-25.97	-24.33	-21.29	18.55	-2.03	-15.12

Table 3. % deviation from the EDD solution for *M = 20*.						
	Procedure					
n	MDD	LIN1	LIN2	SLK	SLKP	FV
15	-26.17	-23.48	-20.33	17.17	7.91	-15.90
20	-26.18	-22.83	-20.82	15.88	4.55	-16.29
25	-28.44	-26.47	-23.12	16.05	2.49	-21.29
30	-28.79	-26.22	-23.81	19.31	2.22	-20.77
40	-29.20	-27.37	-25.65	18.70	-2.38	-23.02
50	-30.81	-28.80	-27.26	19.48	-5.59	-27.26
75	-32.51	-31.19	-28.78	19.33	-10.31	-26.53
100	-33.47	-32.69	-30.28	19.79	-12.83	-28.57
Ave.	-29.45	-27.38	-25.01	18.21	-1.74	-22.45

The results show that the LIN1 procedure had the lowest average *% Dev* for M = 5 and the MDD procedure had the lowest average *% Dev* for M = 10 and 20. The LIN1 and MDD procedures were either first or second best for all combinations of n and M. These procedures were the only procedures to have an average deviation that was more 10% below the EDD solution for of the combinations of n and M. The LIN2 procedure had the third best average *% Dev* for all the combinations of n and M and had an average deviation that was more than 10% below the EDD solution for all the problem sizes with the exception of n = 15 and M = 5. The FV procedure also generated better solutions than the EDD procedure for all of the combinations of n and M. The SLK and SLKP procedures performed the poorest. For all of the combinations of n and M the SLK procedure had a positive % DEV and SLKP procedure had a positive % DEV for n < 30.

In order to show the effect of the due date range (*R*) and tardiness factor (*r*) on the results tables 4 and 5 are presented. Table 4 shows the *% Dev* by due date tardiness factor (*r*) for *n = 50* and *M = 10*.

Table 4. % deviation from the EDD solution by *r* for *n = 50* and *M = 10*.						
	Procedure					
r	MDD	LIN1	LIN2	SLK	SLKP	FV
0.0	-22.32	-21.11	-17.02	20.25	-0.22	-13.84
0.2	-28.85	-27.10	-23.42	21.11	-4.82	-16.86
0.4	-31.86	-31.76	-27.85	17.24	-9.85	-21.89

The results by due date tardiness factor (r) show that the MDD and LIN1 procedures performed the best for each level of r for this setting of n and m. The two procedures had fairly close performance. It appears that the performance of both procedures improves as r increases.

Table 5 shows the *% Dev* by due date range factor (*R*) for *n = 50* and *M = 10*.

Table 5. % deviation from the EDD solution by *R* for *n = 50* and *M = 10*.						
	Procedure					
R	MDD	LIN1	LIN2	SLK	SLKP	FV
0.2	-23.71	-21.70	-19.65	23.83	-9.01	-14.01
0.6	-28.21	-27.21	-22.69	15.45	-4.14	-19.06
1.0	-31.10	-31.07	-25.95	19.32	-1.74	-19.52

The results show that the MDD and LIN1 MDD procedures were the best procedures for each level of R. The performance of the both procedures was fairly close for all the levels of R. It appears that the performance of both procedures improves as R increases.

CONCLUSION

In this paper seven dispatching heuristics were proposed for minimizing total earliness and tardiness in no-wait flow shops. These procedures were tested on problems of various sizes in terms of the number of jobs and machines, and nine sets of distributions that determine the tightness and range of due dates. All of the procedures are very efficient and were able to generate solutions quickly for all the problem sizes tested.

The results showed that the two procedures, MDD and LIN1 were the consistently top performing procedures and are recommended.

A future area of additional research would be developing additional dispatching procedures that generate better solutions for the problem. An improvement could also be developed that can be applied to the dispatching heuristics and could also form the basis for the development of metaheuristics for the problem.

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DECISION SCIENCES INSTITUTE
A Cross-Country Analysis on the Antecedents of E-government Adoption

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ABSTRACT

This research-in-progress develops and empirically tests a model of country level e-government adoption. In doing so, it bridges important gaps in the literature. Factors such as accountability, quality of governmental policies, effectiveness of law, and corruption are included in our model to examine their influence on country level e-government adoption. Secondary data collected from 163 countries are used to empirically examine the hypotheses presented in the study. The hypotheses are confirmed using PLS analytical procedures and the findings are reported. We discuss the results and their implications for researchers and practitioners.

KEYWORDS: Electronic Government, Adoption, Corruption, and Cross-country

INTRODUCTION

E-government is defined as, “the use of information and communication technologies (ICTs) to improve the activities of public sector organizations” (Merhi, 2016). These tools are used to increase transparency and accountability between government agencies and public administrations and the people (Merhi and Koong, 2015). E-government systems facilitate easier access to information, services, and the governing practices of those in position of power (Al-Hujran et al., 2015). E-government is more prominent in developed countries while developing countries begin adapting to the change. Some benefits of e-government adoption may include, increased levels of convenience, decrease costs which can lead to growth in revenue, and decrease time and effort associated with e-services (Lu and Nguyen, 2016). E-government also has a positive effect on the infrastructure of a country. Increasing efforts in e-government development and effectiveness leads to technological innovations, and employment opportunities, thus increasing economic prosperity within the country (Hassan, 2017). Previous studies have shown that e-government can positively influence control of corruption, economic growth, and efficiency (Hasan, 2017). However, these potential benefits can only be achieved if the system of e-governance is implemented properly. For successful implementation a certain level of transparency and trust must be mutually assured from both the governing body and the citizens.

Even with all the benefits that come along with e-government adoption, many countries face barriers to its implementation, even at the lowest level (Al-Hujran et al., 2015). This research-in-

progress investigates the impact of macro-level factors on e-government adoption. These factors are: accountability, quality of governmental policies, effectiveness of law, and corruption. To our best knowledge, the impact of these factors have not been examined in the current literature. Thus, this research fills a gap in the literature and adds to the body of knowledge.

E-government is an international phenomenon that continues to be more and more appealing to countries worldwide. The United Nations E-Government Survey for 2016 shows that 148 countries are providing at least some form of transactional service online (UN E-Government Survey). This topic has become increasingly more relevant since the number of Internet users has increased over seven-fold in the last 15 years, reaching over 3.2 billion (Davidson, 2016).

This study examines secondary data gathered from 163 different countries. Our objective is to investigate the factors that affect a country's e-government adoption.

LITERATURE REVIEW

In literature, the primary variable used to analyze e-government within a country is the e-government development index, which is used to measure ability, and how willing a country's administration is to adopt ICTs with the intent deliver information and services to the public (Kosenkov, 2015). Another measure used is the e-participation, which is used to encourage the public to engage in the use of ICTs (Merhi and Koong, 2013). Government effectiveness measures the effectiveness of the government's actions based on the, level of quality of publics services and civil services, quality of policy formulation and implementation as well as government's overall commitment to these policies (Kaufmann et al., 2006). We use e-government development index as our dependent variable to measure adoption of e-government systems.

While the adoption of e-government by countries is increasing, the rates vary. Researchers (Pavlou 2003; Rose and Straub 2001, Mahmood et al. 2004) found that the adoption of e-governments by consumers is hindered by:

- Lack of efficiency and effectiveness of policies and rules,
- Need of infrastructure that supports these systems,
- Low e-maturity levels,
- Low level of education, and
- Government policies.

Studies that investigated the effects of country-specific factors on the adoption of e-services point to significant differences in e-government adoption between countries and that country-level factors may influence adoption rates. For instance, researchers (Ferguson and Yen 2006; Javalgi and Ramsey 2001; Zhu and Thatcher 2010) have shown that government policies, supportive legal environment, compatible socio-cultural infrastructure, ICT infrastructure, culture differences have impact on e-commerce adoption. We argue that these factors may also influence e-government adoption.

RESEARCH MODEL

The adoption and the use of e-government vary across countries because the institutional and resource environments in a country can influence the e-government adoption rates. In particular, it is proposed that a country's environment factors, namely accountability, quality of governmental policies, effectiveness of law, and corruption impact e-government adoption.

E-government implementation and acceptance within a country depends on the political stability of the government within a country. When citizens have the right to elect government officials, and the power to hold them accountable for their actions, the country has a democratic environment (Gallego-Alvarez et al., 2010). The more politically stable a government is, the more accepting its citizens will be to adopt new ICTs and other benefits of e-government. We hypothesize that an increase in voice and accountability will have a positive effect on e-government.

H1: Accountability positively impacts on e-government adoption.

Regulatory quality is measured by the ability of a country's government to implement policies and regulations that help promote the development of the country (Krishnan and Teo, 2012). Due to e-government typically allowing easier access to government resources, we hypothesize that regulatory quality will have a positive effect on e-government.

H2: Policies with high quality positively impact e-government adoption.

The rule of law stems from a country's use of laws to govern. World Bank describes Rule of Law as a measure that "...captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence" (World Bank, 2017). We hypothesize that rule of law will have a positive effect on e-government.

H3: Effectiveness of law and rules positively impacts e-Government adoption.

Corruption is one of the biggest barriers to e-government adoption; furthermore, if control of corruption increases, it should be easier for e-government efforts to increase (Anderson, 2008). We hypothesize that reducing the impact that corruption has on e-government will increase the likelihood of e-government adoption within the country, and that control of corruption has a positive effect on e-government.

H4: Corruption negatively impacts e-Government adoption.

These research hypotheses are depicted in Figure 1.

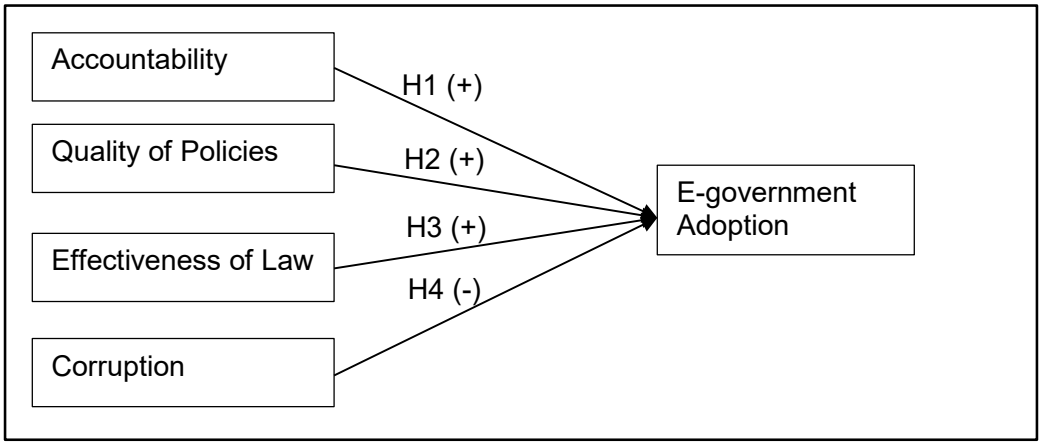


Figure 1: Research Model: E-government adoption and its antecedents

METHODOLOGY

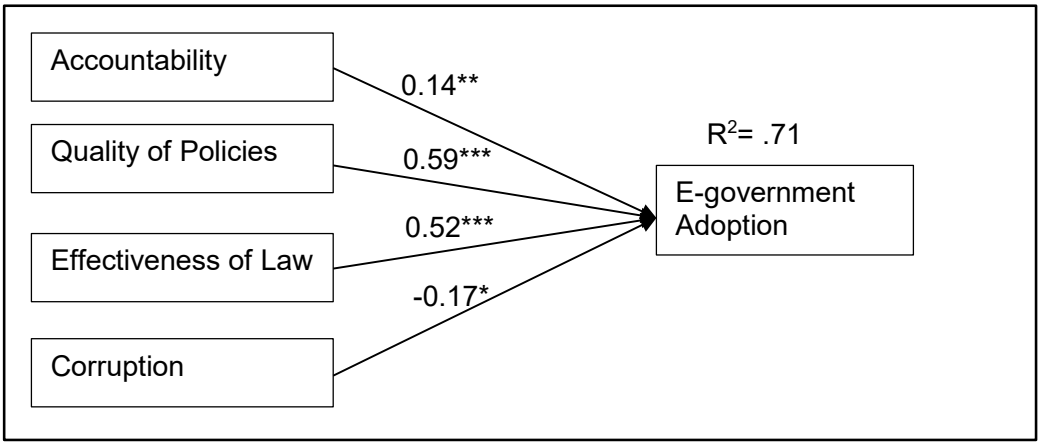
Data

Our original data consist of 193 countries from the UN E-government Knowledge Database. The datasets used come from the Transparency International 'Corruption Index 2016', The 'UN E-government Survey 2016', and the 'Worldwide Governance Indicators 2016'. After collecting the data on all the countries, we narrowed our selection to countries who had significant data on all variables, which brought our final count to 163 countries. The dependent variable is e-government, the independent variables are accountability, quality of governmental policies, effectiveness of law, and corruption, and the control variables are population and GDP.

Analysis and Results

The data were analyzed using descriptive statistical analytic procedures followed by testing the path model using SmartPLS software. The descriptive statistics are not included in this paper but will be presented at the conference. We are expecting to have more progress on this project by then and will present our findings at the meeting. Results of the paths are presented in Figure 2.

The collected were examined for potential outliers and normalization. We found no outliers and that our data were normal across all variables.



***: significant at 0.001 level; **: significant at 0.01 level; *: significant at 0.05 level

Figure 2: Results

The results of PLS analysis show that all hypotheses are supported. We posited that higher accountability level of citizens, higher qualities of governmental policies, and effective rules increase the level of adoption of e-government. We also hypothesized that lower level of corruption increases the adoption the level of e-government adoption.

IMPLICATIONS & CONCLUSION

The ever-increasing adoption of E-Government amongst varying governmental agencies has led to many studies that measure the effects E-Government has on countries and their citizens. This research-in-progress is an attempt to construct a model that depicts the relationships between country-level factors and e-government adoption and empirically test it. This study contributes to the literature in two important ways. Although researchers have studied the effects of country-factor on e-government, no study has yet investigated the impact of the selected factors used in this study. Thus, this research adds to the literature by introducing new factors, namely accountability, quality of governmental policies, effectiveness of law, and corruption. Second, empirically investigating the relationships, postulated between the macro-level factors and e-government adoption, using data from a relatively large number of countries.

This research offers some implications for policy makers. By identifying the factors that are related to the general environment, specifically the factors listed above, in a country, decision makers in governments can help improve the national development of their countries and get the best benefit out of e-government. E-government may provide governments, citizens, and commercial organizations with numerous benefits such as cost savings and convenient way to access and submit data to governments, transparency, interoperability which improve the societies. These benefits may in turn affect the national economy since organizations and citizens compose a big part of the economy.

The outcomes reported in this research-in-progress are confined to the secondary data. Second, this study examines the relationships of four macro-level factors and e-government adoption. Many other determinants have been found to also influence e-government adoption and diffusion. However, the variables used in this study have been found to be both stable and useful in describing the phenomenon. We are hoping to get feedback from the reviewer and the attendees at the conference to improve and continue this research.

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All references are available upon request.

DECISION SCIENCES INSTITUTE
A Decision Tree–Based Classifier for Providing E-Visit Services

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ABSTRACT

This study proposes a decision-tree based e-visit classification approach (DTEVCA) to identify clinic visits as e-visits using the clinics' medical records and patients' demographic data. The efficiency and validity of the DTEVCA are verified using a large data set and the results indicate that this approach can accurately classify clinic in-office visits that could switch to e-visit services. This study can help the countries that have not yet implemented e-visits to improve the policy formulation process. The concept of this study is feasible not only for e-visit services but also for other new products or new policies.

KEYWORDS: E-Visit, Healthcare Analytics, Data Classification, Decision Tree, Healthcare Insurance Data Mining

INTRODUCTION

An e-visit represents a novel health care service, providing an online consultation platform for patients and physicians to communicate in a synchronous manner, which means that patients can consult physicians via real-time video conferencing technology (Kaufman, et al., 2009; Mehrotra, et al., 2013; Polinski, et al., 2016). Through e-visits, physicians make diagnoses, implementations, and prescriptions if necessary by asking patients' symptoms, inspecting patients' physical conditions, and checking patients' medical records.

Although some countries, i.e., the United States and Canada, have implemented e-visits for years (Gilman and Stensland, 2013; O'Gorman, et al., 2016), the implementation of e-visits is not in conformity with the medical laws and regulations in most of the Asia countries. In Taiwan, subjected to the related physician's act (Taiwan Legislative Bill, 2016), physicians must make the diagnosis, decide the intervention, and write out the prescription in person except for some rural areas and special cases permitted by the government.

To confront these aforementioned problems, adopting e-visits into the current medical system is a potential solution. E-visits allow patients to get health care online for nonemergency medical needs. Through information and communication devices such as computers or smart phones,

patients can have an online consultation with physicians instead of in-office visits (Hickson, et al., 2015). It can increase the rate of patient accessing to health care because patients can contact physicians with no limitation of fixed consulting hours and avoiding long travelling distances between home and the clinic (Nijland, et al., 2009). On the other hand, e-visit introduces more flexibility on scheduling of the medical workforce and decreases the burden of the clinic offering the in-office visits (Hickson, et al., 2015; Nijland, et al., 2009). In addition, e-visits are more efficient and effective compared to the in-office visits. Health care providers can serve the same quality of care at a lower cost by adopting e-visits that do not need bricks and mortar (Nijland, et al., 2009). E-visits can also lower the price for seeking health care since the cost of e-visits is only a small fraction of the cost of in-office visits (Rohrer, et al., 2010). Therefore, e-visits may be a promising solution to solve insufficient health care resource issues in many Asian countries, such as Japan and Taiwan.

However, e-visits are not the perfect solution because there presents some challenges before implementing e-visits. For instance, both health care providers and patients are worried about the reimbursement coverage of e-visits. A health care provider requires an adequate pay and a patient demands a reasonable price of an e-visit. One corresponding solution was that the medical insurance covers only under some situations, such as patients living in rural areas, to balance the cost. For another challenge, the scope of e-visits excludes certain medical conditions, such as emergency health problems and physical examinations; under these conditions, e-visits cannot substitute for in-office visits. Some inherent problems of in-office visits retain after implementing e-visits.

To solve the patient classification problem for reimbursing e-visits, the best approach is to use e-visit records to construct a classification model. However, there is no e-visit data in most of Asian countries since these countries have not implemented e-visits, yet. Therefore, the major issue of the e-visit classification problem is the lack of the target class attribute (whether the visits are e-visits or not) to train the classification model. To obtain the crucial target class label attribute for each clinic visit, this study proposes to assign the target class label based on the conclusion of three previous e-visit studies (Albert, et al., 2011; Mehrotra, et al., 2013; Polinski, et al., 2016).

Polinski et al. (2016) surveyed 1,734 patients using e-visits at a MinuteClinic in January-September, 2014. Mehrotra et al. (2013) compared e-visits and in-office visits at four practices in the Pittsburgh between January 2010 and May 2011. They examined two common conditions for e-visits: sinusitis and urinary tract infection (UTI). Albert et al. (2011) surveyed first users who were contacted within 6 months of the e-visits of UPMC's HealthTrak e-Visit system. The telephone interviews were completed in 2009 with 121 patients. The criteria found in these e-visit studies are: (1) the characteristics of patients who use e-visits in other countries; (2) the scope of e-visits from the opinions of the researchers in the related studies; and (3) the consideration of the local situation.

It is impossible to use the criteria to assign target class attribute directly due to the different formats of attributes between the criteria and the collected dataset; moreover, some studies in different countries may have contradicted results. Before generating the class label attribute, we have to perform three processes. First, we need to summarize the results and collect the classification rules from previous studies. Second, we need to make some justification of the classification rules from previous studies to fit the medical circumstance we are facing. Third, we need to preprocess the dataset to match the attributes of the classification rules from previous studies. After these three processes, we can apply the classification rules from previous studies to the dataset with the class label attribute to train the model to get the classification rules that fit

the medical circumstance we are facing. In conclusion, this study aims to build a decision-tree based classification model for the e-visits based on the demographic data and electronic medical record of patients for the countries where e-visits have not yet implemented.

PROBLEM DESCRIPTION

The aim of this study is to classify clinic visits into two classes: use and nonuse of e-visits, based on patients' demographic data and electronic medical records. This study assumes that a reliable medical record database exists, so how to collect data is not a concern in this study. The collected data is consist of *r* relation schemas. Each relation schema represents one topic of information, such as a patient, a medical institution, or a doctor visit record. The next step is processing the relation schemas to a dataset for classification. There are *n* tuples and each tuple represents the record of a visit in the dataset. A tuple has an *m*-dimensional attribute vector, representing the characteristics of a patient or a doctor visit. Each value of the vector measures one of the corresponding m database attributes, respectively. For example, the attributes may be gender, age, or education level in this study. For a more general case, each tuple should contain a class label attribute, which represents the inclination of using e-visits or not. Classification is a two-step supervised learning process. The first step builds a classifier by a training dataset, and the second step evaluates the classifier by a test dataset.

Based on the above description, there are three challenges in this study. The first challenge is to process data so that it is possible to derive a doctor visit dataset for classification from the collected data to build a classifier. The second is how to deal with the lack of the class label attributes. The last is to apply or modify a classification model with acceptable performance to obtain a set of clear, logical, and explainable classification rules, or in other words, to build a classifier.

For the first challenge, this study must handle some issues of a dataset because it is critical for the quality of classification results to depend on the quality of input data. The first issue is to deal with missing-value data. The second issue is the lacks of the expected data attributes in the whole dataset. For example, the travelling distance between the home and the clinic of each visit may be a significant attribute to determine if a patient uses e-visit or not, as shown in Mehrotra et al. (2013). In most cases, the distance data is not including in the dataset due to difficulty of data collecting. The third issue is to avoid random data errors, such as typos and conceals.

The fourth issue is the outliers in the dataset that significantly affect the classification results. The fifth issue is the inconsistency of data among relations. For example, the gender data is usually represented categorically by Male and Female, or sometimes by binary data, 0 and 1, in different relations. The sixth issue is the inadequate forms of the data, making them hard to be adopted in the classification model. For example, there may be birthday data of patients in some datasets but only birth year in others. The seventh issue is to consider two aspects of redundancy in attributes: removing the redundant attributes and dealing with the huge amounts of attributes that are impossible to be included all in the classification model. Lastly, a drawback of decision-tree algorithm is that the discretization of continuous variables in the separating processes may cause errors. Therefore, this study should carefully consider and exercise the process of data discretization before classification model building.

The second challenge is dealing with the class label attribute, also called, *Y*, in this study. For the countries where the e-visits have implemented, collecting the value of *Y* for each doctor visit is not a problem. The classification model can use the value of *Y* collected from the medical

institutions providing e-visits service directly. In contrast, for the countries where the e-visits have not implemented, how to assign a value of *Y* to each tuple for classification becomes a tough difficulty to tackle. This study faces the condition that there is no value of *Y* in some of the Asia countries because in these countries, health insurance does not reimburse patients for e-visits. Therefore, how to assign a value of *Y* is a critical problem before building a classifier for e-visits. To reduce the complexity of classification, this study assume that the value of *Y* is binary, representing use or nonuse of e-visits, or in other words, the class label attribute $Y \in \{N, Y\}$, where "*N*" is for nonuse and "*Y*" is for use.

The last challenge is to fit a classification model for e-visits with acceptable performance. In addition, the output of model has to accord with the expected result. Therefore, this study needs to consider some important issues. The first issue is choosing the most suitable decision-tree algorithm based on the overall picture of data. The second issue is to split the dataset into a training dataset and a test dataset. The third issue is specifying the node splitting criteria when building a decision tree. The fourth issue is to select the attribute for splitting when building a decision tree. The fifth issue is setting the stopping condition for splitting nodes. The sixth issue addresses the underfitting or overfitting problem. The seventh issue is estimating the accuracy of model. The last issue is to compare the performance among different models.

In summary, this study aims to solve the classification problem of identifying the e-visits. Three challenges are addressed: (1) to process data so that a dataset is sufficient to build a classifier; (2) to generate the class label attributes; and (3) to build a classifier that provide a set of clear, logical, and explainable classification rules.

THE DTEVCA

This study aims to classify clinic visits into two classes: use and nonuse of e-visits. In order to derive a set of clear, logical, and explainable rules, we propose a data classification approach called the Decision-Tree Based E-Visit Classification Approach (DTEVCA). The four major steps of the DTEVCA are: (1) data collection; (2) data preparation; (3) assigning the class label attribute, *Y*; and (4) model building. Firstly, we have to collect the demographic data and electronic medical records of patients. Then we preprocess the data to derive a visit dataset for classification. For the countries that have not yet implemented e-visits, the class label attribute, *Y*, is assigned to identify a visit as an e-visit or not. Lastly, the DTEVCA trains the decision-tree based classification model and summarize the classification rules.

To understand the characteristics of patients and the pattern of the medical behavior, we need to gather the demographic data and medical records. For the countries that have constructed the electronic medical database, we can obtain the data directly; otherwise, we can collect the data from the hospitals or clinics. In addition, the collected data should exclude patients under 18 years old, since they usually do not have the self-determination rights in medical care in most countries.

To derive a feasible dataset for classification, the steps for data preparation are cleaning, reduction, transformation, and integration. If the data is from different sources, we need to deal with the inconsistency problem of the dataset. Since the collected data may be from different sources or from one source maintained by different divisions, different attributes refer to the same meaning. We convert the different attributes in different datasets with the same meaning to the same single attribute. The visit dataset may contain many redundant attributes unrelated to the target class label attribute. To solve the redundancy problem and reduce the volume of the dataset, we need to remove the irrelevant attributes directly and use correlation analysis to detect

redundancy among the remaining attributes. Next, to solve the missing data problem, the way to fill the missing value of this attribute depends on the numerical attribute's distribution. If the attribute is approximately normally distributed, the missing value is assigned as the mean whereas if the attribute is extremely skewed, the missing value is assigned as the median. If the data type of an attribute is categorical, we assign the value of the mode class to the missing value.

Since the DTEVCA is a decision-tree based approach, the attribute tends to be split at a particular value of a numerical attribute without any explainable reason when training the model. Hence, we use the discretization to convert numerical data into categorical data. For taking account of rationality, the discretization method will follow some well-known standards or statistical criteria. For example, the age data can be divided into age groups based on the standard of UN or WHO. Other numerical data can use mean and standard deviation to determine the intervals.

In this study, we collect three experts' opinions. From the literature review, we choose the three researches related to e-visits as our experts' opinions. The first expert is the research of Polinski et al. (2016), called Expert 1 in the following discussion. The second expert is the research of Mehrotra et al. (2013), called Expert 2 in the following discussion. The third expert is the research of Albert et al. (2011), called Expert 3 in the following discussion.

In addition, we need to adjust the experts' opinions to make them more suitable to the countries that have not yet implemented e-visits since different countries have different situations and different patient distributions. For example, Mehrotra et al. (2013) studied e-visits in Pittsburgh of Pennsylvania in U.S. and found that the season is a significant factor of using e-visits. In other words, the usage of e-visits is higher in the winter than in the other seasons of the year. It can infer that the bad weather in the winter may increase the inconvenience of office visits. However, in the places such as Taiwan or other subtropical countries, the weather in the winter is completely different from Pittsburgh of Pennsylvania in U.S. and thus is not a significant factor to affect patients using e-visits. Therefore, we should adjust this expert's opinion if we want to apply it to the case in other subtropical countries.

According to the opinions of Expert 1, 2, and 3 (Albert, et al., 2011; Mehrotra, et al., 2013; Polinski, et al., 2016), DTEVCA generates three new attributes, Y_1, Y_2, and Y_3 to represent the classification results of the three experts, respectively. We assign the value of Y_1, Y_2, and Y_3 for the training dataset. In order to ensure the values of Y_1, Y_2, and Y_3 corresponding to the experts' opinions, we use the Chi-square test with significance level of 5% to compare the distributions of patients' characteristics. We then integrate the outcomes of each record by the majority rule to combine experts' opinions, which means that the visit is e-visit if half of experts' opinions are positive. In other words, for a tuple, if two or more Y_1, Y_2, and Y_3 are positive, the value of Y of this tuple will be positive. Lastly, the training dataset with Y_1, Y_2, Y_3 and Y is ready for training the expert classification models.

To build the e-visit classification model, we will follow three steps: (1) train several tree-based models by altering the parameters for better performances with the training dataset; (2) use the test datasets to assess the tree-based models generated in (1) by performance measurements; and (3) perform statistical techniques on performance measurements to select the best model. To build a decision-tree based model, it is important to choose proper attributes and criteria for node splitting. The parameters that we can choose include the attribute selection rules, node splitting criteria and stopping condition. The criteria for node splitting include information entropy, Gini index, misclassification error, etc. In addition, the way to split the nodes can be multi-way or binary way. We can set the stopping condition as the minimum data number of leaf nodes or the

maximum depth of tree levels. In the model building algorithm, we can also choose pre-pruning or post-pruning the tree to optimize the model. In this study, as the expert classification model, DTEVCA uses the well-known algorithms CART, C5.0, and Ctree.

We use four measurements to evaluate the performance of each model by the test data. First, we construct the confusion matrix to compare Y and Y' (the classified Y) to summarize the counts of true positive (TP), true negative (TN), false positive (FP), and false negative (FN). The four measurements, accuracy, recall (true positive rate), specificity (true negative rate), and precision are computed by the following formula.

The probability of being correct or Accuracy is computed as (TP + TN) / (FP + TN + TP + FN). Recall or true positive rate which can be computed as TP/(TP + FN), such that the denominator represents actual positive cases. Recall indicates an ability to identify the positive case of a model correctly, so higher Recall implies fewer Type-II errors have occurred when applying the model. Specificity, computed as TN/(FP + TN) or 1 – FP/(FP + TN), is the true negative rate and tells us how accurately our model will identify true negatives. Precision, computed as TP/(TP + FP) or 1 – FP/(TP + FP), is the exactness or percentage of tuples that the classifier labeled as positive that are actually positive. Precision tells us how accurately our model will identify true positives.

For each model, we will compute one set of measurement with accuracy, recall, specificity, and precision for each trial run of test dataset. If the DTEVCA builds decision tree models on a large collected dataset, it is suggested that the DTEVCA take 30 random samples as test data and thus there will be 30 sets of measurements with accuracy, recall, specificity, and precision for evaluation.

To distinguish which model has better performance, we use statistical tools such as *t* test or ANOVA test to compare the models. In addition, before applying the statistical tests, we should check all requirements of the tests. Taking a large collected data for example, there are 30 test datasets with 30 sets of measurements with accuracy, recall, precision, and specificity for each model. To compare the performance of accuracy, we gather all accuracy measurements of each model, and check the requirement condition of ANOVA test. We can then do the two-way ANOVA test for comparing three models by the accuracy measurements.

For the final model selection, we rank the priority of these four measurements. In this study, the distribution of Y is not expected to be extremely imbalance, so to accurately identify each object as positive and negative is very important. However, it is estimated that the number of negative counts is more than the number of positive counts and hence the count of true positive will be more influential than the count of true negative when analyzing the performance of classifiers. Moreover, the underestimate of the positive value is more serious than overestimate the positive value since the stability of the e-visit system is important. The underestimate may lead to system crashes. Hence, the priority of four measurements used to select the final best model is: (1) accuracy, (2) recall, (3) precision, and (4) specificity. Using the statistical tools and priority of measurements, we can determine the best tree-based model for the problem in this study and sum up a set of clear, logical, and explainable classification rules of identifying patients who should be reimbursed by insurance policy when adopting e-visits.

COMPUTATIONAL ANALYSIS

In this section, we implement the DTEVCA with the National Health Insurance Research Database (NHIRD) in Taiwan to demonstrate its feasibility. Moreover, we try to estimate the

possible usage of e-visits; though e-visits are not yet available in Taiwan. In addition, to show the relative merits of the DTEVCA, we design an experiment for comparison with two other binary classification algorithms: logistic regression (Cox, 1958) and random forests (Breiman, 1958) (a black-box algorithm). We implement the logistic regression and random forests algorithms by the packages stats (R Core Team, 2016) and random forest (Liaw and Wiener, 2002) in R (R Core Team, 2016).

The demographic data and medical records of patients are collected from the National Health Insurance Research Database (NHIRD) in Taiwan, provided by the National Health Research Institutes (2015). The NHIRD is a complete patient medical database because nearly 100% population in Taiwan was enrolled in the National Health Insurance Policy. The NHIRD not only spans decades but also contains the details of each doctor visit for each patient. In this study, to reduce the complexity, we only focus on one-year-period data in 2012. For some factors, we may use the data in the previous year (2011) as well. This study only covers the population above 18 years old and the doctor visits of western medicine. We exclude the population under 18, the visits of Chinese medicine, and dentistry at first. Since the data is from the same NHIRD database, there is no inconsistency problem. DTEVCA merges the related attributes into one visit dataset.

To assign values to the class label attribute, Y, we adopt the majority rule to combine three experts' opinions. First, we create attributes, Y_1, Y_2 and Y_3, according to the opinions of Expert 1 (Polinski, et al., 2016), Expert 2 (Mehrotra, et al., 2013) and Expert 3 (Albert, et al., 2011), respectively. However, the opinions obtained from these three experts may be inconsistent for some records and thus the DTEVCA determine the value of Y for each record by the majority rule to combine experts' opinions. Before applying the opinions of the experts to generate the values of attributes, Y_1, Y_2 and Y_3, we adjust some of experts' opinions according to the conditions in Taiwan, such as the medical insurance coverage factor and the bitter cold winter weather factor.

We then assign the values to the three attributes, Y_1, Y_2 and Y_3, according to the three experts' opinions and applicability. If the applicability of a visit is "N", the value of Y_1, Y_2 and Y_3 is "N." If the applicability of a visit is "Y", the values of Y_1, Y_2 and Y_3 follow the experts' opinions respectively. To confirm that the distributions of Y_1, Y_2 and Y_3 are corresponding to the experts' opinions, we apply Chi-square test to check the proportion of each rule and the positive value in Y_1, Y_2 and Y_3. Because the p-values are all larger than significance level 5%, we can confirm that the distributions all follow the rules of the experts' opinions. Finally, we use the majority rule to determine Y.

We build three decision tree models for the three experts respectively, by CART, C5.0, and Ctree, and assess the model by 10-fold cross-validation. To obtain the highest accuracy and the minimum number of nodes used in the rule to avoid overfitting problem, we should choose C5.0 as the algorithm to build these three experts' classification models. Then, we can apply these experts' classification models to classify the 30 test datasets to derive Y_1, Y_2 and Y_3. Lastly, we apply the majority rule to determine the value of Y.

To select the best final classification model from $\text{Tree}_{\text{CART}}$, Tree_{C50}, and $\text{Tree}_{\text{Ctree}}$, we use the 30 test datasets to evaluate these models and calculate the four performance measurements (accuracy, recall, precision, and specificity) for each model. Consequently, we will compare these performance measurements by statistical tools at the significance level 5%. First, we compare the accuracy measurements of these three models by two-way ANOVA and conclude that the accuracy performances of $\text{Tree}_{\text{CART}}$, Tree_{C50}, and $\text{Tree}_{\text{Ctree}}$ are different. We then compare the accuracy measurements for each pair of models by Tukey's multiple comparison test and

conclude that $Tree_{C50}$ = $Tree_{Ctree}$ > $Tree_{CART}$, which implies that though $Tree_{C50}$ is better than $Tree_{Ctree}$, the evidence is not strong enough to show the difference.

Second, we compare the recall measurements of these three models by two-way ANOVA and conclude that the recall performances of $Tree_{CART}$, $Tree_{C50}$, and $Tree_{Ctree}$ are different. We compare the recall measurements for each pair of models by Tukey's multiple comparison test and conclude that $Tree_{C50}$ = $Tree_{Ctree}$ > $Tree_{CART}$. Hence, though $Tree_{Ctree}$ is better than $Tree_{C50}$, the evidence is not strong enough to show the difference.

Third, we compare the precision measurements of these three models by two-way ANOVA and conclude that the precision performances of $Tree_{CART}$, $Tree_{C50}$, and $Tree_{Ctree}$ are different. By applying Tukey's multiple comparison test on the precision measurements for each pair of models, we conclude that $Tree_{C50}$ > $Tree_{Ctree}$ > $Tree_{CART}$. In other words, there is a strong evidence to show that $Tree_{C50}$ performs better than $Tree_{Ctree}$ based on the precision measurement. Finally, we can select $Tree_{C50}$ as the decision tree algorithm to generate our final e-visit classification model.

In the experiments, we compare the results of $Tree_{C50}$ to the results of logistic regression model (Cox, 1958) constructed by stats (R Core Team, 2016) and the random forests model (Breiman, 1958) built by randomForest (Liaw and Wiener, 2002) in R (R Core Team, 2016). For the logistic regression model, we first identify the multicollinearity problem among the attributes of the training dataset by computing the generalized variance inflation factor (GVIF). We remove the attribute edu_level because the GVIF of edu_level is 5.29, which is higher than 5. We then remove the unrelated attributes by coefficient test or p-value > 5% until remaining attributes are significant. Finally, we obtain the final logistic regression model (LM).

For random forest, we control two parameters to fit the random forests model: the number of trees to grow (ntree) and the number of attributes randomly sampled at each split (mtry). We tune the random forest model on parameters of ntree and mtry by 10-fold cross-validation and select the best random forest (RF) model of ntree = 300 and mtry = 4 with the highest accuracy performance. We then classify each visit by this RF model. Because random forest is a black-box algorithm, the classifying result of each visit is obtained without clear rules to explain the RF classification result.

Finally, we compare average performance measurements of accuracy, recall, precision, and specificity by the selected three different binary classification models, $Tree_{C50}$, LM, and RF, as listed in Table 1. We compare the accuracy performances of three models, $Tree_{C50}$, LM, and RF, by two-way ANOVA. Because the p-value of the two-way ANOVA is $4.86 \times 10\text{-}72$, we reject the null hypothesis and conclude that the accuracy performances of $Tree_{C50}$, LM, and RF are different. By applying Tukey's multiple comparison test on the accuracy measurements for each pair of models, we conclude that $Tree_{C50}$ = RF > LM, which implies that though $Tree_{C50}$ is better than RF, the evidence is not strong enough to show the difference.

We then compare the recall performances of three models, $Tree_{C50}$, LM, and RF, by two-way ANOVA. Because the *p*-value of the two-way ANOVA is $3.6 \times 10\text{-}72$, we reject the null hypothesis and conclude that the recall performances of $Tree_{C50}$, LM, and RF are different. By applying Tukey's multiple comparison test on the recall measurements for each pair of models, the evidence is strong enough to conclude that $Tree_{C50}$ > RF > LM. For precision performance, since the p-value of the two-way ANOVA is $5.38 \times 10\text{-}65$, we reject the null hypothesis and conclude that the precision performances of $Tree_{C50}$, LM, and RF are different. The Tukey's multiple comparison tests on the precision measurements for each pair of models show that the evidence is strong

enough to conclude RF > $Tree_{C50}$ > LM. For specificity performance, because the p-value of the two-way ANOVA is 5.9×10-54, we reject the null hypothesis and conclude that the specificity performances of $Tree_{C50}$, LM, and RF are different. The Tukey's multiple comparison tests on the precision measurements for each pair of models show that the evidence is strong enough to conclude RF > $Tree_{C50}$ > LM.

Table 1: The average performance measurements of $Tree_{C5}$, LM, and RF

Average Performance	Model		
	C5.0	LM	RF
Accuracy	0.9400	0.9075	0.9397
Recall	0.8591	0.7306	0.8483
Precision	0.8244	0.7610	0.8303
Specificity	0.9584	0.9478	0.9605

To sum up, because LM has the worst performance on all four measurements, LM is not a good choice to solve the problem of e-visit classification. $Tree_{C50}$ has the best performance on recall measurement but RF has the best performance on both measurements of precision and specificity. Though $Tree_{C50}$ performs a little better than RF does on accuracy measurement, the evidence is not strong enough to show the difference. Moreover, the $Tree_{C50}$ model provides a set of clear, logical, and explainable rules but the RF model, a black-box model, provides no such rules. According to the research objectives in this study, the $Tree_{C50}$ model can provide a set of clear, logical, and explainable rules for e-visit classification. Moreover, these rules provide more information for the governments to plan the medical policies about e-visits. Therefore, we can conclude that $Tree_{C50}$ is a better choice for solving the e-visit classification problem.

CONCLUSIONS

This study proposes a decision-tree based e-visit classification approach (DTEVCA), a systematic approach to identify those clinic visits which are qualified as e-visits by using the clinics' medical records and patients' demographic data. For the counties that have not yet implemented e-visits, this study proposes a way to identify a visit as an e-visit so as to assign the value of class label attribute. The result of the DTEVCA provides a set of straightforward rules due to the tree-based algorithm and these rules can help insurance providers to classify and explain the clinic visits as an e-visit or not clearly. Moreover, the performances of DTEVCA are better compared with the other two binary classification algorithms: logistic regression and random forest.

Though e-visits are generally not available in every country, the DTEVCA is able to deal with both cases: e-visit available and e-visit unavailable. For the places where e-visits are not available, the governments could apply the DTEVCA to estimate the possible number of e-visits as well as to establish rules of reimbursing e-visits on behalf of the insurance providers. Furthermore, the governments can also make a complete plan of allocating resources before implementing the new e-visit policy. The concept of DTEVCA is not only feasible for e-visits but also other "new services" such as new products or new policies. For example, when a company plans to launch a new product in a new market, they can use the concept of DTEVCA to estimate the sales and find the target customers according to the results of the existing products in the developed markets.

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DECISION SCIENCES INSTITUTE
A Global Supply Chain Production and Distribution Network Design Model

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ABSTRACT

A global supply chain network design model that plans procurement of inputs, realization of products of multiple design categories for various customer classes and distribution of products to global markets is proposed. Products with higher level designs are realized in supply chain's own plant and the basic level outsourced. Location and allocation of production and distribution centers are planned to maintain proximity for facilitating quick replenishment to retail outlets. The overall objective of the research is to address customer requirements for products with multiple design categories at globally located retail outlets for optimizing cost and obtaining superior supply chain performance.

KEYWORDS: Multiple design category, Outsourcing, Customer class, Global supply chain model, Quick replenishment.

INTRODUCTION

Given the current competitive business situations, Supply chains(SCs) have been planning innovative ways to differentiate (Fitzsimons et al, 2014) their products and services in the eyes of customers. For consumer product like automobiles and apparels such differentiation is difficult because of the various design levels as expected by various classes of customers. But offering of such multiple design products, especially in the case of Fashion SC and Automobile SC where customers prefer new designs and changes in design, may be considered as one of the responsive SC strategies (Roh et al, 2014). Such variation is also expected by the customer with respect to raw materials used in the product, product outlook, and colors. Over and above, these customers do not want to wait for the product of their choice. We may note that today customers do need to wait for their delivery when businesses are offering innovative ways to ensure quickest possible delivery (Marino et al, 2018).They need fastest delivery of product or would like to pick their product with expected design and specification from brick and mortar store if they have time. For global companies the main challenge is the location of plant and distribution center(DCs) and allocation of product to them in such a way that time needed for transportation of product from plants to DCs, and DCs to markets (retailers) should be as low as possible. As such added with the complexities of managing production and distribution of products with multiple designs, strategic global Supply Chain(GSC) network design should consider and integrate location and allocation of resources in the GSC design process for the effectiveness and superior performances of a GSC (Song et al, 2018; Melnyk et al, 2013). Most of the global companies manage distribution time and cost by deciding optimum route within the available alternatives for the multimodal routes for DC-retailer combinations. Since distribution to market may sometimes be needed to be made within the quickest possible time based on the following up or special requests from sales outlets, SC operations may not have much control on distribution at the operations level. But SC design at the strategic level should plan location and allocation of distance of Plant-DC combinations to ensure minimum possible distance for plant -DC combinations to minimize cost and influence overall delivery time to customer for improving response time to market. One of the possible other alternative solution could be

keeping high level of inventory at the sales outlets such that customer service for picking up from store/show room or retail centers can be managed at the highest possible level. But such policy is not only expensive but also not feasible for apparels and automobiles. There is always a probability of product becoming obsolete if such inventory cannot be sold before next model/design comes out. In such situations location of production and distribution center is critical for optimizing cost and satisfying customers. The next challenge for the business is to display the latest designs and taking out the old designs and making sure that relatively older products are not occupying space, such that new product can be sufficiently displayed to attract visiting customers. Addressing design change and handling of issues of taking out old products are not within the scope of this research.

Given the business objective to address multiple design products for various customer class, realization of products of such designs including optimum location allocation of plants and DCs are addressed by the proposed research model. Fulfilling product realization that includes multiple design levels is a very difficult and complex planning process complying with market needs. SCs for premium apparel, automobile and similar products should take the responsibility for managing higher level designs in their own plants as a core part of business and go for outsourcing for general design category to obtain cost competitiveness. Outsourcing decision is a much-discussed issue in SC management. SC literature recommends outsourcing considering advantages to manufacturing plant of SC (see Li et al, 2015; Lin &Chen, 2015). Since in this research, the SC is going for outsourcing general category of product which is almost a commoditized item, the outsourcing decision of this research is following the approach of Brewer et al. (2013) to obtain cost advantage without affecting any other business factor.

For ensuring fulfillment of customer expectations as well as achieving competitive advantage the SC should manage realization of all or at least critical components of the products in their own controlled plants and depend on a high-quality supplier pool for non-critical component. Based on above discussion a global supply chain(GSC) network design that includes plant-DC location and allocation for quick replenishment, outsourcing of products for general designs, managing higher design levels in their own plants taking noncritical components from suppliers if possible, should be highly competitive in the market places. This research proposes a GSC network design model for addressing each of these features to obtain superior performance by a GSC. To the best of our knowledge GSC design literature does include such a model based approach that contributes by including innovative approach for addressing a complex business situation for handling product with multiple designs, and each design with multiple customer class levels, and a commitment for competitive cost by outsourcing a part of demand in addition to quickest delivery to market for the overall success of a GSC. An effective SC model-based design for addressing each of the complex requirements are very much necessary for becoming competitive and successful in Fashion marketing, apparel SC and in Automobile. This research will facilitate complex GSCs for apparels, premium automobiles and similar products for achieving such requirement effectively. It will also facilitate SC managers to derive critical managerial insights for achieving these objectives to become competitive in the market places.

The paper is organized in the following way: it studies relevant background literature in Section 2 and presents methodology in Section 3 which also includes the mathematical model for designing effective GSC network discussed above. Section 4 illustrates applicability of the model using a numerical example and Section 5 concludes and discusses.

LITERATURE REVIEW

GSC network design for location and allocation resources(plants, DCs, retail outlets) for quick replenishment of product at sales outlets and SC design for managing realization of products of various design categories are the two streams of research that created background of this research.

Location and Allocation of Resources in GSC Network Design Stream:

It is now established in SC literature that an effective SC management should be an integrated process for sourcing and management of inputs, transforming them into customer expected product, and distribution of product to customers (Melo et al, 2009; Caniato et al. 2013). For addressing such an integrated management process effectively, SC network design is recognized by the practitioners to be a strategic issue for a business. Such an effective network design is crucial for the success of a GSC considering that an optimal SC network structure facilitates achieving high level of performances in the global market (Melnyk et al, 2013). For designing SC network one of the critical issue is the location of facilities including distribution centers, plants, and sales outlets. Here strategic issues are deciding the locations for warehouses and assigning them to sales outlets (see the review study in Bougelben & Boulaksil, 2018) and similar is the assignment of plants for supplying to warehouses, and may be allocation of products to plants in a GSC. Since this research needs to decide location of plants and warehouses to supply product to multiple global markets, multi-level facility location is also relevant to this study (Astorquiza et al, 2018). The products addressed by the GSC(premium apparels and automobiles) of this research attract the customers based on availability of design categories as current as possible. As such prompt/speedy delivery of product from plant to DCs and from there to sales outlets/retailers is a crucial requirement. In addition, based on discussion before, distribution of product from DCs to sales outlets are often influenced by the following up of sales outlets with the DCs, importance for location of DCs considering optimum DC-sales outlet distance combinations may often get compromised. Location allocation model addresses optimal cost and times for transporting product from plants to DCs and for distribution of product from DCs to sales outlets. Despite the fact that SC planning and design should address both(as discussed), location allocation decision issues that may be mentioned as the specific characteristics of a Facility Location model should have to adequately address SCM planning needs (Melo et al, 2009) for its effectiveness. Similar specific characteristics of SCM planning needs seem to be applicable for designing Apparel SCs. In such SCs strategic decisions for location and allocation of DCs considering optimum distance for plant-DC combinations becomes crucial for ensuring prompt /speedy delivery of product with multiple designs from plant to DCs. Such is also the case because of close monitoring or following up by Sales outlets for availability of latest designs in their store as discussed before. A similar approach is the market-plant strategy as covered in Stevenson (2015) where plants take the role of DCs to ensure quick replenishment of product. Optimum distance for Plant-DC combinations followed in this GSC model serves almost similar purpose by keeping plants-DCs in the same country. In addition, in the era of Omni Channel when customers have been preferring e-tailing, distribution-retailer location is not as important as the distances for plant-DC combinations for supplying product to customer directly and quickly, when percentage of customers going for brick and mortar store is decreasing. Recent OMNI channel review study in (Melacini et al, 2018) mentions progressive growth of e-commerce sales and rising interest of research in OMNI-Channel retailing in academicians and practitioners even if there are some limiting issues in OMNI channel operations.

GSC Network Design for Managing Realization Product of Various Designs Stream:

Planning and managing of product for different design categories for a SC is always a complex problem (Gunasekharan et al, 2014, Jacobs & Swink, 2011). For large products such a problem starts from the selection of product architecture. Often times, influence of modular and integral product architectures is studied for large size products (Pashei & Olhager, 2017). In a GSC, selection of architectures influences cost and operations. But in both the cases (integral or

modular) number of capable plants for assembly equipped with required technologies in SC corporate operated plants and suppliers (or outsourcing vendor) selections are key influencing issues as observed in Pashei & Olhager's research. Such influences are obvious because in a GSC network the firm needs to concentrate on meeting customer's requirements through manufacturing products in its plants and by outsourced vendors, distributing products through DCs, getting components from suppliers (Olahager et al, 2015) based on designs selected from some architecture. Product Design has been mentioned in the literature as large determinant for cost of producing and delivering product (Hong & Roh,2009). In today's competitive market product designs decide the direction of competitive advantage for the years to come (Hong et al, 2011). This is such because it is established in the operations management literature that product design is the main determinant for process design (Marsillac & Roh,2014). Marsillac & Roh's research considered case study based exploration to identify support that may be obtained from suppliers. With the aid of suppliers one of the case could reduce the cycle time for the production. This research procured noncritical components and raw materials from the suppliers to manage components needed for products of various designs and obtain some degree of cost competitiveness. In that perspectives allocation of supply orders to suitable suppliers is also important in managing a GSC network with multiple designs. So, it is apparent that for managing product designs aligning with effective process design, expectation of retailers/customers in the markets and important suppliers need to be incorporated in an extended view in the manufacturing network (Cheng et al, 2011, Olhager et al,2015). Chen & Fung (2013) empirically studied relationship configurations of SC with supplier and customer and their effect on SC performance studies. Based on their several findings they mentioned that relationships continuously develop and change in a dynamic global SC situation. As such managers need to continuously evaluate current relations and its impact on other relationship and their value creation potential.

GSC network for Fashion items, especially for international fashion retail based SCs the problem of new product Development(NPD) is considered as the integration of new product development and design(NPD). Similar to offerings of multiple product to make it almost customized product, NPD is considered as a success factor (Caniato et al, 2014). It is apparent that NPD makes the GSC network dealing with fashion retail a complex one with multiple products by adding several NPDs.

This research considered findings in the above background literature and planned the methodology for developing GSC network design model aligned with the findings.

METHODOLOGY

Considering complexity of multiple products with multiple designs for each having multiple levels for each design, multiple distribution centers, and markets at global locations, a mathematical model based planning and design of the proposed global supply chain seems to be appropriate. The model proposed is a Mixed Integer programing model for Designing a GSC model that will address multiple design products for multiple markets quickest possible delivery of products to customers. This section includes Problem Statement, Notations to define the mathematical model equations and the GSC network design model.

Problem Statement

We consider the problem of a global supply chain(GSC) that needs operation and marketing plan to handle a complex business similar to Zara, the fashion marketing supply chain. Let $P(p \in P)$ be the set of products to follow set of design $D(d \in D)$ to address various customer class requirements based on quality and feature. Let ($d \in D^{hl}$) set of design category considered as high-quality level; ($d \in D^{ml}$) set of medium level product design; $d \in D^{bl}$) set of basic level product

design. Products of designs D^{hl}, D^{ml} are realized in GSC operated plants J and design D^{bl} are managed through outsourced Vendors J' and transported to a set of globally located distribution center K(k∈K) from which products are distributed to a set of retail outlets R($r \in R$) at various globally located markets M($m \in M$).The overall objective of this research is to design a GSC network planning model that will minimize cost and in turn improve overall performance of the business by addressing multiple products of different design category targeted for various customer segments at different countries by addressing production, outsourcing, procurement of inputs and distribution of product to retail outlets according to their expected delivery performance.
We could not locate any research in the SC literature that addressed integration of such complex but practical and innovative business planning issues of multiple designs with multiple levels for each design involving multiple products in the GSC network design model. In addition, it addressed location and allocation of resources, realization of product by manufacturing and outsourcing and planned fast replenishment of product at globally located sales outlets with competitive cost. As such this research contributes significantly by introducing this innovative model based GSC network design approach.

Notations: Indices

$C(c \in C)$ set of components
$D(d \in D)$ set of designs, Let $(d \in D^{hl})$ set of design considered as high quality level based on quality and feature; $(d \in D^{ml})$ set of medium level product design; $d \in D^{bl}$) set of basic level product design; D^{hl}, D^{ml}, and Dl^{b} are partitions of D
L: set of levels, L=(hl,ml,bl)
$I(i \in I)$: set of inputs/raw materials
$J(j \in J)$: set of plants operated by supply chain
$J'(j' \in J')$: set of vendors who have been enlisted by the supply chain for outsourcing production of product of design D^{bl} and sending them to distribution centers.
K ($k \in K$) : set of distribution center(DC) K at the country of production center
M ($m \in M$): set of markets
τ=*transportation mode: 1: truck, 2 air, 3 air and truck* (*multimodal*)
P ($p \in P$) set of products
Q(q∈Q) a set of Quality assurance vendor to conduct final inspection of product before distributing to retail outlets.
S(s∈S): set of enlisted suppliers who are in agreement with SC to supply ensured quality raw materials.
T($t \in T$) periods.
R($r \in R$): retail outlet.
Q($q \in Q$): set of accredited quality assurance contractor.

Parameters

a_{st} =1, if supplier s is assigned supply order at period t; 0 otherwise.
BNN : a big number.
CA_{pdlj}: cost of assembling product p of design *d level l(hl, ml)* by plant j.
CAW_{kpd} : capacity of DC k for accommodating product of design d.
$CS_{pdlj'}$: cost of producing product p of design *d level l(bl)* by outsource vendor *j'.*
CM_{cj} : cost of manufacturing component c in SC operated plant j
CQI_p: quality inspection cost per product *p.*
CR_{is} : cost of raw material i from supplier *s.*

CQA_p : average final inspection cost for each product at the DCs.
cz_{cj}^{t} : Component *c* to be manufactured in SC operated plant *j* in period *t*.
$DN_{pkr\tau}$: average distribution cost of product *p* from DC k to retail outlet *r* using transportation mode τ for unit distance.
ds_{pd} =1, if product *p* selected design *d*; 0 otherwise.
DM_{pdl}^{tm} : Average demand for product *p* of design *d* of level *l* from market *m* for time *t.*
$ds_{krm:}$ distance between DC *K* may be in any country/market identified by DC # and the retailer in market *m* (may be in any country, identified by market #).
$Dtrt_{jk}$: distance between plant *j* and DC *k;* they can be in any country.
FA_{pdj} : fixed cost of assigning assembly jobs of product *p* of design *d* to plant SC plant *j*
$FS_{pdlj'}$: fixed cost for assigning production of product *p* of design *d* and design level *l*(*BL*) to outsource vendor *j'*
FM_{cj} fixed cost for manufacturing component *c* in plant *j.*
FR_{is} fixed cost for assigning orders for raw material *i* to supplier *s.*
FQA_{qp} fixed cost for assigning QA job of product *p* to quality assurance firm *q.*
y_p^{kmrt} : product *p* of design *d* level *l* distributed to retail outlet r from DC *k* in market *m* at time period *t.*
x_{pdl}^{tjk} : product *p* of design *d* level *l=hl* and *ml* that are realized in SC plants j and sent to DC *k.*
$xo_{pdl}^{tj'k}$: product *p* of design *d* level *l=bl* from outsourced vendor *j'* at time period *t* sent to DC *k.*
w_{kmr} =1; if *DC k* is allocated to supply product to retail outlet *r* in market *m*; 0 otherwise.
wo_{kpd} =1, if DC k is opened and it has the capacity to accommodate product *p* of design *d.*
ρ_{pdc} : component *c* needed for producing product *p* of design *d.*
$os_{pj't}$ =1, if outsourcing of product order is assigned to vendor *j'* in period *t*; 0 otherwise.
$qa_{qp:}$ 1, if final inspection is conducted by the quality assurance vendor *q* on the product *p* received in DC ; 0 otherwise.
$TR_{ic:}$ estimating equivalent raw materials/inputs requirements by component *c*.
TD_{kmr} =a big number distance which is the set highest distance possible to travel by truck .
u_{cjt} =1, production of component *c* is assigned to plant *j*, 0 otherwise.
v_{jpd}=1, if assembling of product *p* of design *d* is assigned to GSC operated plants *j* 0 otherwise.
z_{ist}: input/raw materials *i* to be procured from supplier *s* in period *t*
$trt_{krm\tau=1:}$ time for transportation by truck
$trt_{kmr\tau=2:}$ time by air*;* $trtkmr_{\tau=3;}$ time by mixed mode
α =1, if $trt_{kmr\tau=2}$ (Air transportation mode) is selected; 0 otherwise; β=1 , if $trt_{kr\tau=3}$ (multimodal) is selected from $\alpha+\beta\leq 1$
Seemod: an auxiliary 0/1 variable to decide transportation mode
FW_{kp} fixed cost for opening DC *k* to warehouse product *p.*
FAR_{kr} fixed cost for allocation of DC *k* to supply retailer *r*.

GSC Network Design Model

Constraint (1) ensures selecting a design by a product for its production. Constraint (2) provides the option of selecting at least one category out of three categories (*bl, ml,* and *hl*) for the selected design. Constraint (3) balances product supplied by outsourced vendor and product realized in the GSC operated plant with the overall average demand for product of the GSC. Constraint (4) balances product distributed from DC to retail outlets with the product supplied to DCs. Constraint (5) allocates DCs to retail outlets at markets. Constraint (6) allocates each DC to more than one retail outlets and constraint (7) allocates more than one DC to a retail outlet in markets to improve product availability resiliency of the retailers. Constraint (8) limits

transportation of product from outsourced vendor and from SC operated plant to a DC based on capacity of DC. Constraint (9) ensures allocation of only an open DC to supply to a retail outlet. Constraint (10) decides distribution distance from DC to retailer if the DC is allocated to retailer based on constraint (5). Constraint (11) ensures transportation of product from a plant to a DC only when the DC is allocated to a retailer. Constraint (12) sets transportation distance limit between plant-DC combinations to minimize such distances for quick product availability by the customer. Constraint (13) allocates a plant to a DC for transporting product. Constraint (14) checks whether the final inspection has been conducted by a competent QA vendor. Constraint (15) determines components needed to be produced in SC operated plants for the production of planned products at the top two levels of design. Constraint (16) computes raw materials and other inputs to be procured from suppliers. Constraint (17) assigns production of product of higher design level product to a GSC operated plant. Constraint (18) assigned outsourcing product order to the vendor with whom SC has a contract. Constraint (19) assigns supply order to suitable suppliers. Constraint (20) allocated production of critical components to the SC operated plants. Constraints (21), (22), (23), (24) and (25) selects transportation mode based on distances. Distribution distance between a DC and retail outlet of a market verified by constraint (21). If it is higher than the set limit that cannot be travelled by transportation mode truck, constraint (22) decides travelling distance for the (DC-retailer) combination based on air transportation mode. Based on constraint (21) if the distance cannot be covered by truck, alpha becomes 1, but if it needs a domestic airline support, then beta becomes 1, alpha becomes zero and constraint (23,24 and 25) come into action. Constraint (26) imposes integrality

$$ds_{pd} = 1 \qquad \forall p, d \tag{1}$$

$$\sum_{l=hl,ml,bl} dss_{pdl} \geq 1 \qquad \forall p, d \tag{2}$$

$$\sum_{m \in M} DM_{pdl}^{mt} = \sum_{j \in J} \sum_{k \in K} x_{pdl|l=hl;ml}^{tjk} + \sum_{j' \in J'} \sum_{k \in K} xo_{pdl|l=bl}^{tj'k} \qquad \forall t, p, d \tag{3}$$

$$\sum_{j \in J} \sum_{k \in K} x_{pdl|l=hl;ml}^{jkt} + \sum_{j' \in J'} \sum_{k \in K} xo_{pdl|l=bl}^{j'kt} = \sum_{m \in M} \sum_{r \in R} y_{p}^{krmt} \qquad \forall m, t, p, d, l \tag{4}$$

$$y_{pdl}^{krmt} \leq w_{krm} BNN \qquad \forall k, r, m, t, p, d, l \tag{5}$$

$$\sum_{r \in R} w_{krm} \geq 1 \qquad \forall k, m \tag{6}$$

$$\sum_{k \in K} w_{krm} \geq 1 \qquad \forall r, m \tag{7}$$

$$\sum_{g \in G} \sum_{l=\{hl,ml\}} x_{pdl|l=hl;ml}^{tjk} + \sum_{j' \in J'} \sum_{l=bl} xo_{pdl|l=bl}^{tj'k} \leq wo_{kpd} CAW_{kpd} \qquad \forall p, d, k, t \tag{8}$$

$$w_{krm} \leq wo_{kpd} \qquad \forall k, r, m, p, d \tag{9}$$

$$ds_{krm} \leq w_{krm} BN \qquad \forall k, r, m \tag{10}$$

$$v_{jk} \le w_{krm} \qquad \forall j,k,r,m \tag{11}$$

$$dtrt_{jk} \le v_{jk} SET_{jk} \qquad \forall j,k \tag{12}$$

$$x_{pddl}^{tjk} \le v_{jk} BN \qquad \forall p,d,dl,j,k,t \tag{13}$$

$$xo_{pdl}^{tj'k} + x_{pdl}^{tjk} \le qa_{qp} BNN \qquad \forall p,d,l,t,j'' j'k,q \tag{14}$$

$$\sum_{p\in P} \sum_{d\in\{D_{hl},D_{ml}\}} \rho_{pdc} \sum_{k\in K} \sum_{l\in L} \sum_{j\in J} x_{pdl}^{tjk} = \sum_{j\in J} cz_{cj}^{t} \qquad \forall c,j,t \tag{15}$$

$$\sum_{c\in C} TR_{ic} \sum_{j''\in J''} cz_{cj}^{t} = \sum_{s\in S} z_{is}^{t} \qquad \forall i,t \tag{16}$$

$$\sum_{k\in K} \sum_{l\in HL,ML} x_{pdl|l=hl;ml}^{tjk} \le v_{jpd}^{t} BM \qquad \forall j,p,d,t \tag{17}$$

$$\sum_{d\in D} \sum_{l=bl} \sum_{k\in K} xo_{pdl}^{tj'k} \le os_{pj't} BMN \qquad \forall p,j',t \tag{18}$$

$$z_{is}^{t} \le a_{st} BNNN \qquad \forall i,t \tag{19}$$

$$cz_{cj}^{t} \le u_{cjt} BNN \qquad \forall c,j,t \tag{20}$$

$$TD_{kmr} - ds_{krm} \le M(1 - see \bmod) \qquad \forall k,r,m \tag{21}$$

$$ds_{krm} - trt_{krm\tau=1} \le M * see \bmod \qquad \forall k,r,m,\tau \tag{22}$$

$$ds_{krm} - trt_{krm\tau=2}\alpha - trt_{krm\tau=3}\beta \le M(1 - see \bmod) \qquad \forall k,r,m,\tau \tag{23}$$

$$\alpha + \beta \le 1 \tag{24}$$

$$trt_{krm\tau=3} = trt_{krm\tau=2} + trt_{kr'r\tau=1} \qquad \forall k,r,m,\tau \tag{25}$$

$$\begin{aligned} &a_{st} \in \{0,1\}, \forall st; u_{cjt} \in \{0,1\}, \forall cjt; os_{pj't} \in \{0,1\}, \forall pt, j' \in J'; \\ &v_{jpdt} \in \{0,1\}, \forall jpd; qa_{qp} \in \{0,1\}, \forall pq, \forall p; v_{jk} \in \{0,1\}, \forall jk, w_{krm} \in \{0,1\}, \\ &\forall krm; wo_{kpd} \in \{0,1\}, \forall kpd; ds_{pd}, dss_{pdl} \in \{0,1\}, \forall pd, \forall l \end{aligned} \tag{26}$$

Objective Function

Objective function of the GSC Network Design Model defined in equation (27) minimizes *Total GSC cost*. Total GSC cost is defined in equation (28) in terms of its components: Product Realization cost (*PRC*), Raw materials cost (*RMC*) and Transportation and Distribution cost(*TDC*). *PRC* defined in equation (29) includes: costs for manufacturing of product of different designs at high and medium level in SC operated plants; procurement cost of product at basic level for different designs from the outsource vendor; fixed cost for allocating(setting up) medium and high design level products of different designs in the SC operated plants; fixed

cost for assigning procurement order to outsource vendor; cost of manufacturing components for high and medium design level products in the SC operated plants, and fixed cost for allocating (setting up) manufacturing of components to SC operated plants for computing product realization cost. RMC defined in equation (30) computes raw materials cost by considering supply cost of raw materials from the supplier and fixed cost for assigning orders to the suppliers. TDC defined in equation (31) computes transportation and distribution cost by incorporating quality assurance cost for the high and medium design level products transported from SC operated plants to DCs and the basic design level products supplied to DCs by the outsource vendor; cost for distributing products from DCs to retail outlets based on distances travelled and average cost of distributing a product; fixed cost for assigning quality assurance responsibility to an accredited quality assurance organization; fixed cost for opening a DC to accommodate product supplied from the SC corporate operated plant and outsource vendor; fixed cost for assigning a DC to retail outlets to distribute product, and transportation cost based distance for plant DC combination and average cost for transporting products form SCs own plant.

Objective Function: *minimize Total GSC Cost* (27)

Total GSC cost: Product realization cost (*PRC*) +Raw materials (*RMC*) +Transportation and Distribution cost (*TDC*) (28)

$$PRC = \sum_{p\in P}\sum_{d\in D}\sum_{j\in J} FA_{pdj}\sum_{t\in T} v^{t}_{pdj} + \sum_{p\in P}\sum_{d\in D}\sum_{j'\in J'} FS_{pdj'}\sum_{t\in T} os_{pj't} + \sum_{c\in C}\sum_{j\in J} CM_{cj}\sum_{t\in T} cz^{t}_{cj} + \sum_{l\in\{hl,ml\}}\sum_{j\in J} CA_{pdlj}\sum_{t\in T}\sum_{k\in K} x^{tjk}_{pdl} + \sum_{p\in P}\sum_{d\in D}\sum_{l=\{bl\}}\sum_{j'\in J} CS_{pdlj'}\sum_{t\in T}\sum_{k\in K} xo^{tj,k}_{pdl} + \sum_{c\in C}\sum_{j\in J} FM_{cj}u_{cj} \quad (29)$$

$$RMC = \sum_{i\in I}\sum_{s\in S} CR_{is}\sum_{t\in T} z^{t}_{is} + \sum_{c\in C}\sum_{j\in J} a_{is}FAR_{is} \quad (30)$$

$$TDC = \sum_{p\in P} CQI_{p}\sum_{t\in T}\sum_{d\in D}\sum_{k\in K}\left(\sum_{j'\in J'}\sum_{l=bl} xo^{tj'k}_{pdl} + \sum_{j\in J}\sum_{l=\{hl,ml\}} x^{tjk}_{pdl}\right) + \sum_{p\in P}\sum_{k\in K}\sum_{r\in R}\sum_{m\in M}\sum_{\tau\in TM} DN_{pkmr}ds_{krm}\sum_{m\in M}\sum_{t\in T}\sum_{d\in D}\sum_{l\in L} DM^{mt}_{pd} + \sum_{p\in P}\sum_{q\in Q} FQA_{pq}qa_{qp} + \sum_{k\in K}\sum_{p\in P} FW_{kp}\sum_{d\in D} wo_{kpd} + \sum_{k\in K}\sum_{r\in R} FAR_{kr}\sum_{m\in M} w_{krm} + \sum_{j\in J}\sum_{k\in K} DTC_{jk}DTR_{jk}\sum_{d\in D}\sum_{l\in\{hl,ml\}}\sum_{p\in P} x_{pdljk} \quad (31)$$

NUMERICAL EXAMPLE

An example GSC firm (mentioned as GSC henceforth) that markets 6 products with 3 designs having 3 design levels (high, medium and basic levels) for each design of each product is considered to illustrate applicability of the model by generating random assumed data. The GSC markets the products in 5 global markets (USA, UK, Singapore, India and Italy) through 10 retail

outlets in each market. The GSC manages realization of high and medium design level products in its 5 plants (located 3 in USA, 1 in UK and 1 in Singapore) and transports the products to 5 DCs, also located in globally (3 in USA, 1 in UK and 1 in Singapore), and from there products are distributed to retailers in 5 global markets. The GSC manages basic design level products for designs 1,2, and 3 through 4 outsource vendors from India. The GSC operates through contractual arrangement with the outsource vendors based on the quoted cost for receiving the product at DCs according to the schedule mentioned in the contract. In addition, the GSC procures raw martials and other inputs for manufacturing from a pool of 4 suppliers through contractual arrangement to supply the ordered items to manufacturing plants according to contractual stipulations. The GSC knows average demand of product for its 5 products based on its marketing and operations data from the past several years. This section presents model output based results mainly. It includes limited information on the model inputs. Input data are included when such inputs are necessary to understand and explain model outputs.
In this research countries are not identified as a model index to reduce complexity of solving the model. The model is designed as a linear one for facilitating solution such a complex business situation. The model is already complex with several indices. Markets, Plants, DCs and Retailers are identified by the numbers tagging the number with location. Meaning the numbers also provides information about its country of location. The model decides distribution of product, assignment of product to plants based on capacity and cost; allocation of plants to DCs based on transportation cost and distances, allocation of DCs to markets based on distribution distances and cost and demand from Retailers. Costs and distances are based on tagged location for the facilities.
Table 1 presents average overall demand of products in the markets. For an example, average demand for product 1 in market 1(USA) is 10,090 units as shown in Table 1.

Table 1: Average Demand of Product in Markets

	USA	UK	Singapore	India	Italy	
Product	Market 1	Market 2	Market 3	Market 4	Market 5	Total
1	10,090	10,403	10,929	10,210	10,985	52,617
2	11,682	11,508	10,381	10,511	10,417	54,499
3	10,917	10,175	11,458	11,207	10,164	53,921
4	10,800	10,179	11,003	10,021	10,561	52,564
5	11,448	11,442	10,837	11,361	11,095	56,183
6	10,962	12,138	10,631	10,668	10,297	54,696

Table 1a: Demand of a Typical Product (Product 1) at three Design levels for 3 Designs in Markets

		Design 1 levels			Design2 levels			Design 3 levels			
Product	Market	HL	ML	BL	HL	ML	BL	HL	ML	BL	Total
1	1	1,237	1,314	1,034	1,153	1,259	1,210	1,103	934	846	10,090
	2	1,082	1,271	990	925	891	1,126	1,558	942	1,618	10,403
	3	1,181	974	1,064	1,399	1,322	1,098	1,459	1,134	1,298	10,929
	4	1,364	1,015	1,282	1,096	930	1,017	1,058	1,521	927	10,210
	5	1,495	1,017	1,267	1,212	1,261	1,371	1,208	1,076	1,078	10,985
		6,359	5,591	5,637	5,785	5,663	5,822	6,386	5,607	5,767	
	HL: High level; ML: Medium Level; BL: Basic level										

Table 1.a presents details of product 1 demand for designs 1,2, and 3 and at three levels for each design. According to Table 1.a demand for product 1 at market 1 for design 1 at high, medium and basic levels are [1,237,1,314, and 1,304], for an example.
Table 2 presents model decision on production and transportation of product from GSC's own plant to DCs. As discussed before GSC's own plant only produces high and medium level product of three designs used by the GSC firm. According to Table 2, the model allocated products 1 to 6 to Plant1 and assigned plant 1 to supply product to DC1, for an example, as may be observed in Table 2. The model assigned products 2,3,4 and 6 to plant 2 and transported products from plant 2 to DC2. The model similarly assigned only product 3 to plant 3 and transported them to DC 3. The model decided similar transportation decision for the plants 4 and 5 also. Such transportation decision by the model is obvious because in each country where the GSC has a plant, it has a DC also. The model had the option to transport product from a plant in other country to a DC. But constraint (12) restricted the model to limit transportation distance to a set limit for obtaining fast delivery to retail outlets. We may also verify whether the model manufactured required HL and ML product amount in GSC's plant to fulfill market demand. For an example the model realized product 1: 23,398(in plant1) +6,386(in plant 4)+5,607(in plant5)=35,391 units of HL and ML level product 1 from this Table 2, which should be same: if we add: demand for HL and ML product [1,495+1,017+1,212+ 1,261+ 1,208+1076]=35,391for all three designs as presented in Table 1.a.

Table 2: Model Output for Production and Transportation of Product from Supply Chain's Own Plant

	Products of **designs** at HL and ML						Total	Transferred to DCs
Plants	1	2	3	4	5	6		
1	23,398	17,721	23,659	17,526	19,241	18,814	120,359	1
2		12,386	6,059	10,793		11,526	40,764	2
3			6,305				6,305	3
4	6,386	5,503		6,444	17,959	5,696	41,988	4
5	5,607						5,607	5

Table 3: Typical Supply of Basic Level Product by Outsource Vendor 1

Outsource Vendor	**Products** with 3 designs at Basic level						Supplied to DC
	1	**2**	**3**	**4**	**5**	**6**	
1	975	725					1
	1,720	4,847		9,48			2
	1,707	2,291		6,383			3
		2,586		1,927			4
	1,420	3,005		2,876			5

Table 3 presents supply of basic level products by a typical outsource Vendor (out of 4 vendors). For an example Vendor 1 supplied 975 units of product 1 to DC 1 and 1,720 units of to DC2.
Table 4 presents assignment of DCs to retailer based on which the model distributes product from the DCs to retailers in the 5 markets. For an example:M:1-5 shown at the intersection of row for DC1 and column for Retailer 1means DC 1is allocated to retailer 1 in all five markets (M1-5); M:0 at the intersection of row for DC 2 and column for Retailer 1: means DC2 is not allocated to retailer 1 in any market (M:0). Taking one more example for further discussion:

M:1,3,4 in the intersection of DC3 and Retailer 1 means DC 3 is allocated to Retailer 1 in markets 1,3, and 5.

Table 4: Model Output on Allocation of DCs to Retailers in Markets.										
	Retailers in markets									
DC	1	2	3	4	5	6	7	8	9	10
1	M:1-5	M:1-5	M:2-5	M: 1,4	M:1-5	M:1,2,4,5	M:1,3	M:0	M:1-5	M:1
2	M:0	M:1,2,4,5	M:1	M:1-5	M:0	M:1-5	M:3,4	M:1,2,3,5	M:0	M:3,5
3	M:1,3,4	M:0	M:1-5	M:1,2,4,5	M:0	M:3	M:0	M:1	M:1,4	M:1-5
4	M:2,5	M:2-5	M:1,3,4,5	M:1,3,4,5	M:0	M:0	M:2,5	M:1-5	M:1,2,3,4	M:2,4
5	M:0	M:0	M:5	M:0	M:1-5	M:0	M:1,2,4,5	M:1,4	M:0	M:0

Table 5: Model Output on Typical Distribution of Product from DCs to Retailers in Markets.											
	Distribution of **Product 1** from DCs to **Retailers in Market 1**										
DCs	1	2	3	4	5	6	7	8	9	10	Total
1				648	688	545	426		688	688	3,683
2				677		688		426			1,791
3				482				688		688	1,858
4				262				253	262		777
5					688		688	605			1,981
	Distribution of **Product** 1 from DCs to **Retailers in Market 2**										10,090
1	422	642	371			642			642		2,719
2		642				642		642			1,926
3			642							642	1,284
4	642	642	488				421	642	642	421	3,898
5							576				576
	Distribution of **Product** 1 from DCs to **Retailers in Market 3**										10,403
1	583	823	609		823		823		823		4,484
2				341		240	473	240		823	2,117
3	242		583			567				482	1,874
4		482		240				482	427		1,631
5					823						823
	Distribution of **Product** 1 from DCs to **Retailers in Market 4**										10,929
1	649	649	649	443	649	599			649		4,287
2		206		443		416					1,065
3	649		649	206						439	1,943
4		481		487					649	649	2,266
5					649						649
	Distribution of **Product** 1 from DCs to **Retailers in Market 5**										10,210
1	654	654	632		450	405					2,795
2		450		450		450		199			1,549
3			405	405					654	654	2,118
4	654	405		450			453	654			2,616
5			599		654		654				1,907
Sum of 10,985+10,210+10,929+10,403+10,090=52,617											10,985

Table 5 presents typical model output for distribution of product (only product 1 is shown out of 6 products) from the DCs to Retailers in each of the 5 markets for illustration and some

verification. It may be mentioned here that the products distributed from DCs are transported to DCs from GSC operated 5 plants (see the Table 2) and outsource vendor in Table 3. According to Table 5 information 648 units of product 1are distributed from DC1 to retailer 4 in Market 1(see the market 1 information in the top part of Table 5) and, similarly 422 units of product 1 are distributed from DC1 to retailer 1 in market 2 (see the Market 2 distribution part), for example. Please verify assignment of DC 1 is allocated to Retailer 4 in Market 1 and 4 and DC 1 is allocated to Retailer 1 in all market according Table4. We may verify some more information on allocation of DCs to retailers in Markets of Table 4 based on these select model output in Table 5. Let us first check exceptional retailers and related DCs. For an example, based on Table 4, DC 1 is not allocated to supply Retailer 8 in any market. Based on Table 5, no product is distributed from DC 1 to retailer 8 in any market (see tables 4, and 5). Similar verification may be done for M:0 in Table 4 for Retailer 1and DC2; or Retailer 1 for DC5 and others. We may partially verify for M:1-5, since such allocation is made for all products and all retailers. But we have only Product 1 in Table 5. For an example M:1-5 for retailer 1from DC1 in Table 4. Market 1 does not have distribution from DC 1 to retailer 1 for product 1 (see Table 5). But for all other markets 2,3, 4 and 5, Retailer 1 is supplied from DC1 for product 1(See Table 5). Overall product 1 distributed may also be verified whether it complies with demand as shown in Table 1. Based on last row and column for Table 5 overall 52,617 units of product 1 is distributed from 5 DCs to 10 retailers, which is equal to the demand shown in Table 1.

As discussed before since overall objective of model is minimizing cost the Model took the shortest transportation distance and located DCs, and allocated plants to DCs based on constraint (12) where set distance considered were 180 miles. In addition model only transported product from plant 1 to DC1 and Plant 2 to DC2 and similar for other plant- DC combinations. By such allocation the model ensured transportation from plant to DC within one country and managed with transportation mode truck only. This will facilitate GSC ensuring quickest product availability in the retail outlets.

In the case of distribution, the model took similar measures within the routes available for fastest delivery with minimum cost. Based on Market 1 segment of Table 5, the model distributed most of the products (3,683+1,791+1,858)/10,090=73% for retailers of market 1(USA) from DCs 1, 2, 3 which are located in USA and managed with minimum cost with limited air travel.

For market 2, which is in UK (see the Market 2 part of Table 5) , the model took highest possible units (see 3,898 units) from the DC4 which is in UK for the retailers of market 2. The model took the remaining products are from USA DCs, and only 576 units from Singapore DC to reduce distribution cost.

For markets 3, 4, and 5 the model favored USA based DCs because of multi-modal and Air cargo related cost advantages. For India and Italy market freight charges from USA is better than from Singapore or UK, so these were obvious. For Singapore the model took product mostly from USA also because of cost advantages in the as assumed for the example case.

GSC uses 18 components for producing their 6 products with 3 designs at high and medium design levels in their plants.

Table 6: Model Output on Components Manufactured by GSC Operated Plants

	Components manufactured by the assigned plants for the products								
Plants	4	5	6	10	11	12	16	17	18
1	75,140	75,140	37,570	107,251	142,718	71,359			
2							41,634	47,000	41,634
3							6,305	12,610	6,305
4							54,075	71,280	54,075
5							5,607	11,214	5,607

Based on usage of components/per product (BOM) model equation (15) determined the components needed for the product considered for this example case and assigned to SC operated plants. Table 6 presents model output for the components that are realized by the assigned GSC plants. According to Table 6 GSC needs 9 components (components 4 to 6; 10 to 12;16 to18) out of 18 components. For an example, plant 1 manufactured 75,140 units of component 4. The model assigned plant 1 for manufacturing components 4 to 6; 10 to 12. The model assigned plants 2,3, 4 and 5 for realizing components 16 to 18, as may also be seen in Table 6.

Table 7: Model Decision on Procurement of Raw Materials from Assigned Suppliers

	Estimated raw materials in thousand yards assigned to suppliers								
Suppliers	1	2	3	4	5	6	7	8	9
1					1,497				
2			3,009			6,000	5,360	5,360	
3	902	869							5,360
4				2,464	6,000	3,217			

Table 7 presents model decision on procurement of raw materials from the assigned suppliers 1 to 4. The model estimated raw materials requirements and assignment of suppliers for their procurement through equation (16). For an example, 1,497 thousand yards of raw material 5 are procured assigning order to supplier 1, as shown in Table 7.
The overall GSC total cost (Total cost, objective 1) as computed by the model is $119.6 million that includes Production cost (PRC): $2.04 Million, Raw materials cost (RMC) : 117.05 million and Transportation and Distribution cost (TDC): $0.52Million for complying with market demand as presented in Table 1. The model is solved using commercial solver LINGO 14 in a Dell Latitude Series Desktop computer with processor Intel® core (TM)i7- 4800 CPU @2.70GHZ 2.70 GHZ, with RAM: 8 GB. The Model involved: 21, 473 total variables, 1761 integer variables, and 56,161constraints for the numerical example and it took at an average 7 minutes to arrive at the global optimum solution for the example case.

Table 8: Model Sensitivity for Variation of GSC Cost with the Change in Demand

Demand	In $ Million	Components of Total GSC cost in $ Million		
	Total GSC cost	Total Production Cost	Total Raw materials Cost	Total transportation and Distribution Cost
Base Case*0.7	81.21	1.44	79.3	0.47
Base Case*0.85	99.73	1.74	97.5	0.49
Base Case	119.6	2.04	117.05	0.52
Base Case*1.15	139.63	2.33	136.76	0.54
Base Case*1.30	160.24	2.64	157.05	0.55

Based on the above analysis it is apparent that the model effectively decided all GSC planning issues including procurement of raw materials; realization of high and medium level products for the three designs of products in SC operated plants and basic level products from outsourced vendor, transportation of the realized products to the allocated DCs, and distribution of the products to retail outlets from the DCs assigned to them within optimum time and successfully

complied demand of product with optimum cost. The model is sensitive to demand changes if we consider other SC requirements do not change.
We tested such sensitivity by making the plant, DCs and suppliers un-capacitated. Table 8 presents model sensitivity for the total GSC cost and components of total GSC costs with the increase and decrease in the product demand. For this sensitivity analysis we considered model result without increase and decreases as the base case and computed model outcomes for optimized cost figures by decreasing demand in two steps at the rate 15% in each step and similarly by increasing the demand in two steps at the same rate as presented in Table 8.
As expected, with the increase in demand the optimized cost figures increased compared to base case and the costs decreased with the decrease in demand as may observed in the Table 8. It is also apparent that the optimized figures due to the increment and decrements of demand are not proportional. For an example, based on model outcomes in Table 8 with 15% increase in demand Total GSC cost increased to: $139.63million , which is higher than 119.6(base case optimum cost)*1.15=$137. 54Million. Similar is the case for decrement in demand; with 15% decrement in demand optimized total cost decreased to $99.73 Million which is lower than 119.6(base case optimum cost) *0.85=$ 101.66 Million. The reason for such variations are not-changing of fixed costs for setting up an allocated plant for production; opening a DC, or assigning orders to suppliers do not change with change in demand. Only variable costs are affected by change in demand for handing higher or lower units of products, raw materials, and truckloads.

CONCLUSION AND DISCUSSIONS

The overall GSC network design model contributed in SC literature by introducing an effective approach for planning realization of multiple products having multiple designs including multiple levels for each design of product to address various customer classes in the globalized market. The GSC design model took the innovative approach for allocating plants to DCs within the shortest distance possible. It also effectively planned allocation of DCs to retailers to obtain optimum route for distribution to achieve optimum replenishment cost at the retail outlets of globally spread markets. The design approach utilized core competency of the GSC by realizing higher design level products at their own plants and addressed cost competitiveness by outsourcing basic level designs. This strategic GSC network design model can be very effectively applied for planning and managing Fashion SC like Zara, where multiple designs, variation of fabrics and frequent changing designs are addressed in its globally located retail outlets. It may also be also applied in premium Automobile industry to handle design variations and suppliers at multiple tiers in addition to Fashion SC.
The research has the scope to extend it for handling rolling over the old designs with new designs after a specified time frame for keeping the retail outlets attractive to various classes and to reduce inventory and obsolescence cost.
The research provides many managerial implications. The following may be considered for significant business benefits:1) when dealing with complex business situations of marketing product in GSC network with multiple designs, controllable levers are critical to obtain superior performance in terms of quick delivery of product to sales outlets. Allocation of production plant and DC in close proximity, if possible in the same country may be considered as a controllable and assuring beneficial lever. Next implication of this research is to exploit outsourcing to obtain cost competitiveness when the organization has one or more almost commoditized product or part of a product in their product portfolio. Finally, a planning and design model of proposed caliber should be used by the SC managers to simulate with different alternatives and making informed decisions.

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A literature Review on the Impact of Antecedents of Supply Chain Resilience on Mitigating Supply Chain Disruption Risks

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ABSTRACTS

In this paper, we conduct a literature review to examine the impact of supply chain flexibility, agility, redundancy, and collaboration (as the most widely known resiliency practices) on mitigating supply chain disruption risks. We investigate the relationship between disruption and resiliency through assessment of the impact of each resiliency enhancer on mitigating each supply chain disruption (demand, supply, process, control, and environmental disruptions). Our results showed that while flexibility has been mentioned frequently in the literature as the most important strategy to cope with demand, supply, process, and environmental disruptions, collaboration has been regarded as the most important strategy to cope with control disruptions.

KEYWORDS**:** Supply chain resilience, Supply chain risk management, Flexibility, Agility, Collaboration, Redundancy

1. INTRODUCTION

Supply chain risk management (SCRM) is “the management of supply chain risks through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity” (Tang, 2006a, p. 453). According to Aqlan and Lam (2015), SCRM is an asymmetric approach for identifying, assessing, mitigating, and monitoring the risks for potential disruption in a supply chain network, in order to mitigate the negative effects of the disruptions on supply chain operations. According to a report by IBM (2008), supply chain executives at IBM believe that SCRM is the second-most important issue for their company.

A general categorization of supply chain risk is to classify risks into operational risks and disruption risks (Kleindorfer and Saad, 2005; Tang, 2006; Chen et al., 2013). Disruption risks typically are defined as unplanned events that restrict a supply chain system; they may result from man-made or natural disasters such as economic downturns, technology changes, terrorist attacks, hurricanes, and strikes. Operational risks are more about supply-demand coordination events, which may result from inadequate or failed processes, control, people, or systems (Christopher and Peck, 2004; Wakolbinger and Cruz, 2011; Chen et al., 2013; Ghadge et al., 2012; Lockamy and McCormack, 2010; Gurning and Cahoon, 2011; Nooraie and Parast, 2015; Yang et al., 2017). Thus, operational risks are relatively more controllable than disruption risks. Moreover, catastrophic events such as 9/11 in 2001, the tsunami in 2004, hurricane Katrina in 2005, hurricane Harvey in Houston in 2017, and hurricane Maria in Puerto Rico in 2017 are motivation for supply chain researchers to consider supply chain risk and its effects on the design of supply chains (Chopra and Sodhi, 2004; Tang, 2006a; Thun et al., 2011; Wilding et al., 2012; Heckmann et al., 2015; Ho et al., 2015; Kamalahmadi and Parast, 2016a).

Supply chain resiliency (SCR) reduces the impact of disruption risks by identifying strategies that allow a supply chain to react while recovering to its original or even better functional state. SCR has received more attention in recent years as one of the main characteristics of a firm to improve responsiveness to unexpected dynamics in the business environment (Kamalahmadi and Parast, 2016; Borekci et al., 2015; Ponomarov and Holcomb, 2009; Ates and Bititci, 2011).

Melnyk et al. (2014) asserted that SCR is at the heart of current supply chain management thinking. A study by the World Economic Forum (2013) indicated that more than 80% of companies are concerned about their SCR (Tukamuhabwa et al., 2015). Hence, SCR is of a great interest for firms and organizations (Ivanov, 2017; Borekci et al., 2015; Scholten and Schilder, 2015; Jüttner and Maklan, 2011).
In this article, we aim to address these key questions in SCRM and SCR:
(1) What is the current state of research in SCR and in supply chain disruption risks?
(2) Regarding the various sources of disruption risks in supply chains (i.e., supply risk, demand risk, environment risk, process risk, and control risk), which SCR capability should a firm invest in as the best strategy to build a supply chain resilient against disruption risks?
(3) What are the gaps in current research that future research should address?
We address our research questions by reviewing the articles published in major academic and practitioners' journals from 2000 to 2017 using a systematic literature review process (Kamalahmadi and Parast, 2016b; Tukamuhabwa et al., 2015; Ho et al., 2015).
The remainder of this study is organized as follows: Section 2 is a review of the literature on SCR and the supply chain resiliency enhancers: flexibility, agility, collaboration, and redundancy. Section 3 is a discussion of the research methodology. Section 4 is a discussion about the major findings of this study. Section 5 has the conclusions and Future Research of this study.

2. LITERATURE REVIEW

In this section, We provide a review of the literature for flexibility, agility, collaboration, and redundancy as the most important enhancers of supply chain resiliency.

2.1. Supply Chain Resilience (SCR)

Resilience in a supply chain can be defined as a firm’s ability to withstand a disruption and recover from the disruption to its original state, or even move toward a more desirable state after being disturbed (Christopher and Peck, 2004). Pettit et al. (2013) defines resilience with the “four Rs”: robustness, resourcefulness, recovery, and review. To improve SCR, diverse strategies have been recommended in the literature (Urciuoli et al., 2014; Colicchia et al., 2011; Tang, 2006a). While resiliency enhancers can include a wide range of organizational practices, the literature recognizes the impact of flexibility, agility, collaboration, and redundancy strategies as the most important organizational capabilities to improve a firm's responsiveness to supply chain disruption (Tukamuhabwa et al., 2015; Yang et al., 2017; Tomlin, 2006; Simchi et al., 2013; Christopher and Peck, 2004; Sheffi and Rice, 2005; Das and Lashkari, 2015; Kamalahmadi and Parast, 2016a; Pettit et al., 2013; Ponis and Koronis, 2012; Jutnner and Maklan, 2011; Sodhi et al., 2012; Jain et al., 2017). Christopher and Peck (2004) recommended the inclusion of resource redundancy, agility, supplier flexibility, and a collaborative planning approach (as a part of risk management culture) for creating SCR. Tukamuhabwa et al. (2015) indicated there are twenty-four different strategies for achieving SCR. They showed that increasing flexibility, improving supply chain agility, forming collaborative supply chain relationships, and creating redundancy have the most effect on improving SCR.

2.2. Flexibility

Flexibility refers to the ability of a firm to flexibly respond to long-term or fundamental changes in the supply chain and market environment by adjusting the configuration of the supply chain. So this measure indicates the flexibility of a firm in responding to environmental changes, demand changes, supply changes, and technology changes (Overby et al., 2006; Li, et al., 2009; Dominik et al., 2015; Blome et al., 2014). Some research indicated the important role of flexibility in enhancing SCR (Das and Lashkari, 2015; Tukamuhabwa et al., 2015; Tang and Tomlin, 2008; Sheffi, 2005; Christopher and Peck, 2004). Das (2011) asserted that the inclusion of effective flexibility measures is an established fact that makes a business more responsive by resolving most supply chain uncertainty issues. Fang et al. (2012) asserted that through flexible

system organization, a resilient supply network can be realized both effectively and efficiently. Also, flexibility creates SCR by enhancing prompt adaptability during turbulence (Christopher and Holweg, 2011).

2.3. Agility

Agility is described as the ability to efficiently change operating states as a response to environmental uncertainty or volatile market conditions (Lim et al., 2017; Narasimhan et al., 2006; Faisal et al., 2006a). Agility is one of the most powerful ways to achieve a resilient supply chain capable of rapid responses to changing conditions (Christopher and Peck, 2004). Tukamuhabwa et al. (2015) indicated that agility is one of the most important capabilities to enhance SCR. Braunscheidel and Suresh (2009) asserted that agility is critical for disruption mitigation and response time efficiency. They defined agility as a risk management initiative that enables a firm to respond rapidly to market changes and potential or actual disruptions in the supply chain. Supply chain managers can decrease the risks that are related to inventory management by dealing with extremely responsive suppliers (Chopra and Sodhi, 2004).

2.4. Collaboration

Supply chain collaboration refers to the ability to work efficiently with other entities for mutual benefit in areas such as forecasting, postponement, and risk sharing (Pettit et al., 2013). In a collaborative culture, supply chain partners openly communicate and work together to share information, in order to improve supply chain visibility, reduce supply chain uncertainty, and enhance competitiveness (Chen et al., 2013). Collaboration plays an important role in enhancing the competitive advantage of a supply chain and can significantly reduce overall cost and uncertainty (Gold et al., 2010; Carter and Rogers, 2008). Moreover, a high level of collaboration across a supply chain can help mitigate disruption and reduce risk (Jain et al., 2017; Li et al., 2015, Chen et al., 2013). Beske and Seuring (2014) maintained that collaboration can be understood as one step further than cooperation. According to Świerczek (2014), supply chain integration is a strategic collaboration of both intra-organizational and inter-organizational processes. He believes that cooperation, collaboration, and coordination between supply chain members provide an intensive integration in the supply chain. Decision synchronization and incentive alignment are two major contributions of collaboration in a supply chain; they are essential for successfully responding to the disruption in the supply chain (Jain et al., 2017).

2.5. Redundancy

According to Christopher and Peck (2004), redundancy involves the strategic and selective use of spare capacity and inventory that can be invoked to cope with a crisis, such as demand surges or supply shortages. Sheffi and Rice (2005) recommended that building redundancy is an effective option to create resiliency and enhance recovery from disruptions. Kamalahmadi and Parast (2017) showed how implementation of three types of redundancy strategies (inventory, backup suppliers, and protected suppliers) can improve a firm's performance in a turbulent and complex business environment that requires mitigating the effects of supply chain disruption.

To provide a review of the effect of SCR drivers, we examine the impact of flexibility, agility, collaboration, and redundancy on mitigating supply chain disruptions in terms of demand, supply, process, control, and environmental disruption (Christopher and Peck, 2004). To the best of our knowledge, this is the first study to investigate the effect of supply chain resiliency enhancers on mitigating each type of supply chain disruption. Our research indicates which enablers of supply chain resiliency (flexibility, agility, collaboration, and redundancy) have been identified by research as the most important strategies to mitigate each type of supply chain disruption (demand, supply, process, control, and environmental). In addition, our review thoroughly covers both academic and practitioner journals, book reviews, conference proceedings, and other related reviews and reports. Our study covers all the publications from 2000 to 2017, using three phases in collecting publications: (1) searching databases and

journals by using keywords to find articles, (2) screening the articles in a first phase, and (3) analyzing the information of the articles.

3. RESEARCH METHODOLOGY

In this research, we adopt a literature review methodology that has been recently encouraged by Kamalahmadi and Parast (2016b) and Tukamuhabwa et al. (2015), in order to advance theory in supply chain risk management research. In accordance with Tukamuhabwa (2015), we use a three-phase approach in order to avoid bias, improve validity of the findings, and collect the relevant publications (Figure 1). First, we searched databases and journals using specific keywords (Phase 1: sourcing articles). Second, we screened publications obtained in the first phase (Phase 2: article screening process), with several objectives: (1) remove duplicates, (2) do two-stage inspection of articles, and (3) check cited articles. Third, we extracted and analyzed the information from the publications obtained from Phase 2. According to Kamalahmadi and Parast (2016b), since the concept of SCR was not discussed much before 2000, we considered publications starting with the year 2001.

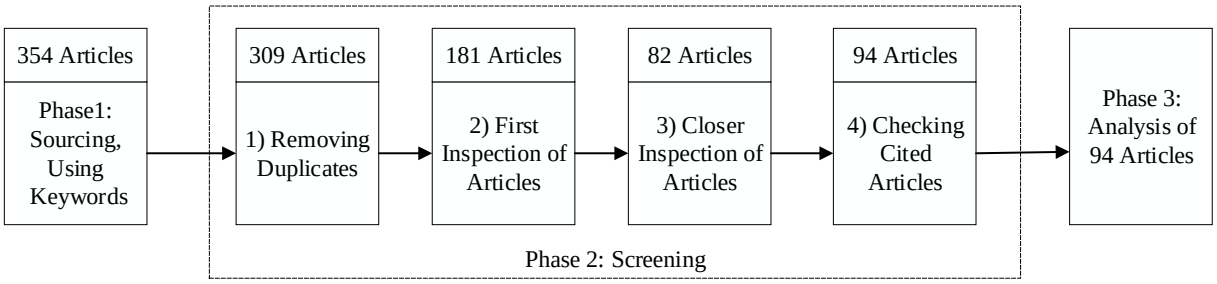

Figure 1. Overview of the review process

Phase 1: Sourcing articles

In this phase, in order to start with high-quality databases for our research and in line with Kamalahmadi and Parast (2016b), we used the widely accepted quality rating published by the Association of Business Schools (ABS), UK, as Academic Journal Guide 2015 (AJG 2015). Using AJG 2015, we consider three different domains of management for this research: Operations Management (OM), Operations Research and Management Science (OR/ MS), and General Management (GM). Table 1 identifies the journals where the reviewed articles were published. Each journal's AJG 2015 ranking is on a scale of 1 to 4, where 4 is highest.

Table 1. List of journals reviewed and their AJG 2015 rankings

List of Journals	AJG Ranking
Operations Management (OM)	
Production and Operations Management (POM)	4
Journal of Operations Management (JOM)	4
International Journal of Operations and Production Management (IJOPM)	4
International Journal of Production Research (IJPR)	3
Manufacturing and Service Operations Management (MSOM)	3
International Journal of Production Economics (IJPE)	3
IEEE Transactions on Engineering Management (IEEE-TEM)	3
Journal of Supply Chain Management (JSCM)	3
Supply Chain Management: An International Journal (SCM)	3
Journal of Business Logistics (JBL)	2
Operations Research and Management Science (OR/ MS)	

Management Science (MS)	4
Operations Research (OR)	4
European Journal of Operational Research (EJOR)	4
Decision Science Journal (DSJ)	3
General Management (GM)	
Harvard Business Review (HBR)	3
MIT Sloan Management Review (SMR)	3
California Management Review (CMR)	3

In order to identify and collect the publications for our research, we used major business and management databases, including Emerald, Elsevier Science Direct, ABI/ Inform Global ProQuest, Wiley, INFORMS, Google Scholars, Springer, Taylor and Francis Online, along with each journal of Table 1. A total of 19 keywords were identified by the authors for this research ("Flexibility/ Flexible", "Agility/ Agile", "Redundancy/ Redundant", "Collaboration/ Collaborate", "Cooperation/ Cooperate" "Supply Chain Flexibility/ Agility/ Collaboration/ Redundancy/ Cooperation" together with "Disruption", "Uncertainty", "Risk", or "Resilience"). This search was conducted using keywords contained in the article titles, abstracts, and keywords, as well as in the articles. Using these keywords, 354 publications were retrieved.

Phase 2: Article screening process

The retrieved articles were subjected to these four steps:

First, we cross-checked all the articles to eliminate duplicate results retrieved from different databases. This reduced the number of articles from 354 to 309. Second, we reviewed and screened the articles. This involved conducting an initial check with regard to the title, abstract, and keywords identified in the articles. This step retrieved the papers that are related to supply chain resiliency strategies (supply chain flexibility, agility, collaboration, and redundancy). This reduced the number of articles to from 309 to 181. Third, we reviewed the introduction, conclusion, and implication sections of the 181 papers to retrieve the papers that investigated the effect of each type of supply chain resiliency strategy on mitigating each type of supply chain disruption (demand, supply, control, process, and environmental disruption). This step can help to identify which strategy of supply chain resiliency enhancer (supply chain flexibility, agility, collaboration, or redundancy) has been discussed to mitigate which supply chain disruption (demand, supply, process, control, or environmental). This reduced the number of articles to from 181 to 82. Finally, by checking the references and citations in each of the 82 papers, we could increase the number of publications to 94. This procedure resulted in 94 quality research publications that are the basis of the literature review presented in this study.

Phase 3: Analysis of the articles

This phase involved extracting and documenting information from each of the 94 papers. The information extracted included the definition of each supply chain resiliency enhancer and its effect on each type of supply chain disruption risk driver, along with strategies for building a resilient supply chain.

4. FINDINGS

For this study, we discussed the most important strategies of SCR to cope with each sources of disruption risk. Our results showed that while flexibility has been mentioned frequently in the literature as the most important strategy to cope with demand, supply, process, and environmental risk, collaboration has been mentioned several times in the literature as the most

important strategy to cope with control risk (Figure 2). Moreover, our findings showed that for mitigating demand disruptions, manufacturing flexibility is the most important dimension of supply chain flexibility; for mitigating supply disruptions, supplier flexibility is the most important one; for mitigating process disruptions, process flexibility is the most important one; and for mitigating environmental disruptions, logistics flexibility and operational flexibility are the most important ones. Finally, to mitigate control disruptions, collaborative communication, information sharing, and trust are the most important dimensions of supply chain collaboration.

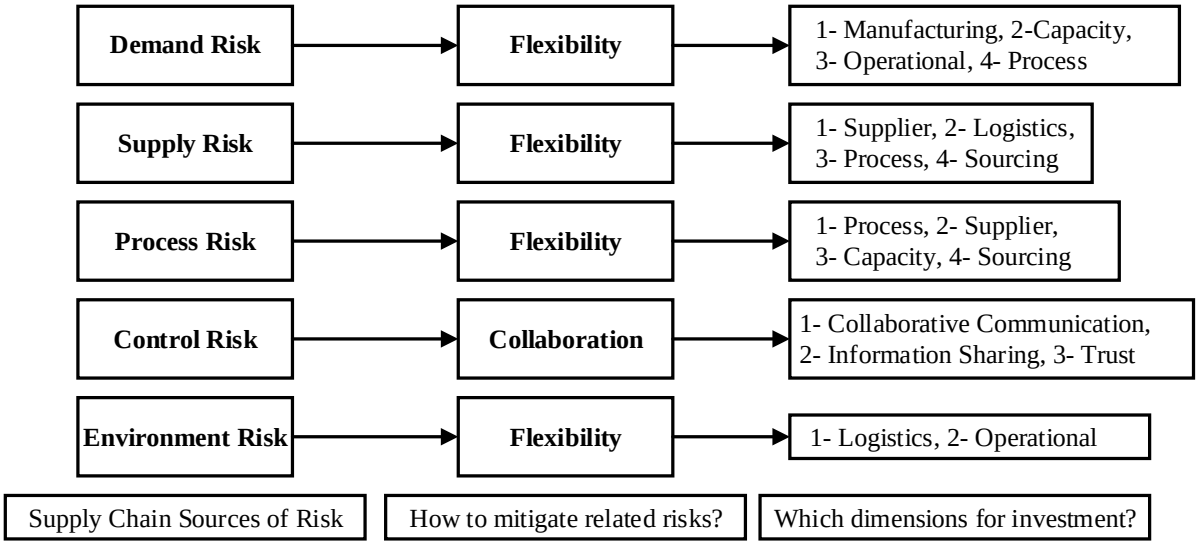

Figure 2. SCR strategies and their dimensions to mitigate each type of supply chain disruption risks

5. CONCLUSIONS AND FUTURE RESEARCH

In this research study, we addressed several research questions in SCRM and SCR. First, we investigated the current state of SCR in the literature. Then, we identified some important strategies of SCR enhancers that mitigate supply chain disruption risks. In addition, this study showed investing in which strategy of SCR enhancers (flexibility, agility, collaboration, and redundancy) is of great importance for firms when faced with different types of disruption risks (demand, supply, process, control, and environmental risk).

The literature review presented here is different from previous studies in terms of its aim, scope, approach, methodology, and contribution. The research for this paper was performed via a structured review of 94 peer-reviewed publications, including journal papers, conference proceedings, and book chapters within an 18-year time frame (2000 to 2017). After conducting a comprehensive review of the literature in the SCR, our findings showed that while flexibility has been mentioned frequently in the literature as the most important strategy to cope with demand, supply, process, and environmental risk, collaboration has been mentioned several times in the literature as the most important strategy to cope with control risks. We then proposed an SCR timeline and framework for identifying the most important strategy of SCR in coping with each type of supply chain disruption risk (Figure 2).

Despite of the findings and implications, this study also presents limitations. First, while we considered the impact of four important antecedents of SCR, considering the role of the other antecedents of SCR such as visibility, integration, structure and knowledge, and reengineering can be investigated in future research. (Kamalahmadi and Parast, 2016b; Ponomarov and

Holcomb, 2009; Christopher and peck, 2004). Second, other categorization of supply chain risks (e.g. Ho et al., 2015; Simangunsong et al., 2012; Sodhi et al., 2012; Tang, 2006a; Peck, 2004) can be considered for investigation in future research.

ACKNOWLEDGMENTS

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APPENDIX

Appendices (the summary of 94 reviewed papers) are available upon request.

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DECISION SCIENCES INSTITUTE
A New r^2 for Time Series Forecasting

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ABSTRACT

Forecasting time series data minimizing RMSE using Solver moving averages allows comparison with better naïve models (parameters do not need optimizing) than the standard average of the data (Y-bar). R^2 values for regression formulas can be misleading comparing model error measures with Y-bar.

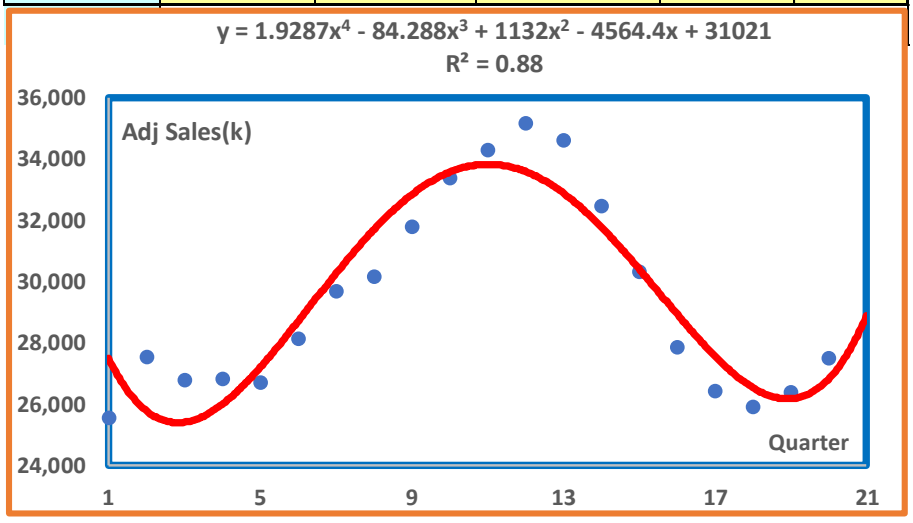
KEYWORDS: Forecasting, Time Series, Error Measures, Moving Averages, Regression

INTRODUCTION

The deseasonalized data (adjusted) sales in $(000) for Food Service Corporation (feeds firefighters in California during wildfires during the fire season) is shown in Figure 1, with an Excel Trend Line for a quartic (4th power) equation and the biased R^2 value of 88% shown above the graph. This R^2 value is very misleading value, if we use the Solver with moving averages instead of regression. This regression R^2 means that 88% of the error incurred if you used just a straight line average is explained by the quartic curve, which seems to indicate that this is a very good curve fit but is far from it, and certainly not the best forecasting model.

Figure 1: Deseasonalized Data for 20 quarters and forecast for QTR 21 with Excel Trend Line

Seasonally Adjusted Foodservice Co. Quarterly Sales $(000)					
Sales	Year 1	Year 2	Year 3	Year 4	Year 5
Quarter 1	25,542.7	26,703.5	31,778.8	34,614.2	26,428.0
Quarter 2	27,534.1	28,117.4	33,370.8	32,474.4	25,917.9
Quarter 3	26,757.2	29,676.7	34,298.8	30,320.6	26,383.5
Quarter 4	26,813.3	30,165.1	35,166.0	27,861.0	27,485.1



"HOW ARE YOU? COMPARED TO WHAT?" 5 NAÏVE MODELS

Figure 2 shows the results of a 2-period Solver Moving Average with the 5 **naïve models** (no Solver and just simple math) comparisons for 3 types of errors, with RMSE being chosen to minimize at this time. The two-period weights are in **D32:E33**. **Figure 3** is the Solver setup.

Figure 2. Summary of 2-period Solver Moving Average and Naïve Models and Weightings

	A	B	C	D	E	F	G	H
1	Moving Average Model for 2-3 Periods							
2	Food Service Co for Firefighters in So Cal							
3		Minimize		Error Measures				
4		R.M.S.E.	Forecast	R.M.S.E.	M.A.D.	M.A.P.E.	df	
5	2-Period Solver Model		28,195.38	976.80	807.43	2.75%	18	
6	Total Average		29,370.44	3,194.14	2,898.03	9.76%	19	N
7	Cumulative Average		29,370.44	3,355.51	2,801.76	9.18%	19	A
8	3 Per Smoothing		26,595.49	2,404.53	2,046.37	6.87%	17	I
9	2 Per Smoothing		26,934.30	1,854.06	1,531.48	5.14%	18	V
10	Next = Last		27,485.08	1,363.46	1,169.07	3.95%	19	E
11		64.48%		48.7%	52.3%	51.4%	r^2	
12	n = 20	P_1	P_2					
13	Quarter	Adj Sales(k)	Model	Quarter	Adj Sales(k)	Model		
14	1	25,543		18	25,918	25,504		
15	2	27,534		19	26,384	25,589		
16	3	26,757	28,818.2	20	27,485	26,684	Δ_1	1101.57
17	4	26,813	26,256.2	21		28,195		
18	5	26,703	26,849.6					
19	6	28,117	26,632.6					
20	7	29,677	29,029.1					
21	8	30,165	30,682.1					
22	9	31,779	30,480.0					
23	10	33,371	32,819.3					
24	11	34,299	34,397.3					
25	12	35,166	34,897.2					
26	13	34,614	35,725.2					
27	14	32,474	34,258.5					
28	15	30,321	31,094.7					
29	16	27,861	28,931.8					
30	17	26,428	26,275.0					
31	18	25,918	25,503.9					
32	19	26,384	25,589.0	W_{-1}	W_{-2}	W_{-3}		
33	20	27,485	26,683.8	164.48%	-64.48%			

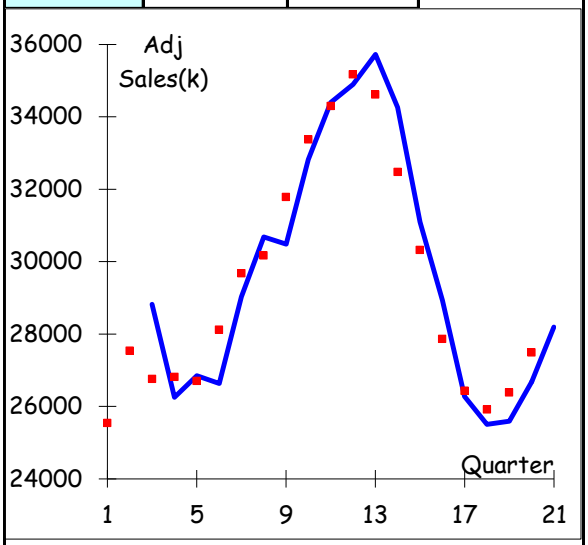
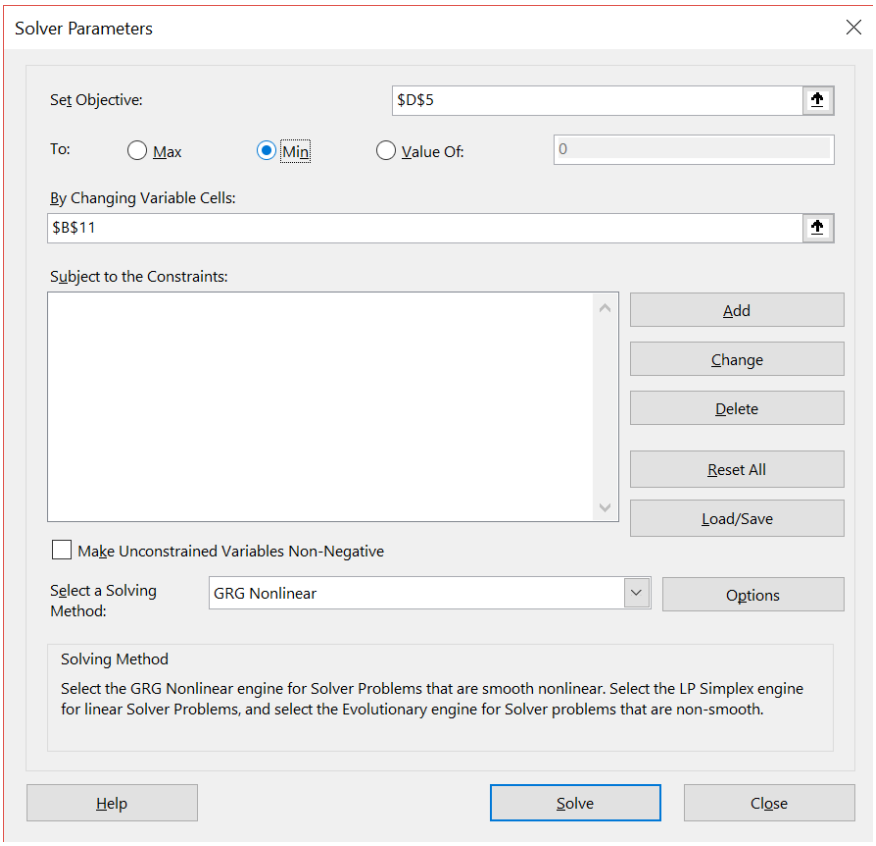


Figure 3. Solver Setup for 2-period Model



There are many naïve models besides Y-bar (overall or total average) which we can compare with our 2-period Solver model to determine how "well" this fit explains error. *A "naïve" model requires no optimization* and for causal data (X,Y) used in forecasting, the only regression naïve model is the average of all the data to be used (Y-bar). However, if time series data is used (Y values for consecutive time periods with no missing data in the sequence), then there are several naïve (or simple models), as listed below. Figure 2 shades the best naïve models for each error measure in light pink.

Total Average (Y-bar) - 1

This average is compared against all the known Y-values and RMSE, MAD or MAPE is calculated for each data point. A fallacy in using this is that one does not know the total average until the end!

Cumulative Average - 2

This would be the average of the first period to predict the second, the average of the first two periods to predict the 3rd period, up to all n periods to predict Y_{n+1}, which is the value Y-bar. The idea is that in period *i* you really only know *i-1* pieces of data but have a good estimate of Y-bar.

3-period smoothing - 3

This uses a simple moving average of the last 3 periods of information, weighted equally. Thus you can only start predictions for $\acute{Y}_4$, and predict $\acute{Y}_{n+1}$ as $(Y_{n-2} + Y_{n-1} + Y_n)/3$.

2-period smoothing - 4

This uses a simple moving average of the last 2 periods of information, weighted equally. Thus you can only start predictions for $\acute{Y}_3$, and predict $\acute{Y}_{n+1}$ as $(Y_{n-1} + Y_n)/2$.

1-period smoothing - 5

(Next=Last). "Next = Last" is the simplest of the naïve models in that the forecast for next period, $\acute{Y}_i$, is the previous actual value, Y_{i-1}, or technically a 1-period moving average. For most time series data with any movement, this usually gives the best error measures of all 5 naïve models.

The results for 2-period Solver Moving Average and the 5 naïve models minimizing RMSE (and showing results for MAD and MAPE, has been shown in Figure 2 and has blue shading in row 11 to indicate an $r^2 \geq 30\%$ and a good forecast model by my rule of thumb. If there are no Solver models with $r^2 \geq 30\%$ then use the best naïve model and forecast.

The problem with standard moving averages, is that usually the weights are equal and no optimal set of weights is determined, because it was too difficult mathematically to determine those weights 25 years ago. Also weights were restricted to being non-negative, which turns out to be a huge mistake. But in the last 25 years, with the introduction of PCs, spreadsheets and the built-in Solver with gradient search, determining the optimal weights (and now just P_1 and/or P_2, is no longer a barrier. In fact, 2-period and 3-period Solver models reduce to quite simple formulations (Hesse, 1977; Hesse, 1998-2018). Minimizing RMSE is very stable for even 4th order polynomials, while minimizing MAPE or MAD has convergent difficulties which are usually overcome by using the RMSE coefficients as starting points for the gradient search routine.

SOLVER MOVING AVERAGE MODELS:

2-Period Solver: Next = Last + $P_1 * \Delta_1$ P_1 unrestricted (1)

3-Period Solver: Next = Last + $P_1 * \Delta_1 + P_2 * \Delta_2$ P_1, P_2 unrestricted (2)

where P_i is unconstrained, and Δ_1 = difference between the last two data points and Δ_2 is the difference between the 2nd and 3rd last points.

Originally, I used weights (W_i) (but allowed them to be unsigned) and then realized that since the sum of them should be 100%, the formulas could be modified more simply. So instead of having 2-3 variables, one constraint, and non-negativity requirements, the problem is actually one less variable, no constraints and unrestricted variables. This led to my discovery that 2- and 3-period Solver models were just an adjustment of the last data value (or adjusting Next=Last)..

The problem with standard regression techniques for curve fitting linear, quadratic, cubic and higher order polynomials is that R^2 is compared to being dead – or "flat line"! The error of using

the average of the data (Y-bar) is taken as the comparison, and the general formula to compute R^2 is

R^2 = (1-(model error/naïve error)^2) (3)

and the error measure could be RMSE, MAD or MAPE or even MSE (but that's usually incredibly large).

For a 2-period Solver Model, the formula for the forecast is $\acute{Y}_{n+1} = Y_n + P_1*\Delta_1$ where Δ_1 is the difference between the last 2 data points, Y_n and Y_{n-1}. In this case, the optimal P value is -64.48% and equivalent to weights of 164.48% for Y_n and -64.48% for Y_{n-1}. Thus there is only one variable (P_1) for the Solver and it is unrestricted. Notice that by allowing the weights (and thus also the proportions P) to be negative, we can find much better error measures. This was not even dreamed of 25 years ago, and has revolutionized moving averages as a powerful predictor for time series data.

First notice the RMSE for each of the 5 naïve models. The Total Average RMSE for Y-bar is 3,194.14, and lowest of the 5 is Next=Last and is shaded and its RMSE is 1,363.46. The r^2 values are for the Solver models and those error measures are compared with Next=Last, so that r^2 for RMSE is 48.7% or 1-(976.80/1,363.46)^2. Notice also that there is not much difference in r^2 when using MAD or MAPE for this data set, although those values would be a bit higher if the Solver minimized each of those. What this tells us is that this data is very well behaved and since minimizing RMSE is the most stable of these 3 gradient search routines, we will stick with RMSE. If there was a lot larger value of r^2 for MAPE or MAD, we would then run the Solver minimizing the best of these. Also, my "rule of thumb" is that an r^2 of 30% or higher is acceptable and is thus shaded in light blue.

MOVING AVERAGE SOLVER MODELS SUMMARY

When we Move/Copy this worksheet, we can then use the Solver to find optimal values of both P_1 and P_2, which in turn determine the weights for the last 3 data points to forecast the fourth. P_2 is multiplied by the difference of 2 and 3 data points ago. In the summary shown in **Figure 4** we see that the 3-period Solver Moving Average produces an even better r^2 value of 62.03%. The red font indicates the optimal error measure in each column. Of course, what optimizes RMSE will also optimize its companion r^2. Also shown in Figure 4 are the weights derived from the P's.

Figure 4. Solver Moving Average Summary

Food Service Co for Firefighters in So Cal					
Moving Average Summary					
n = 20	Forecast	R.M.S.E.	R.M.S.E.	Δ_1	Δ_2
Best Naïve	Quarter=21	Error	r^2	1,101.57	465.64
Next = Last	27,485.084	1,363.457	0.00%	P_1	P_2
2-period Solver	28,195.383	976.800	48.68%	64.48%	N/A
3-period Solver	28,390.263	840.193	62.03%	88.11%	-14.05%
W_{-1}	W_{-2}	W_{-3}			
164.48%	-64.48%		2-period Solver Moving Avg		
188.11%	-102.17%	14.05%	3-period Solver Moving Avg		

IS YOUR FORECAST SMARTER THAN A 5TH GRADER?

Now let's turn to regression, and see what happens when we minimize RMSE in the summary portion of my Linear Regression template shown in Figure 5.

Figure 5. Regression Summary

Linear Regression Summary				Food Service Co for Firefighters in So Cal				
	R.M.S.E.	R.M.S.E.	Degrees of	Forecast Model				
n = 20	Error	Unbiased r^2	Freedom	a +	bX +	cX^2 +	dX^3 +	eX^4
Y-bar	3,194.14	0.00%	19	29,370.44				
Linear	3,259.11	-4.11%	18	28,788.97	53.838			
Quadratic	2,005.57	60.58%	17	22,637.92	1,731.398	-79.8838		
Cubic	1,998.32	60.86%	16	24,797.02	629.701	48.1260	-4.0638	
Quartic	1,245.47	84.80%	15	31,021.41	-4,564.402	1,131.9848	-84.2876	1.92868

For the Regression Summary in Figure 5, note that the polynomial coefficients in the Quartic row match the Excel quartic trend line seen in Figure 1, but r^2 is now the unbiased value of 84.80% instead of the biased R^2 of 88.00% because it takes into account degrees of freedom. This is the reason I used the symbol r^2 to avoid confusion with Excel's symbol R^2. Give this summary, we still see the Quartic model as the most viable of the regression models when errors are compared to Y-bar.

COMPARISON WITH BEST NAÏVE MODEL

But even this r^2 value of 84.80% is misleading, because it is measured against Y-bar and not the best naïve model. A complete summary of the Moving Average and Regression models is shown in **Figure 6**, where the base of r^2 is the RMSE of Next=Last (1,363.457) instead of 3,194.1 for Y-bar to recompute the real r^2 for the Linear Regression Summary in the 4th column.

Figure 6. Final Summary of true r^2

Moving Average Summary					
n = 20	Quarter=21	RMSE	RMSE	Δ_1	Δ_2
Model	Forecast	Error	r^2	1,101.6	465.6
Next = Last	27,485.1	1,363.457	0.0%	P_1	P_2
2-period Solver	28,195.4	976.800	48.7%	64.48%	N/A
3-period Solver	28,390.3	840.193	62.0%	88.11%	-14.05%

Linear Regression Summary								
n = 20	Quarter=21	RMSE	RMSE	Forecast Model				
Model	Forecast	Error	r^2	a +	bX +	cX^2 +	dX^3 +	eX^4
Y-bar	29,370.4	3,194.1	-448.81%	29,370.44				
Linear	29,919.6	3,259.1	-471.37%	28,788.97	53.838			
Quadratic	23,768.5	2,005.6	-116.37%	22,637.92	1,731.398	-79.884		
Cubic	21,609.4	1,998.3	-114.81%	24,797.02	629.701	48.126	-4.064	
Quartic	28,878.6	1,245.5	16.56%	31,021.41	-4,564.402	1,131.985	-84.288	1.92868

Now all only one of the regression curve fits has positive a r^2 value, and in this case (not always), the Quartic regression r^2 0f 16.56% is much worse than our best Solver Moving Average r^2 of 62.0%. So if we used the quartic curve fit, we would not even be as smart as a 5th grader! This because as a general rule, I don't use a model unless r^2 is $\geq$ 30%, and I recommend using the best naïve model, which now is Next=Last (and not Y-bar). Thus the forecast for Quarter 21 is 28,390.26k instead of 28,878.6k or about $490,000 less than the quartic forecast. This example should convince users that Regression statistics should be viewed with healthy suspicion if time series data is involved. The RMSE for the best Regression is actually about 50% higher than the best Solver Moving average (1245.5 vs. 840.2), and it only makes sense to go with the model with the much better error measures (lowest RMSE and highest r^2) unless the forecast seems beyond reason or reality.

ANOTHER WARNING AND INTERESTNG FACT

Another important lesson from this exercise is that even though the quartic fit "looks" graphically like it gets close to the actual data points, the error measure says differently. Many students will just say that the quartic fits the data the best because it has a smooth curve instead of the 3-period Solver model. The two graphs are shown below, side by side, in Figure 7. Many of my MBA students swear that just looking at the graph they can tell that the regression model has less error than the Solver moving average!

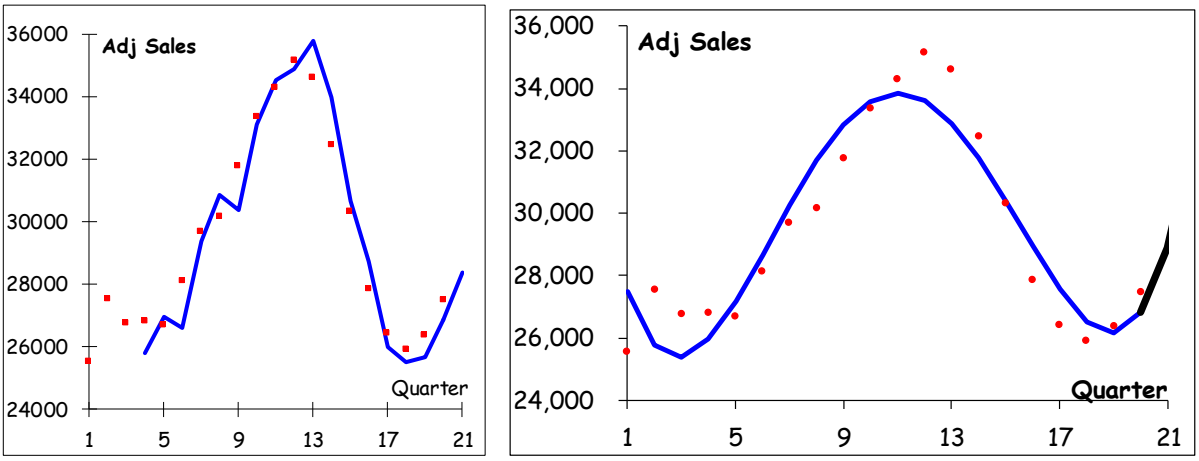


Figure 7. 3-period Solver Moving Average Quartic Regression

The only drawback about using Solver Moving Averages for forecasting is that you can only go forward one period. With regression formulas, you can go forward (or backwards or anywhere in between) as many periods as desired, but extending more than about 25% of the range of the data is fraught with possible pitfalls. The idea of using a regression formula (polynomial) is to capture the general trend of the curve and make sure that the r^2 is satisfactory as well as the error measure. But this r2 has to be measured using the error of the minimum naïve model.

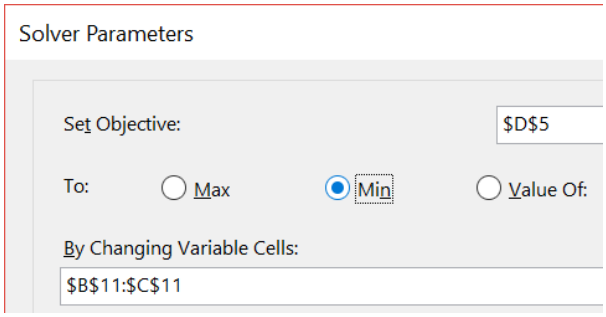
Figure 8 illustrates an interesting fact with the summary of the 3-period Solver Moving Average. Note that the r^2 values for each of the 3 error measures in cells **D11:F11** are almost identical. This means that the data is fairly well behaved and without extreme ranges that would favor one error measure over another.

Figure 8. 3-Period Solver Moving Average Summary

	A	B	C	D	E	F	G	H
2	Food Service Co for Firefighters in So Cal							
3		Minimize		Error Measures				
4		R.M.S.E.	Forecast	R.M.S.E.	M.A.D.	M.A.P.E.	df	
5	3-Period Solver Model		28,390.26	840.19	708.97	2.39%	17	
6	Total Average		29,370.44	3,194.14	2,898.03	9.76%	19	N
7	Cumulative Average		29,370.44	3,355.51	2,801.76	9.18%	19	A
8	3 Per Smoothing		26,595.49	2,404.53	2,046.37	6.87%	17	I
9	2 Per Smoothing		26,934.30	1,854.06	1,531.48	5.14%	18	V
10	Next = Last		27,485.08	1,363.46	1,169.07	3.95%	19	E
11		88.11%	-14.05%	62.0%	63.2%	63.2%	r^2	

Figure 9 shows the Solver setup for this 3-period Solver Moving Average.

Figure 9. 3-period Solver Setup



CONCLUSION

When using Time Series data for forecasting, it is wise to use both Solver Moving Averages and Linear Regression and compute r^2 as compared to the best naïve model, and not just Y-bar (Total Average or Y-bar). This can make a huge difference in analysis, and by showing the actual error and an r^2 which makes sense, to help convince those who automatically think regression is always the best method and now should realize that there may be much better moving average Solver models to consider. My Excel templates for this article are free upon request.

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Hesse, R., *Learning to Use Managerial Analysis Templates* (ebook); *LUMAT2*, pgs 204:6-28. Blue Pond Publishing, 1998-2018[1].

[1] It took the author 10 years to figure out simplifying from W_i to P_i would explain that the Solver Moving Average models simply improves upon Next=Last. This ebook material has been updated at least twice yearly for the last 20 years.

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A Predictive Modeling on Safety Management System's Lifecycle Effectiveness in the United Airlines (UA)

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ABSTRACT

As Safety Management System (SMS) deals with the management of safety risks, it is important to monitor its lifecycle in terms of its performance. Assessing the effectiveness of this lifecycle constitutes a systematic approach that leads to better management. In this paper, a two-part methodology is proposed, utilizing a set of problem reports as the basis, stemming from the dispatchers' SMS department of a major airline. Text analysis performed on these reports followed by the development of a regression model leads to a surprised/planned measure that contributes to the assessment of the effectiveness of the SMS lifecycle for the airline.

KEYWORDS: Safety management system, Lifecycle effectiveness assessment, Regression, Text analysis, Decision theory

INTRODUCTION

Safety Management System (SMS) is a system to assure the safe operations through effective management of safety risks. It uses policies, procedures, and bulletins among others to deal with safety issues. When one of these approaches is implemented, it is assumed that the targeted issue will be resolved. In reality, the implemented SMS method is only functional for a period of time. The issue may arise again at a later date or a similar type of issue may appear. Hence, the effectiveness of the SMS lifecycle needs to be assessed so as to improve the reaction time in managing emerging issues and to ensure all issues are properly dealt with.

One way of judging the success of an SMS lifecycle is through the problem reports written by the people actively applying new implementations. These problem reports are direct indicators of the performance of a new SMS execution; so, by extension, they are indicators of the

performance of the SMS lifecycle. Analyzing sets of problem reports can thus provide types of measures in how effective the SMS lifecycle is. In particular, the surprised or planned characteristic of a problem report can signal how well or not, the SMS lifecycle is functioning. The objective is then to determine the surprised or planned feature of a new problem report. To tackle this, the approach is broken up into two parts. In the first, text analytics is performed on a set of problem reports and its output is used as input in the second part to build two regression models, comparing manually given surprise scores and computer surprise scores.

The structure of the paper is as follows. The next section provides a brief overview of how SMS is implemented in various other sectors. We, then, explain the two-stage proposed solution methodology that consists of data analysis, metric creation and regression models. How this proposed framework can be performed to assess the effectiveness of the SMS is later discussed.

LITERATURE REVIEW

Numerous industry-specific instruments have been developed to measure the performance of SMS in sectors such as healthcare, manufacturing, construction, and aviation. Redinger and Levine (1998) developed a universal performance tool to measure the effectiveness of many Occupational Health and Safety Management Systems (OHSMS). Their model's inputs are auditable clauses, each of which describes one or more auditable issues within the selected management systems. Based on policy analysis and system theory, five key performance variables are generated, that also reflect the meaning and purpose of the inputs. They are given a score from zero to five, and the final output is an average of those scores.

Teo and Ling (2006) proposed a model to measure the effectiveness of the safety management systems of construction sites. Through surveys and workshops with experts, important factors affecting safety are gathered. The most crucial factors are then determined by using the analytic hierarchy process and factor analysis. The output of the model is a construction safety index, which is calculated based on the multi-attribute theory.

Kirezieva et al. (2013) developed an assessment tool of the Food Safety Management System (FSMS) implemented in the fresh produce sector. They established three sets of indicators for each step of the production chain (cultivation, processing, trade). Each indicator was validated by experts and has four levels (low, basic, average, advanced), describing the different ways the activities can be implemented. The system output is a comprehensive assessment of the FSMS, in which improvements are identified.

Hee et al. (1999) presents the Safety Management Assessment System (SMAS) that assesses human and organization factors in marine systems. An assessment is composed of three phases: an evaluation of information, system visits, and a final review. It is aided by a computer program, which takes in all numerical evaluations, creates a database, and displays the assessment results. SMAS also includes a training plan for the user and the criteria utilized are quantified with ranges, which considers uncertainty.

SOLUTION METHOD

R programming language is utilized for data analysis and for statistical computing. For statistical analyses, R programming has a broad set of facilities that has been specially constructed. R packages consist of inbuilt statistical algorithms with sheer amount of machine learning algorithms

and mathematical models. R also contains a broad range of graph drawing tools, which makes it to produce standard graphs of your data. The problem reports make up the basis of the data analysis and are from an SMS department of an aviation industry.

The data for this study is taken from United Airlines between the dates of September 1, 2015 and July 2, 2016. It constitutes problem reports emanating from the dispatcher's department of SMS. Specifically, the data contains information on the description of the issue, a list of its contributing causes, the date and time it occurred, the date and time the problem report was created, and a suggested resolution section. Here, the necessary information is taken from the data for building the regression model to improve the effectiveness of the SMS.

Part I

There are only so many synonyms pertaining to the emotion of surprise. Indeed, surprise can be elusive in a text if no actual synonym is present; it is often the context that provides the feeling of surprise. As a result, contextual metrics are defined, which, depending on their combinations, may indicate a measure of surprise or planned (whether the issue is already known). These metrics are split into two groups: one related to the causes or consequences of the issue at hand, the other concerning the emotions surrounding the issue. Specifically, the first group is comprised of the following categories: Oversight (M1), Communication (M2), Safety (M3), Recurring (M4), and Discrepancy (M5). And the second group consists of Ownership (S1), Blame (S2), Annoyance (S3), Confusion (S4), and Concerned (S5). Oversight is defined as a failure to notice something. Communication describes the exchange of information or the lack thereof. Safety encompasses anything related to safety and legality. Recurring designates actions or issues that occur repeatedly. Discrepancy refers to a non-compatibility between facts. Ownership characterizes someone acknowledging their mistake. Blame means a wrong or a mistake is assigned responsibility. Annoyance depicts irritation, anger, and being fed up. Confusion signifies uncertainty or a lack of understanding. Concerned includes the emotion of being worried or recommending.

To simplify the following steps, the set of problem reports are pre-processed; all letters are put in lowercase and common words such as very, also, then, are removed, as well as apostrophes. Then each of these categories is populated with text terms pertaining to the set of problem reports. Once the cluster of words or dictionaries are filled, they are optimized for textual analysis. To minimize the number of words, only the root of words with a variety of endings is kept. For example, the words misidentify, misidentifies, misidentification, and misidentified were all present in the initial oversight dictionary. Due to their common root, these words are replaced with misidentif in the final dictionary. This reduces the number of words in the dictionary and at the same time, increases the dictionary's reach.

Next, the metrics are run against the set of problem reports. For a problem report, it is given a value of 1 for a metric if one of the terms in that dictionary is present in the report; otherwise it is given a value of 0 for that metric. At the end of this step, the reports are categorized with respect to the aforementioned metrics, in binary scores. However, out of the 185 problem reports, only 5 are not captured by these metrics, either due to not containing enough text and/or being too technical.

Part II

Starting with the computer-scored regression, the independent variables are the metrics previously defined and the dependent variable is the time difference between when the implementation occurred and when the problem report was written. The idea behind the dependent variable is that the emotion of surprise is more intense when new issues stemming from the implementation arise and that feeling abates over time as more people are aware of those issues.

For the manual surprise-scored regression, the metrics are still the independent variables, but the dependent variable is a surprise score given by a human. In essence, each problem report is manually reviewed and scored for a human understanding of surprise. A group consensus is used to balance out the scores.

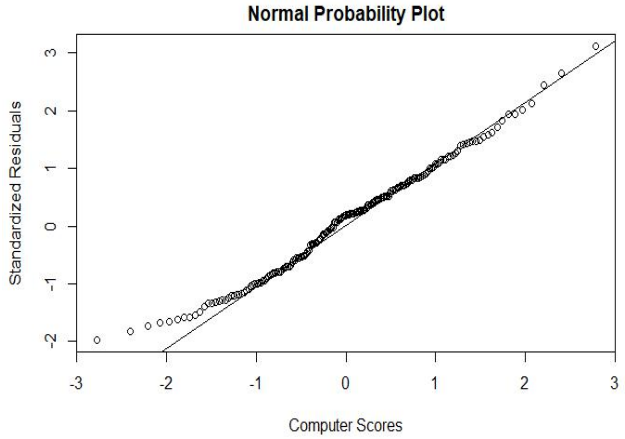
Both regression models are built progressively, starting with only the main metrics. Second order interactions are then added, followed by the removal of highly non-significant terms via a stepwise regression function. The most extreme outliers are then removed, which leads to the final regression model. Throughout each step, the normality of the residuals is inspected via a normal probability plot and multicollinearity is checked by calculating the terms' values of variance inflation factors (VIF) and flagging those with a VIF higher than 16.

RESULTS

Computer-scored Regression Results

The computer- scored regression model starts with only the main metrics of M1 through M5 and S1 through S5, and no constant term. This yields an adjusted R2 value of 68.10%. Given the relatively low value, all second order interaction terms are added to the regression. This generates a better adjusted R2 value of 74.24%; however, multicollinearity problems are present and many interaction terms are non-significant. Thus, a stepwise regression function is applied to better the model. The resulting regression model has all the main effects and fewer interaction effects, and an adjusted R2 value of 77.83%. Yet, the normal probability plot shows outliers at the upper end, so the most extreme outlier is removed from the regression. This produces a regression model with its residuals following a normal distribution as seen in Figure 1, no multicollinearity problems, and an adjusted R2 value of 79.05%. The extreme outlier that was taken out is one of the cases that has no metrics; because it is one of the later problem reports, it does not fit well with the model. This final model has linear main effects with some second order interaction effects. Table 1 and Table 2 presents a recap of the steps taken to build the computer-scored regression model.

Figure 1: Normal Probability Plot of Computer Scored Regression Model



Regression	Terms	Adjusted R^2
1st	Main metrics (M1 to S5)	68.10%
2nd	Main metrics and all second order interactions	74.24%
3rd	Main metrics and some second order interactions	77.83%
4th	Main metrics and some second order interactions	79.05%

Table 1: Computer Scored Regression model steps

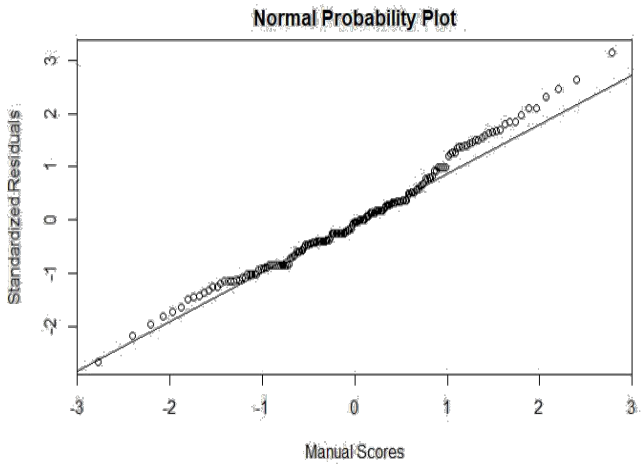
Regression	Multicollinearity	Normality Satisfied
1st	Absent	Yes
2nd	Present	Yes
3rd	Absent	Yes, but with outliers
4th	Absent	Yes

Table 2: Computer Scored Regression model steps

Human-scored Regression Results

Using a similar approach to the first regression, this final model has all main terms but M1, and some interaction effects. Figure 2 displays the satisfied normal probability plot and the adjusted R2 value is 87.67%. Table 3 and Table 4 shows the details of how the final manual-scored regression model was attained.

Figure 2: Normal Probability Plot of Human-Scored Regression Model



The manual surprise-scored regression model shows a strong relationship between the human reading of surprise and the metrics developed. This indicates that the dictionaries built are sufficient to have the computer scores used in the regression model, in place of the manual scores. The difference between the adjusted R2 values of both regressions can be explained by the fact that a human will always better grasp the emotion of surprise than a computer. Further details of the regression model in which all main metrics and all second order interactions have been incorporated and ran by Stepwise Regression can be found in Table 5.

Table 3: Manual Scored Regression model steps

Regression	Terms	Adjusted R^2
1st	Main metrics (M1 to S5)	80.33%
2nd	Main metrics and all second order interactions	83.94%
3rd	All main metrics but M1 and some second order interactions	86.29%
4th	All main metrics but M1 and some second order interactions	87.67%

Table 4: Manual Scored Regression model steps

Regression	Multicollinearity	Normality Satisfied
1st	Absent	Yes
2nd	Present	Yes
3rd	Absent	Yes, but with outliers
4th	Absent	Yes

Table 5: Regression Results-Main metrics and all second order interactions

	Coefficients				
	Estimate	Std. Error	t value	Pr(>|t|)	
M1	53.57	49.19	1.089	0.277744	
M2	167.25	63.74	2.624	0.009538	**
M3	282.41	76.74	3.68	0.000319	***
M4	30.66	57.99	0.529	0.597707	
M5	333.47	29.16	11.438	<0.00002	***
S1	338.52	67.54	5.012	1.43E-06	***
S2	25.08	56.99	0.44	0.660486	
S3	255	113.95	2.238	0.026626	*
S4	135.04	40.54	3.331	0.001079	**
S5	48.88	34.98	1.398	0.164215	
M3:S1	-150.78	100.45	-1.501	0.135328	
M3:S3	244.33	94.77	2.578	0.010845	*
M4:S1	-264.18	155.29	-1.701	0.090873	.
M4:S4	183.66	126.61	1.451	0.148877	
M5:S1	-304.5	69.24	-4.397	2.00E-05	***
M5:S3	-216.91	117.61	-1.844	0.06701	.
S1:S2	271.14	143.18	1.894	0.060096	.
S2:S4	-307.03	109.95	-2.792	0.005878	**
S2:S5	-181.57	100.35	-1.809	0.072279	.
S3:S4	-160.2	96.28	-1.664	0.098123	.
M1:M2	-197.21	99.22	-1.988	0.048589	*
M2:M5	-155.02	70.49	-2.199	0.029313	*
M3:M4	-171.29	96.05	-1.783	0.076438	.
M3:M5	-290.92	85.3	-3.411	0.000823	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Multiple R-squared: 0.8394, Adjusted R-squared: 0.8085

F-statistic: 33.02 on 24 and 158 DF, p-value: < 2.2e-16

CONCLUSIONS

Using a dictionary-based metrics approach, two regression models are constructed that compare the human understanding of surprise with some computer's reading. This level of

surprise output gives a quantitative assessment of the effectiveness of the SMS lifecycle, and the model as a whole provides a framework for it. The approach presented in this paper may be applied to other industries that have a similar concept in how issues are reported. The metrics in and of themselves will need to be redefined specifically for that industry, as each sector has its own technical language and sets of issues.

In terms of future work, for part 1 of the overall approach, the dictionaries can be refined with additional or more root-based terms, and new dictionaries will need to be created to take into account the problem reports not represented by the current metrics. As only binary scores were used for the metrics, continuous variables may be considered as this might give more emphasis to certain dictionary terms. For part 2 of the approach, the output of the regression may be converted from a date to an actual surprise score that could assist in grouping the incoming reports. Each group of reports would then lead to a different corrective action plan. Finally, the reversing effect of when the model begins to show reduced rate of return could be integrated into the model to better mimic the SMS lifecycle.

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A Product-Centric View of Smartphone Adoption

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ABSTRACT

UTAUT 2 provides a theory for understanding the adoption of consumer technology products such as smartphones. However, several key constructs in UTAUT 2, such as hedonic motivation, are centered on the user rather than the product. These constructs do not directly define how smartphone vendors can make the product more attractive. We approach the adoption of smartphones from the perspective of product attributes that engender adoption. These attributes, such as serviceability, supportability, extensibility and viability, are informed by the best-selling book Crossing the Chasm. This research is the first to approach consumer technology adoption from the standpoint of the product.

KEYWORDS: Technology acceptance models, TAM, UTAUT 2, consumer technology adoption, whole product concept

INTRODUCTION

The application of the technology acceptance model (TAM) to consumer technology adoption is a relatively recent development (Venkatesh, Thong, & Xu, 2012). Venkatesh et al. (2012) add new constructs such as hedonic motivation, price value, and habit to the UTAUT (Venkatesh et al., 2003). In the UTAUT 2 (Venkatesh et al., 2012), hedonic motivation is the enjoyment the consumer gets from the product or service (Holbrook & Hirschman, 1982), price value refers to whether the product represents good value for the money (Dodds, Monroe, & Grewal, 1991; Zeithaml, 1988), and habit is the automaticity of behavior (Limayem, Hirt, & Cheung, 2007). However, the adoption of consumer technology differs in a fundamental respect from the adoption of technology by users in businesses or other organizations where the TAM has historically been applied (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989; Karahanna, Straub, & Chervany, 1999; Szajna, 1996; Venkatesh & Davis, 2000; Venkatesh et al., 2003). In the business context, the technology has already been purchased and the user has to decide on whether to use the technology based on its usefulness, ease-of-use, and other factors. In this article, “adoption” in the consumer context essentially means both purchase and use of the technology by the consumer.

As purchase is integral to the adoption decision by consumers, we turned to the literature of marketing practitioners to obtain insight into the drivers of the technology purchase decision. Geoffrey Moore (1991), a noted marketing practitioner, offers the notion of the “whole product”

in his best-seller *Crossing the Chasm*. Moore states that it is essential to consider not just the core of the product, or what the product does, but other attributes surrounding the product such as its extensibility and viability. In other words, one has to take a holistic or a "whole product" view in order to be successful in selling technology products. Moore (1991) identifies the key whole product attributes that facilitate the technology purchase decision as supportability, serviceability, extensibility, viability, and price. We build a model of technology adoption that includes these whole product attributes as drivers of adoption intention. Moore is viewed as a marketing guru by many and his book *Crossing the Chasm* was referred to as the "bible of marketing" in 2006, fifteen years after its publication, by Tom Byers, Faculty Director of Stanford University's Technology Ventures Program (Byers, 2006).

The TAM/UTAUT genre of research has a key weakness in that it does not address the question of what makes an information technology (IT) artifact useful (Benbasat & Barki, 2007). In our model of smartphone adoption, many other antecedents of adoption intention are incorporated, such as supportability, serviceability, extensibility, and viability, some of which make their influence on adoption intention felt not directly but indirectly via mediation by the perceived usefulness (PU) construct. If perceived usefulness is found to mediate the influence of these new constructs on intention, which means they are antecedents to PU, then we have in effect partially addressed the question of what drives usefulness.

We conducted a large-scale survey at a midsize university of about 20,000 students to understand the phenomenon of adoption of smart phones. An incentive was provided to return the survey, and we received 1400 surveys. We obtained a number of interesting results including finding intricate paths of influence in a complex nomological network such as *viability→supportability→perceived ease-of-use→perceived usefulness→adoption intention*. This brings out the importance of the new constructs such as viability and extensibility which are derived from the notion of the whole product mooted by Moore (1991).

LITERATURE REVIEW

Moore's notion of the whole product finds resonance in the shift from products to solutions that major management consultancies such as McKinsey and Booz Allen Hamilton have been advocating for some time. Emphasis on the complete solution is evident in the published works from both McKinsey (Foote et al., 2001; Krishnamurthy, Johansson, & Schlissberg, 2003; Roegener, Seifert, & Swinford, 2001) and also Booz Allen Hamilton (Bennett, Sharma, & Tipping, 2001). Sawhney (2006) notes that many firms from both manufacturing and service industries such as IBM, GE, and UPS have shifted their focus from a product-centric view to one that emphasizes complete solutions particularly as these products and services have become more complex (Davies & Brady, 2000; Gann & Salter, 2000; Hobday, 1998; Sawhney, Balasubramanian, & Krishnan; 2004, Slywotsky & Morrison, 1998; Wise & Baumgartner, 1999). Both management consultants and academics alike are focusing on areas such as value-based solution pricing (Anderson, Jain, & Chintagunta, 1993; Roegener et al., 2001) and solution customization (Krishnamurthy et al., 2003; MacMillan & McGrath, 1997) in a bid to drive value for the customer.

Moore's notion of the whole product and its validation in the solution-centric view of management consultants led us to develop a modified TAM based on the whole product notion. We extended TAM 2 (Venkatesh & Davis, 2000; Venkatesh & Morris, 2000), which itself extends the TAM by adding an antecedent for subjective norms or social influence, by adding

antecedents to adoption intention corresponding to Moore's (1991) whole product attributes such as supportability, serviceability, extensibility, viability, affordability, and monetary value. The incorporation of antecedents in our technology adoption model that are informed directly by the thinking of practitioners also serves to address the concern that some noted IS scholars have voiced that IS research sometimes lacks practitioner relevance (Benbasat & Zmud, 1999). This is not a new issue and is part of the "rigor versus relevance" debate that has been raging in the IS field for quite some time (Applegate & King, 1999; Benbasat & Zmud, 1999; Davenport & Markus, 1999; Lyytinen, 1999). As part of the solution to the problem, Benbasat and Zmud (1999) exhort academics to get more engaged in the discourse of practitioners as a way of learning what is important to them and then tailoring IS research accordingly. Benbasat and Zmud (1999) suggest "going to practitioner conferences, talking to practitioners, reading practitioner and general management journals, teaching executive education courses, and engaging in consulting activities." Davenport and Markus (1999) express similar sentiments and urge academics to produce research that is read and valued by practitioners. Clearly, in order to do so, academics would need to become more aware of what practitioners are discussing among themselves. We have in effect followed the advice and sentiments of Benbasat and Zmud (1999) and Davenport and Markus (1999) in primarily drawing upon practitioner literature (Moore 1991) in developing our model.

In addition to incorporating practitioner knowledge into our theoretical model of technology adoption as a way of addressing the relevance issue, we also tackle a key concern that has been raised by critics of the TAM genre of models. Critics of the TAM have argued that despite two decades of research, the TAM still does not address the central question of what makes an information technology valuable or useful (Benbasat & Barki, 2007). The TAM works with large aggregated constructs such as perceived usefulness in the original TAM (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989) and TAM 2 (Venkatesh & Davis, 2000; Venkatesh & Morris, 2000) or its equivalent called performance expectancy in the UTAUT (Venkatesh et al., 2003) and UTAUT 2 (Venkatesh et al., 2012). Perceived usefulness or performance expectancy essentially captures the value of the information technology being adopted, but it begs the question of what drives usefulness. In other words, the TAM genre treats usefulness as a black box without providing insight into its drivers. Our model of smartphone adoption, on the other hand, shows that a number of the whole product constructs, such as extensibility, supportability, and viability, are actually mediated through the usefulness construct. Therefore, our model addresses the unanswered question in the TAM/UTAUT genre as to what drives usefulness.

THEORETICAL DEVELOPMENT

Model Constructs

Our smartphone adoption model uses as its foundation TAM 2 which identifies perceived usefulness (PU), perceived ease-of-use (PEOU), and social influence (SI) as key antecedents of adoption intention. To the TAM 2, we added additional constructs based on the whole product notion.

Supportability

Supportability (SUPP) refers to the level of support offered on the product and includes training, user documentation, facilities for problem resolution such as help desks, access to experts, and the availability of helpful online information. Supportability is akin to the facilitating conditions construct in the UTAUT (Venkatesh et al., 2003) and the UTAUT 2 (Venkatesh et al., 2012), but

with the difference that in the whole product vector concept, we recognize supportability and serviceability as two distinct constructs whereas the UTAUT and UTAUT 2 do not disaggregate the facilitating conditions construct.

Serviceability

While supportability is about getting help to use the product, serviceability (SERV) is about the ability to have the product repaired when it breaks. Hence, serviceability includes availability of service plans, easy access to service centers and retail outlets, and convenient mechanisms for sending the product back to the vendor for repairs.

Extensibility

Extensibility (EXTEN) refers to the capability of the product being extended and includes the potential of adding new features, availability of accessories, and the ability to integrate the product with other products possibly from third-parties. The notion of product extensibility has really not been addressed in the TAM genre (Davis 1989, Venkatesh & Davis, 2000; Venkatesh et al. 2003, Venkatesh, et al., 2012). Extensibility of the product can certainly be viewed as an element of a complete solution and is therefore supported by the general shift from the product-centric to a solution-centric view as indicted in both the academic and practitioner literature in marketing (Bennett et al., 2001; Foote et al., 2001; Sawhney, 2006; Slywotsky & Morrison, 1998; Wise & Baumgartner, 1999).

Viability

Viability (VIAB) refers to whether the product will continue to remain viable or whether factors such as failure of the vendor, obsolescence of the technology, or change of standards will make the product non-viable in the future. Like extensibility, viability is a new construct that has not been addressed in the TAM genre (Davis 1989, Venkatesh & Davis, 2000; Venkatesh et al. 2003, Venkatesh, et al., 2012). The salience of viability arises from the consumer's need to control risk. Smartphones are expensive and it is natural for the consumer to want to protect their investment. Ever since the introduction of the notion of perceived risk in product purchase decisions by Bauer (1960), many market research studies show that managing risk is indeed salient in consumer psychology (Cox & Rich, 1964; Reid, Teel & Van Den Berg, 1980; Ross, 1975; Simpcock, Sudbury & Wright, 2006; Woodside, 1972).

Monetary Value

Monetary Value (MV) captures whether the buyer is getting good value for their money and is similar to perceived monetary value in Hong and Tam's (2006) study of adoption of mobile data services, and also to the price value construct used in the UTAUT 2 (Venkatesh et al., 2012).

Affordability

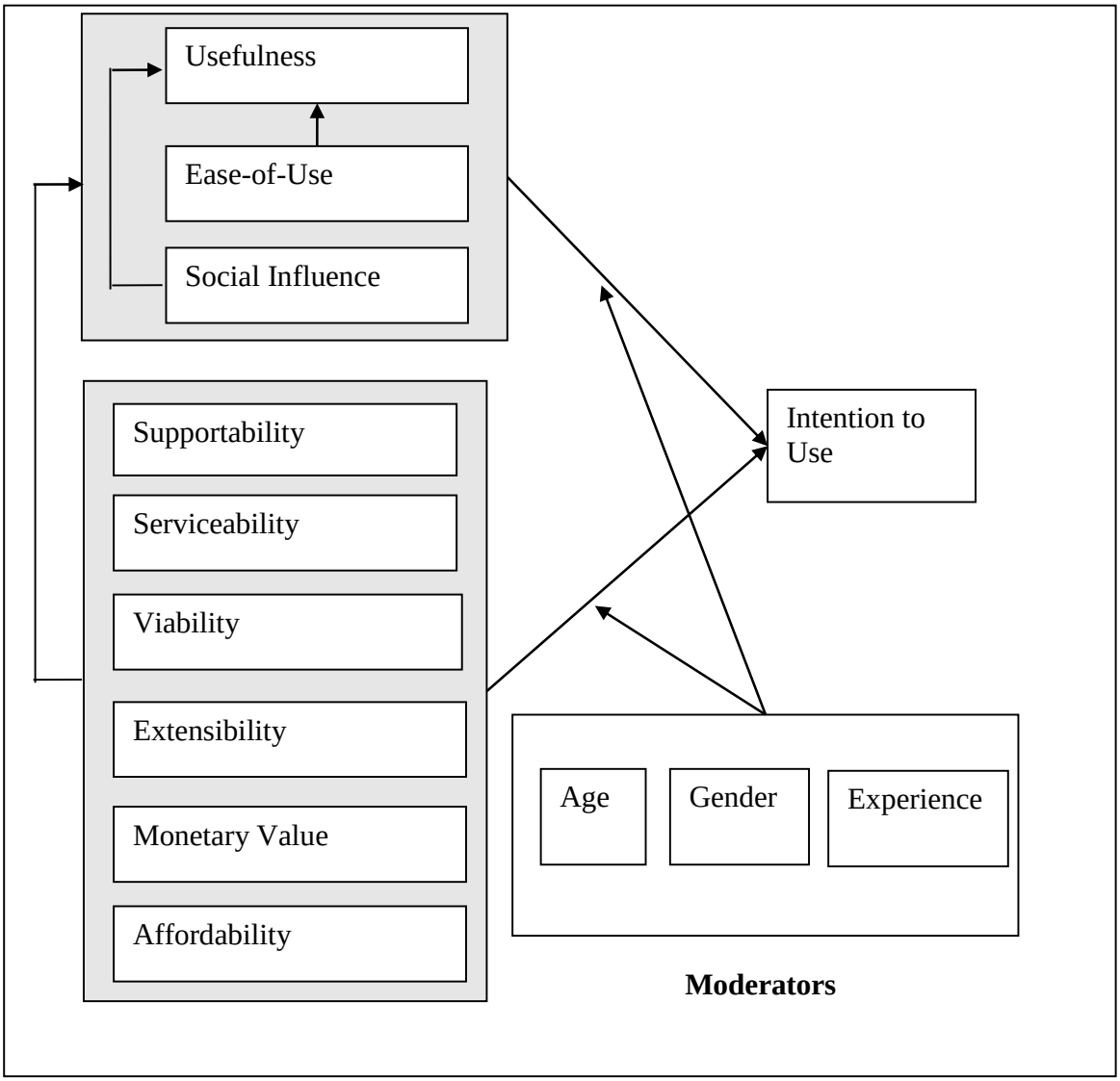
We make a distinction between whether a product represents good value for the money and whether the consumer can afford the product or not. Hong and Tam (2006) and Venkatesh et al. (2012) did not draw a clear distinction between monetary value and affordability (AFF) as they use a single construct for the user's price sensitivity. However, we argue that making such a distinction is necessary otherwise it is hard to tell if the popularity of the product from a monetary standpoint arises from its easy affordability, as appears to be the case with short

message services in China (Chan et al., 2008), or it is due to the highly quality of the product for the price charged.

Hypotheses

Our model of smartphone adoption is shown in Figure 1. For simplicity of presentation, our model is shown in Figure 1 at a block diagram level. The specific paths of causality, mediation, and moderation are described by the hypotheses formulated in this section.

Figure 1: Smartphone Adoption Model



Direct Effects

Since our smartphone adoption model uses TAM 2 as its base, the hypotheses of the TAM 2 are retained in our model. Hypotheses 1 through 3 are the TAM 2 hypotheses. To this we add

Hypotheses 4 through 9 corresponding to the whole product constructs. Conceptually, each construct would be considered to represent an increasingly positive trait of the product as the user perceives increasingly higher values of the construct; therefore, each construct should be positively related to the intention to adopt the product. The direct effects of the TAM 2 constructs and the whole product-based constructs on adoption intention are captured in the following set of hypotheses:

Hypothesis 1: *Perceived usefulness is positively related to adoption intention*.
Hypothesis 2: *Perceived ease of use is positively related to adoption intention.*
Hypothesis 3: *Perceived social influence is positively related to adoption intention*.
Hypothesis 4: *Perceived supportability is positively related to adoption intention*.
Hypothesis 5: *Perceived serviceability is positively related to adoption intention*.
Hypothesis 6: *Perceived extensibility is positively related to adoption intention*.
Hypothesis 7: *Perceived viability is positively related to adoption intention*.
Hypothesis 8: *Perceived monetary value is positively related to adoption intention*.
Hypothesis 9: *Perceived affordability is positively related to adoption intention*.

Mediated Effects

With regard to mediated effects, we know from previous TAM studies that PEOU and SI affect behavioral intention both directly as well as indirectly through PU (Davis et al., 1989; Venkatesh & Davis, 2000). Hence these indirect effects are incorporated in the following hypotheses:

Hypothesis 10: *Perceived ease of use is positively related to perceived usefulness*.
Hypothesis 11: *Perceived social influence is positively related to perceived usefulness*.

Extensibility, or the ability to add more features and capabilities that the user might find useful at a later stage, could be construed as adding to the usefulness of the device. Hence, we augment the mediating role of the PU construct by adding the hypothesis:

Hypothesis 12: *Perceived extensibility is positively related to perceived usefulness.*

In our model, which includes the constructs of supportability and serviceability, it is certainly arguable that the smartphone will be viewed as easy to use if the user can readily find the support needed to use the device as well as be able to repair it when it breaks or malfunctions. Hence, perceived ease of use can act as a mediator of the influence of serviceability and supportability on adoption intention. Consequently, we have:

Hypothesis 13: *Perceived supportability is positively related to perceived ease of use.*
Hypothesis 14: *Perceived serviceability is positively related to perceived ease of use.*

The influence of viability on adoption intention can be felt both directly, as captured by Hypothesis 7, as well as indirectly. Serviceability and supportability of the smartphone can be expected to depend on the long-term viability of the vendor, the technology, and the standards supporting the technology. Also, the extensibility of the smartphone can be expected to depend on the long-term viability of the vendor from whom it was purchased. This leads to the following hypotheses:

Hypothesis 15: *Perceived viability is positively related to perceived supportability.*
Hypothesis 16: *Perceived viability is positively related to perceived serviceability.*

Hypothesis 17: *Perceived viability is positively related to perceived extensibility.*

Moderator Effects

Historically, technology adoption studies have found that the key PU->I, PEOU->I, and PEOU->PU relationships are moderated by gender, where males give more weight to the usefulness of an IT (Venkatesh & Morris, 2000; Venkatesh et al., 2003). Traditionally, boys have been brought up to believe that they must be strong, provide for the family, fix things when they are broken, acquire useful work-related skills, and be more task-oriented. Task-oriented individualism with regard to technology use is less strong in females and they give due importance to how easy the technology is to use and whether there is a community that they are connected to and respect that is using this technology and influencing them to do the same (Venkatesh & Morris, 2000; Venkatesh et al., 2003; Venkatesh, Morris, & Ackerman, 2000). Hence, we capture the results of prior research in the following hypotheses:

Hypothesis 18: The relationship between perceived usefulness and adoption intention is moderated by gender such that it is stronger for males.
Hypothesis 19: The relationship between perceived ease of use and adoption intention is moderated by gender such that it is stronger for females.
Hypothesis 20: The relationship between perceived ease of use and perceived usefulness is moderated by gender such that it is stronger for females.
Hypothesis 21: The relationship between social influence and adoption intention is moderated by gender such that it is stronger in females.

While we have captured the results of prior research in Hypotheses 18 through 21, we also note that as the socialization processes are changed, gender roles can slowly change with time (Feldman & Aschenbrenner, 1983; Helson & Moane, 1987). In our study, given our population of predominantly young and college-educated males and females, we posited that these three key relationships would not be moderated by gender. The historical conditioning of boys and girls about their “appropriate” gender roles is arguably less relevant in today’s high-tech age than it once used to be. Since gender schema theory is really about socialization processes rather than biological gender, we felt that the PU->I, PEOU->I, PEOU->PU, and SI->I relationships would not be moderated by gender for our survey population, or that Hypotheses 18 through 21 would fail to be established in this study. With regard to how the influence of each of the new whole product-based antecedents on adoption intention is moderated by gender, since there is no prior theory on this, we elected to let the data drive the formulation of exploratory hypotheses in this area.

Age has been seen to play a role similar to that of gender in that older people, similar to women, place more emphasis on ease of use and social influence in their intentions to adopt technology (Morris & Venkatesh, 2000; Venkatesh et al., 2003; Plude & Hoyer, 1985). Younger workers as they respond more to extrinsic rewards (Hall & Mansfield, 1995) tend to pay greater attention to the usefulness of the technology (Venkatesh et al., 2003). They see the technology as a vehicle to obtain these rewards. Hence, past research has shown that the following hypotheses generally hold:

Hypothesis 22: The relationship between perceived usefulness and adoption intention is moderated by age such that it is stronger for younger people.
Hypothesis 23: The relationship between perceived ease of use and adoption intention is moderated by age such that it is stronger for older people.

Hypothesis 24: The relationship between perceived ease of use and perceived usefulness is moderated by age such that it is stronger for older people.
Hypothesis 25: The relationship between social influence and adoption intention is moderated by age such that it is stronger for older people.

Again, since our survey population is dominated mostly by young students, we suspected that Hypotheses 23 through 25 may likely not hold in our survey population. Furthermore, as we did in the case of the role of gender in moderating the influence of the whole product-based antecedents on adoption intention, we elected to let the data drive the formulation of exploratory hypotheses on the moderating influence of age since there is no prior theory on this.
The third moderating variable considered in our analysis is experience with the technology. The moderating role that experience with technology has generally played is that it blunts the salience of ease of use (Szajna, 1996; Venkatesh, 1999) and social influence (Venkatesh & Morris, 2000) on intentions to adopt technology. Although our population consists mainly of young college-going males and females with somewhat similar social conditioning, there could still be differences in terms of the breadth and depth of technology usage. A 22-year old female student majoring in computer science may well be more adept at using all the features of a smart phone than a 22-year old male or female student majoring in art history. Hence:

Hypothesis 26: *The effect of ease of use on adoption intention is moderated by experience so that it is stronger for people with less technology experience*.
Hypothesis 27: *The effect of social influence on adoption intention is moderated by experience so that is stronger for people with less technology experience.*

As we did in the case of gender and age, we elected to let the data drive the formulation of exploratory hypotheses on the moderating influence of experience on the relationships between the whole product-based constructs and adoption intention since there is no prior theory on this. Although we have not formulated hypotheses on the moderating influences of gender, age, and experience on the key relationships involving the whole product-based constructs given the absence of prior theory in this area, we saw a connection between viability of the smartphone and general experience with technology. People with long experience with using technology products know how important the viability of the product, the vendor, and the technology standards supporting the product are for the continuance of service and support on the product. All too often, as markets take different turns, start-up companies fail, and standards are superseded by others, service and support on the product stops and that leaves the customer holding the bag. This leads to the hypotheses:

Hypothesis 28: *The effect of viability on supportability is such that it is stronger for people with more experience with technology*.
Hypothesis 29: *The effect of viability on serviceability is such that it is stronger for people with more experience with technology.*

RESULTS

The survey data were analyzed using the methodology of structural equation modeling (SEM) with the help of the AMOS™ software tool. Confirmatory factor analysis (CFA) was first performed to assess the construct validity of all the latent variables in the model.

Confirmatory Factor Analysis

In confirmatory factor analysis (CFA), all items were constrained to load on their own constructs and the inter-construct correlations were allowed to vary freely. Using this approach, we examined the standardized factor loadings of the items to assess construct validity and the reliability of the instrument. Table 1 shows the standardized factor loadings for the initial instrument. In order to get a high Cronbach alpha reliability, we sequentially dropped low-loading items in an iterative process where the factor analysis was re-run at each step till all standardized factor loadings were above 0.7. The final instrument comprised the items PU1, PU2, PU3, PEOU1, PEOU2, PEOU3, I1, I2, I3, I4, I5, MV1, MV2, AFF2, AFF3, AFF4, SUPP5, SUPP6, SERV1, SERV2, SERV3, VIAB1, VIAB2, VIAB5, VIAB7, VIAB9, EXTEN1, EXTEN2, EXTEN3, EXTEN4, EXTEN5, EXTEN6, SI1, SI2, S3, and SI4. The Cronbach alpha reliabilities of the constructs for the refined instrument are given in Table 2. As seen from the table, the Cronbach alphas are all above 0.8 thereby indicating good reliability.

Table 1**:** Confirmatory Factor Analysis

Factor	**Item**	**Standardized Loading**	**Factor**	**Item**	**Standardized Loading**
U (usefulness)	U1	.927	EXTEN (Extensibility)	EXTEN1	.806
	U2	.951		EXTEN2	.744
	U3	.783		EXTEN3	.829
	U4	.706		EXTEN4	.797
EOU (ease of use)	EOU1	.726		EXTEN5	.788
	EOU2	.868		EXTEN6	.76
	EOU3	.872	AFF (Affordability)	AFF1	.486
	EOU4	.692		AFF2	.657
SI (social influence)	SI1	.838		AFF3	.747
	SI2	.804		AFF4	.921
	SI3	.789		AFF5	.826
	SI4	.77	MV (Monetary Value)	MV1	.76
SERV (serviceability)	SERV1	0.896		MV2	.887
	SERV2	0.893		MV3	.703
	SERV3	.883		MV4	-.025
	SERV4	.719		MV5	.647
	SERV5	.671	VIAB (Viability)	VIAB1	.853
SUPP (supportability)	SUPP1	.475		VIAB2	.793
	SUPP2	.712		VIAB3	.058
	SUPP3	.677		VIAB4	-.456
	SUPP4	.706		VIAB5	.801
	SUPP5	.87		VIAB6	-.256
	SUPP6	.87		VIAB7	.816
I (Intention)	I1	.76		VIAB8	.006
	I2	.93		VIAB9	.73
	I3	.955			
	I4	.886			
	I5	.855			

Model Fit

With regard to model fit, the indices in Table 3 generally indicate a well-fitting model. Most SEM researchers suggest that a root mean square error of approximation (RMSEA) of below 0.05 or below 0.06 is needed for a good fit (Hu & Bentler, 1995, 1999; Schreiber et al., 2006). We obtained an RMSEA of 0.057 thus approximately meeting this criterion. While there are several other fit indices that are used to assess the fit of a structural model, some authors (Hu & Bentler, 1999; MacCallum, Browne, & Sugawara, 1996) focus on the Comparative Fit Index (CFI) and the Non-Normed Fit Index, also referred to as the Tucker-Lewis Index (TLI), as being particularly important. Generally, it is recommended that CFI and TLI should be above 0.95 for a well-fitting model. As seen from Table 3, we obtained values of 0.936 for CFI and 0.93 for TLI, again indicating a reasonably good fit. We also report the values of other fit indices such as the Incremental Fit Index (IFI), Normed Fit Index (NFI), and Goodness of Fit Index (GFI) in Table 3. Looking at the various fit indices together, particularly the values of RMSEA, CFI, and TLI that some authors (Hu & Bentler, 1999; MacCallum et al., 1996) view as the key indices, the overall picture that emerges is that we have, perhaps not an exceptionally well-fitting, but certainly a well-fitting model.

Table 2: Cronbach Alpha Reliability Coefficients in Final Instrument

Latent Factor	**Cronbach Alpha**
PU	0.91
PEOU	0.86
SI	0.88
SUPP	0.91
SERV	0.93
EXTEN	0.91
MV	0.81
AFF	0.87
I	0.94
VIAB	0.9

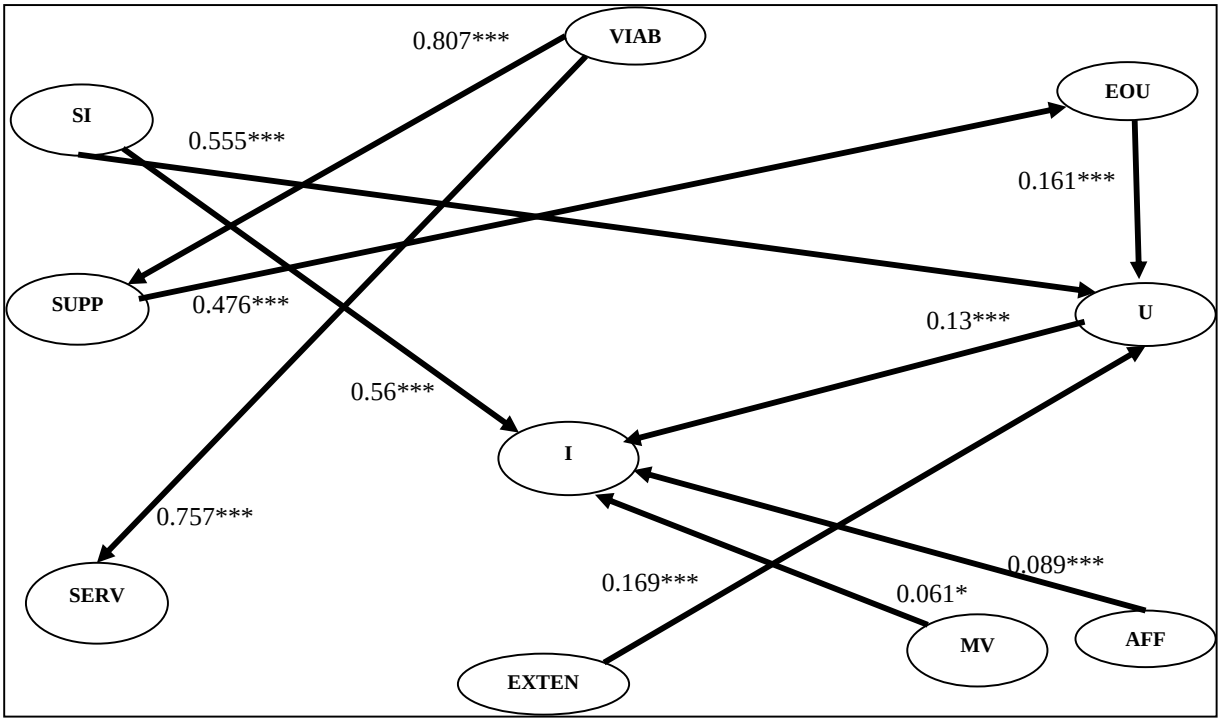
Path Model Hypothesis Tests

The refined instrument was then used to test the hypotheses in the path model as formulated previously. Figure 2 shows the values of the path model coefficients along with their level of significance. Of the direct effects, only Hypothesis 1 (PU->I), Hypothesis 3 (SI->I), Hypothesis 8 (MV->I), and Hypothesis 9 (AFF->I) were found to be significant. The fact that none of the constructs in our whole product vector of attributes other than affordability and monetary value drove adoption intention is, on the face of it, an interesting result. This however does not by any means imply that they are not relevant in the adoption decision. Several of them are indeed very

relevant except that their influence on adoption intention is mediated through other constructs rather than felt directly.

In terms of the mediating relationships, Hypothesis 10 (PEOU->PU) and Hypothesis 11 (SI->PU) tested significant, or that the effects of ease of use and social influence on intention are mediated through usefulness. This is quite consistent with what has been found previously in TAM studies (Venkatesh & Davis, 2000; Venkatesh et al., 2003). The new results on how the influence of the whole product constructs is mediated are that Hypothesis 12 (EXTEN->PU), Hypothesis 13 (SUPP->PEOU), and Hypothesis 15 (VIAB->SUPP) tested significant. Hence, the whole product constructs of extensibility, supportability, and viability do influence adoption intention, albeit they do so in indirect ways. In fact, while extensibility influences intention through one level of indirection via the path EXTEN->PU->I, supportability influences intention through two levels of indirection via the path SUPP->PEOU->PU->I, and viability influences intention through three levels of indirection via the path VIAB->SUPP->PEOU->PU->I. Although Hypothesis 16 (VIAB->SERV) also tested significant, serviceability did not either directly or indirectly influence adoption intention. Therefore, the effect of viability on intention is felt only through the VIAB->SUPP->PEOU->PU->I path involving multiple levels of indirection.

Figure 2: Structural Model of Smartphone Adoption



We also controlled for common methods variance in our study, which is a problem that has been noted about certain TAM studies (Sharma, Yetton & Crawford, 2009; Straub & Burton-Jones, 2007). The common methods variance issue arises from the fact that users tend to make their answers consistent across the independent and dependent variables in a questionnaire. So if a user had already indicated in the early part of the questionnaire that they think a certain IT artifact is useful, easy to use, and has good monetary value, they may be inclined to say that

they will adopt the artifact in the latter part of the questionnaire in order to make their responses appear rational and consistent. This is the consistency motif of common methods bias. But they may not truly have an intention to adopt the device. We addressed this common methods variance issue by giving the survey in two formats to the respondents. In one format, the questions on the antecedents, such as usefulness or supportability, preceded the questions on the dependent variable of intention. In the second format, the questions about the dependent variable of intention preceded the questions about the antecedents. Respondents were randomly chosen as to who received which format of the survey.

Effects of Moderators

We used the multi-group analysis capability in the AMOS™ tool to test the effects of the gender, age, and experience moderators on those relationships that had tested statistically significant. We used the critical ratio for differences between parameters test to evaluate whether a statistically significant difference existed between the corresponding path coefficients in the two groups being compared. The absolute value of the critical ratio for parameter differences was compared to 1.96 to determine whether a moderator effect existed on that relationship at a 0.05 level of significance.

For the gender moderator, we found two relationships that tested significant at the 0.05 level using the parameter differences test. One of them was PEOU->PU where the relationship was stronger for females, which is consistent with what previous studies have found (Venkatesh & Morris, 2000; Venkatesh et al., 2003) that women tend to give more weight to the ease of use of the technology, which is Hypothesis 20. The critical ratio for parameter differences had an absolute value of 2.11 for this relationship. Hypotheses 18, 19, and 21 were not supported. This finding of narrow and limited differences in the thinking of young college-educated males and females about the adoption of trendy consumer technology products is actually very consistent with our earlier surmise that unlike the traditional conditioning of males and females, present-day technically-savvy, college-educated, young males and females are likely to have more in common as far as their social conditioning about technology use is concerned.

For the age moderator, the parameter differences tests showed that the SI->I intention relationship had a statistically significant difference in the path coefficients between the younger and older groups. The absolute value of the critical ratio of differences was 2.83. However, although we had posited in Hypothesis 25 that the SI->I relationship would be moderated by age, our hypothesis was that the effect would be stronger for older people. We had structured Hypothesis 25 in that fashion because prior theory suggests that older people are more responsive to social influence (Rhodes 1983). In this case, the result was that, while the SI->I path coefficient was indeed different for the two groups, it was greater for the younger group. This result although not consistent with prior theory is not surprising when one considers the IT artifact that is the focus of the study. The smart phone is an inseparable fixture in the lives of young people given their heavy usage of cell phone voice calls, texting, and mobile apps for social networking. The smart phone is the quintessential way for youngsters to remain connected with their peer networks. Hence, the peer pressure factor clearly weighs heavily on the minds of young people as they contemplate acquiring gadgets such as smart phones. Also, we had correctly surmised that Hypotheses 22, 23, and 24 would fail to be supported given that our survey population is dominated by young college students.

For the experience moderator, the only hypothesis that tested positive was Hypothesis 28 which posits that people with more experience using technology products will give greater weight to

the importance of viability in terms of the continuance of support. People with longer experience using technology products know first-hand how service and support can be disrupted as companies go under, product lines are discontinued, markets take different turns, or technology standards change. We found that the VIAB->SUPP had a critical ratio for the parameter differences test of 3.1. The other hypotheses 26, 27, and 29 about the moderating influence of experience were not borne out in this study.

DISCUSSION

Theoretical Implications

Our model could potentially be generalized into a more universal model of consumer technology adoption. However, this study focused only on smartphone adoption. Hence, our model would need to be tested with several other types of consumer technology products, before it could be viewed as a general model such as the UTAUT 2. If our model is supported after it is tested with other consumer technology devices, then it would offer a different theoretical model of consumer technology adoption than the UTAUT 2 (Venkatesh et al., 2012). The UATUT 2 uses the UTAUT (Venkatesh et al., 2003) as the base model and adapts it to the consumer technology adoption context by adding antecedents such as hedonic motivation, habit, and price value. Constructs such as hedonic motivation and habit are centered on the user. We have approached the problem differently. The UTAUT 2 can be viewed as a user-centric model of consumer technology, whereas our model is more product-centric. In creating a more product-centric model, we were mindful of the rigor versus relevance debate that has been raging in the IS field for some time (Applegate & King, 1999; Benbasat & Zmud, 1999; Davenport & Markus, 1999; Lyytinen, 1999). That is why we first reached out to practitioner literature to understand their thinking on technology purchase and then incorporated this knowledge into our model of smartphone adoption. Moore's (1991) concept of the whole product, which emphasizes factors such as supportability, serviceability, extensibility, viability, and price in determining the purchase decision, was used to extend the TAM to the context of consumer technology adoption, in particular, the adoption of smartphones.

Another important difference between our model and the UTAUT 2 is that we have built a more granular model. A granular model with finer constructs leads to a more complex nomological network and allows us to find intricate paths of causality through this network. For example, as we found from this study, a construct such as viability makes its effect felt on intention through three levels of indirection via the VIAB->SUPP->PEOU->PU->I path. If all of the constructs in the VIAB->SUPP->PEOU->PU->I path were not explicitly incorporated in the model, one would simply miss the role that viability plays in technology adoption. Finding these paths of causality also helps address the call by Benabasat and Barki (2007) to open up the large black box constructs in the TAM such as PU and PEOU. By surfacing how the constructs of PU and PEOU act as mediators for many other antecedents such as supportability, extensibility, and viability, we are in effect opening these black boxes by showing what drives PU and PEOU.

Our use of more granular constructs also allows us to separate certain other issues more clearly. For example, we separate monetary value from affordability. In both Hong and Tam (2006) and Venkatesh et al. (2012), the monetary aspects are put in a single construct called perceived monetary value by Hong and Tam (2006) and price value by Venkatesh et al. (2012). We argue that the issue of whether one is getting good value for the price is quite different from whether one can afford to buy the product or not at the price being asked for. A buyer may

perceive a Mercedes Benz as providing great value for the price considering the quality of the product and yet not be able to afford it.

Managerial Implications

We have argued that our model of smartphone adoption, which could potentially be extended to a more general model of consumer technology adoption, is more practitioner relevant as it was partly informed by the rigor versus relevance debate (Benbasat & Zmud, 1999). Our technology adoption model directly incorporates practitioner knowledge. Organizational scientists lament the fact that much of the theory about organizational phenomena, such as a theory of what drives purchases of consumer IT artifacts, is not instrumental (Astley & Zammuto, 1992) in that it doesn't inform managerial decisions or practice. Beyer and Trice (1982) suggest there is too much distance between the domain of managers and that of organizational researchers for the theories spun by researchers to be instrumental. The approach we have taken in building our model tackles precisely this problem of non-instrumentality of organizational theory by first reducing the distance between researchers and practitioners through looking at the purchase phenomenon from the eyes of influential practitioners such as Moore (1991).

With the distance reduction accomplished, we develop a variable-rich theory of smartphone adoption, which is also potentially generalizable to a more universal theory of consumer technology adoption. Daft and Lewin (1990) indicate that researchers generally develop parsimonious theories based on a small number of variables that can explain phenomenon over a wide range of organizations. They also assert that organizations, however, represent complex, variable-rich phenomena thus implying a mismatch between the theoretical lens that we fashion and the objects we apply that lens to. Based on Daft and Lewin's (1990) views on the mismatch between parsimonious theories and variable-rich organizational phenomena, our model by being more granular and variable-rich can arguably inform managerial practice in the producers of consumer technology artifacts better than the UTAUT 2 (Venkatesh et al., 2012), which is a more parsimonious theory.

In testing our smartphone adoption model, we found that the whole product constructs of extensibility, supportability, viability, monetary value, and affordability indeed affect adoption intention, although they may do so in various circuitous ways, where their influence on intention is mediated through other constructs such as usefulness or ease of use. Whether their effect on adoption intention is direct or indirect, the empirical fact established here is that they do *matter*. Furthermore, they provide producer-manipulable variables. The producer can change the extensibility of the IT artifact they are offering. The producer can give more attention to creating an architecture for the product that allows for the integration of new functionality as well as the layering of value-added products possibly from other vendors. The producer can adhere to certain technology standards that offer a high level of plug-and-play thus making the integration of third-party products easier. Similarly, ensuring that service and support continue to be provided even on discontinued products can foster the customer's confidence in the viability of the product, which our model reveals is a variable that matters in the adoption decision.

Differentiating between monetary value and affordability also clarifies for the IT producer the main concern in the user's sensitivity to price. Does the user believe the product is priced too high in relation to the value returned, or is the user's problem that they cannot afford to buy the product even though it gives good value for the money? This clarity can enable the IT producer to fashion an appropriate response which could be to increase the quality of the product while keeping the price the same thus increasing the perceived monetary value. Alternatively, they

could develop a low-end product with fewer features at a lower price point to make it more generally affordable.

Other implications of interest to marketers have to do with user demographics and technology adoption. This study showed that there is really not a lot of difference in how young college-educated males and females think about adopting trendy consumer technology products such as smart phones. Traditional notions of gender roles which have historically led to differences in the adoption of technology really don't have as much salience as far as younger college-educated males and females are concerned. Rather than approach college-going males and females with different marketing campaigns, IT producers need to focus on how best to reach both groups through social media, and also to increase the utility of smart phones by providing more mobile apps for them. This would also be in keeping with the observed result of the greater salience of social influence on the intention to purchase such devices by young people. For all of the above ways in which our model can inform managerial decisions and practice, our model can indeed be viewed as an instrumental or utilizable theory (Astley & Zammuto, 1992).

Limitations and Future Research

To begin with, since our model was tested against smartphones only, it cannot yet be viewed as a general theory of consumer technology adoption. However, as it is tested against a variety of other consumer technology devices, our model could certainly grow into a more general model of consumer technology adoption. Another limitation of this study, even within the realm of smartphone adoption, is that it focused on a largely young and college-educated population. The external validity of the results of this study to the population at large therefore needs to be verified through further research. Another limitation is that there could also be other attributes of the whole product beyond the ones that Moore identified that could be incorporated into the model. Perhaps in today's age of social responsibility and environmental consciousness one could consider adding an antecedent on how "green" the product is as a driver to the adoption decision. Finally, a fruitful avenue of further research would be to integrate the UTAUT 2 and our model, once it has been generalized to a broader model of consumer technology adoption, to obtain a more powerful and unified model of consumer technology adoption.

CONCLUSION

In this study, we have proposed an extension to the TAM 2 that incorporates drivers of the technology purchase decision drawn from the notion of the whole product mooted by noted practitioner Geoffrey Moore. This notion implies that a technology product must be viewed holistically in that, in addition to its primary function, vendors must give due importance to the factors of pricing, supportability, serviceability, extensibility, and viability to ensure its success. We tested our model against smartphones and found that the whole product-based constructs of supportability, extensibility, and viability are indeed drivers of smartphone adoption decision, though they may influence this decision more indirectly.

APPENDIX

Instrument

Perceived Usefulness (PU)

- PU1: I do (or would) find this product useful for performing required tasks in my job or school environment.
- PU2: I do (or would) find this product useful for performing optional tasks in my job or school environment.
- PU3: I do (or would) find this product useful for performing personal, non-entertainment tasks (banking, shopping, information searching, etc.).
- PU4: I do (or would) find this product useful for performing personal, entertainment tasks (banking, shopping, information searching, etc.).

Perceived Ease of Use (PEOU)

- PEOU1: I understand how I would use this product.
- PEOU2: It is (or would be) easy for me to learn to use this product effectively.
- PEOU3: Using this product does not (or would not) take much effort on my part.
- PEOU4: I believe the user manuals and other documents are very clear on how to use this product.

Social Influence (SI)

- SI1: Friends and acquaintances would encourage my using this product.
- SI2: Other people who I respect would encourage my using this product.
- SI3: People with authority within organizations (school, business, clubs, etc.) I am involved with would encourage my using this product.
- SI4: My family would encourage my using this product.

Supportability (SUPP)

- SUPP1: I know many people who use the product that could help me if I needed it.
- SUPP2: It would be easy for me to find a lot of documentation for this product.
- SUPP3: I could get training for this product if I needed it.
- SUPP4: It would be easy for me to find user groups, discussion forums, or websites that I could use if I needed help with this product.
- SUPP5: There are vendors of this product that are known for providing a high level of support.
- SUPP6: There are vendors of this product that could quickly resolve any issues or problems I might have.

Serviceability (SERV)

- SERV1: I could easily get this product fixed if it ever failed to function properly.
- SERV2: It would be easy for me to find someone who could fix this product if it ever failed to function properly.
- SERV3: It would be easy for me to find a place to have this product fixed if it ever failed to function properly.
- SERV4: I believe there are vendors of this product that have a retail outlet within easy commuting distance.

- SERV5: I believe there are vendors that offer a variety of maintenance plans such as 1-year, 2-year, and 3-year plans.

Viability (VIAB)

- VIAB1: I believe the main manufacturers of this product will be in business for a long time.
- VIAB2: I believe this product would continue to be supported long after my purchase.
- VIAB3*: I would have a hard time finding a place to have this product fixed if it ever failed to function properly.
- VIAB4*: I believe newer versions of this same product will be made that will make this product quickly obsolete.
- VIAB5: This product has a reputation for being reliable.
- VIAB6*: I believe this product would need to be replaced with a newer version soon after I purchased it.
- VIAB7: I believe this product is available from well-known and established vendors.
- VIAB8*: I believe most vendors who supply this product are new and unproven.
- VIAB9: I believe the industry standards that this product needs to operate will be used for a long time.

Extensibility (EXTEN)

- EXTEN1: I believe there are a large number of accessories related to this product that I could use.
- EXTEN2: I believe this product integrates well with other products I have.
- EXTEN3: I could add accessories or services to this product to make it more useful to me.
- EXTEN4: I believe there are other separate products available that could make this product more useful.
- EXTEN5: I believe there are many vendors of this product that have a reputation for consistently adding features to their products.
- EXTEN6: I believe there are industry-wide standards for connecting this product to other products or accessories.

Affordability (AFF)

- AFF1: I could buy this product with funds I have available (or I did buy it with funds I have available).
- AFF2*: I would need credit to buy this product (or I did buy it on credit).
- AFF3*: If I purchased this device on credit, I would have higher debt than I am comfortable with.
- AFF4*: The product's purchase price likely exceeds my budget.
- AFF5*: The maintenance plans offered with this product would likely exceed my budget.

Monetary Value (MV)

- MV1: I believe this product would generally offer a good value for the money.
- MV2: I believe that at the current prices, this product would generally provide a good value.
- MV3: I believe the maintenance plans for this product generally offer a good value for the money.
- MV4*: The maintenance plans usually appear to be designed simply for the vendor to make money.
- MV5: I expect that this product is reasonably priced.

Intention (I)

- I1: I intend to use or continue to use this product during the next year.
- I2: I anticipate that I will use or continue to use this product during the next year.
- I3: I intend to apply or continue to apply this product in my work or school during the next year.
- I4: I anticipate that I will use this product more than I do right now during the next year.
- I5: I intend to apply or continue to apply this product for entertainment during the next year.

Notes: All items marked by * are reverse coded; all items were measured on a 7-point Likert scale.

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DECISION SCIENCES INSTITUTE

A Review of Adoption Theories for Health Information Systems and Implications for Systems Requirements

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ABSTRACT

Acceptance of healthcare information systems is largely determined by the functionality provided by the systems. Hence, it is important to identify the basic functional requirements that affect acceptance. In this study, articles related to information systems adoption theories and healthcare information systems are reviewed to determine these basic requirements.

KEYWORDS: Health Information Systems, Health Information Technology, Adoption, Acceptance, IS Success Model

INTRODUCTION

The hospital information system (HIS) is defined as the socio-technical subsystem of a hospital, comprising all information processing systems as well as the associated human or technical actors in their respective information-processing roles (Haux et al., 2003).

Information systems are used across different areas of healthcare such as in hospitals, telemedicine, etc. Electronic healthcare record (EHR) systems have largely replaced the paper-based record keeping of patients' history. They offer advantages ranging from integration of different tools (e.g. electronic prescription, decision support systems, emergency information...), to increasing efficiency, and securing access to healthcare information. Prior literature has elaborated on advantages of using these systems. While developing these systems, it is important to understand the factors that influence their acceptance and adoption. Two theories, namely technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT) are widely used to determine factors influencing acceptance of technology.

Requirements in terms of system functionalities vary based upon end users. The research-based literature identifies factors such as costs, efficiency, efficacy, IS theories, model designed specific for a healthcare organization, and so on, that influence the acceptance and adoption of such systems by physicians, pharmacists, nurses, emergency rooms, etc. To our knowledge, no published study has investigated how IS theories such as TAM, UTAUT, and IS Success Model translate into system requirements for healthcare and its impact on their acceptance and adoption.

The objective of this study is to identify the basic requirements for health IS that impact the adoption and acceptance of these systems, based upon established adoption and success theories specifically the technology acceptance model (TAM), the unified theory of acceptance and utilization of technology (UTAUT), and DeLone and McLean's IS success model. This

review will be useful to researchers for advancing the application of other adoption theories and determining their usefulness in assessing adoption of healthcare systems.

The rest of this article is structured as: Firstly, we describe the published adoption and success theories used in our study, followed by a description of our research approach used for selecting and reviewing relevant published studies. The next section presents the reviews of the selected articles, followed by a discussion of the results and concluding remarks.

Overview of IS Theories

Technology Acceptance Model (TAM)

TAM has been applied in various samples of users and information technologies such as computers, business process applications, communication and collaboration systems, system software, worldwide web/internet, and healthcare applications (Aggelidis & Chatzoglou, 2009). It explains the motivation of users using these constructs – perceived usefulness and perceived ease of use.

Table 1: TAM Definition of Constructs (Davis, 1989)	
CONSTRUCT	DEFINITION
Perceived usefulness	The degree to which a person believes that using a particular system or technology would enhance his or her job performance.
Perceived ease of use	The degree to which a person believes that using a particular system or technology would be free of undue effort.

Social influence on adoption of information technology has not been considered as a construct in this model, which is applicable beyond the workplace (Taherdoost, 2018).

Unified Theory of Acceptance and Use of Technology (UTAUT)

UTAUT compares the similarities and dissimilarities among 8 models – technology acceptance model (TAM), theory of planned behavior (TPB), combined TAM and TPB, model of personal computer utilization, motivational model, diffusion of innovation, theory of reasoned action, and social cognitive theory (Khalifa & Alswailem, 2015). It has been derived by modifying the 14 constructs from these 8 models, of which the constructs effort expectancy, performance expectancy, social influence and facilitating conditions have been found to be significant. It includes 4 moderating variables – gender, age, experience, and voluntariness of use (Taherdoost, 2018; Venkatesh et al., 2003).

Table 2: UTAUT Definition of Constructs (Venkatesh et al., 2003)	
CONSTRUCT	DEFINITION
Effort Expectancy	The degree of ease associated with the use of the system.
Performance Expectancy	The degree to which an individual believes that using the system will help him or her to attain gains in job performance.
Social Influence	The extent to which the individuals believe that important others believe that he or she should use the new system.
Conditions	Technical infrastructure to support use of the system.

IS Success Model (ISM)

Based upon the literature review of empirical research articles published in 1981-1987, DeLone & McLean (1992) identified six constructs in their IS success model for determining the success of information systems.

Table 3: ISM Definition of Constructs (DeLone & McLean, 1992)

CONSTRUCT	DEFINITION
System quality	The desirable characteristics of an information system.
Information quality	The quality of information a system produces; characteristics that attribute to quality of information are timeliness, accuracy and meaningfulness.
Use	The interaction of information product with its recipients.
User satisfaction	The users are the decision makers.
Individual impact	The influence an information product has on management decisions.
Organizational impact	The effect of the information product on organizational performance.

Note: In the ten-year updated model, DeLone and McLean (2003) included service quality and net benefits as additional constructs.

METHODOLOGY

We review the literature on health and hospital information systems with respect to adoption and acceptance of the systems by users. We include experimental, non-experimental, and quantitative studies.

Search and Selection Strategy

In addition to the AIS "basket of eight" (*European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of the Association for Information Systems, Journal of Information Technology, Journal of Management Information Systems, Journal of Strategic Information Systems,* and *MIS Quarterly*), we specifically searched the following journals: *Journal of the American Medical Informatics Association, International Journal of Medical Informatics, Procedia Computer Science, Informatics in Medicine Unlocked, Computers in Human Behavior, Journal of Biomedical Informatics, Computer Standards and Interfaces, The New England Journal of Medicine, and Health Affairs*. We also did a general search, using search terms: health information systems, health information technology, adoption, acceptance, and IS success model. The search was limited to studies published from 2003 to 2018. Commentaries and editorials were considered for background information or discussion, not for the review.

Our initial search resulted in 115 articles. The International Journal of Medical Informatics, and the Journal of the American Medical Informatics Association (JAMIA) had the most articles relevant to our search with 20 each.

Inclusion and Exclusion Criteria

Studies that defined health IT adoption and acceptance as their primary objective and provided detailed information about the methodology were included for the review. Full text articles were

then retrieved and examined so as to determine their appropriateness for the review. The scope of the review was restricted to hospital information systems used by physicians and nurses, as well as emergency operation center information systems, so as to better understand the factors influencing the adoption and acceptance of such systems.

Of the 115 articles found, 29 studies whose primary focus was not adoption and acceptance of Health Information Systems, and had little or no constructs identified in their model were excluded. Furthermore, studies focusing on pharmaceutical information systems, computerized physician order entry systems (CPOE), telehealth, telemedicine, were also excluded from the review. Thus, our review focuses on a final set of only 9 papers out of the initial 115. These are shown in Table 4 below.

Table 4: Articles Reviewed

Article #	YEAR	REFERENCES	JOURNAL
1	2003	Van der Meijden, Tange, Troost, & Hasman	Journal of the American Medical Informatics Association
2	2005	Odhiambo-Otieno	International Journal of Medical Informatics
2	2007	Mantzana, Themistocleous, Irani, & Morabito	European Journal of Information Systems
4	2008	Desroches et al.	New England Journal of Medicine
5	2009	Aggelidis & Chatzoglou	International Journal of Medical Informatics
6	2015	Khalifa & Alswailem	Procedia Computer Science
7	2016	Prasanna & Huggins	Computers in Human Behavior
8	2017	Handayani et al.	International Journal of Medical Informatics
9	2018	Aldosari, Al-Mansour, Aldosari, & Alanazi	Informatics in Medicine Unlocked

REVIEW OF THE SELECTED ARTICLES

Van der Meijden, Tange, Troost, & Hasman (2003)

This study reviewed the English and Dutch literature from 1991-2001 regarding the evaluations of patient care information systems that required data entry by health care professionals. The research objectives were to identify the attributes that were used to assess the success of such systems and to test the ability of the IS Success Model framework. The article distinguishes between objectivist and subjectivist studies so as to provide an overview of the study designs as described by Friedman and Wyatt. Of 1077 articles found initially, 202 were selected for further review. Ultimately, 33 articles were reviewed, describing general systems, including hospital information systems, nursing (bedside) documentation systems, and physician order entry forms (POE), and systems specific to a department, including intensive care unit (ICU) systems and anesthesia recording systems. 14 systems were systems used by only nurses, 5 systems used by only physicians, and 11 systems used by both nurses and physicians. The results found information quality to be evaluated the most, as compared to other constructs of the IS Success model. Furthermore, the findings found that evaluation of the systems finished within six months upon implementation, thus affecting the measurement of its impact on the organization's success. Although, this article focused more upon the evaluation criteria for information

systems, it identified the attributes affecting evaluations of failed initiatives, with system development being one of the attributes.

Odhiambo-Otieno (2005)

Odhiambo-Otieno identified the lack of evaluation criteria for the district health management information systems (DHMISs) in Kenya. The objective of the study was to design evaluation criteria so as to assess viability, sustainability and ultimate contribution of DHMIS in the management of the district health system (DHS) in Kenya. Feedback to the DHS personnel was one of the key reasons for designing such system. But the data collected on a routine basis was insufficient for planning and evaluation of the district level health services. This article focuses only on the evaluation criteria for the information systems, but it identifies the information needed by developers while designing the system and the users' requirements to use the system. No IS theories were used in this article.

Mantzana, Themistocleous, Irani, & Morabito (2007)

This study focused on the importance of actors involved with adoption of healthcare information systems. The objective of this research was to identify and define these actors using a structured approach, the IGOHcaps method. The authors classified the actors as accepters, providers, supporters and controllers. Healthcare actors, in the context of this paper were defined as any human and/or organization that accepts, provides, supports or controls healthcare services. Since single case-study was used for the purpose of evaluation of the instrument, the findings cannot be generalized. However, the study validated the importance of including healthcare actors for making decisions for IS adoption as reported in the literature. The actors were categorized as individual or group, but the issues regarding power, control and legitimacy were not considered, which were found to be highly influential towards both categories. As a result, the authors state that their method not only supports the researchers and managers, but is also useful in understanding the importance and effect of healthcare, identifying the healthcare actors as well as may help increase the adoption of IS in healthcare.

Desroches et al. (2008)

Desroches et al. assessed the adoption of outpatient electronic health records by physicians. The constructs measured were user satisfaction, perceived effect of systems on quality of care, and perceived barriers to adoption. The objective of this study was to develop and test measures of adoption, to deliver survey items that could be used to generate similar data over time on the diffusion of electronic records, and on physician's perceptions of the effect of such systems on their practices. Using a modified Delphi study, the determinants of a fully functional electronic health record system as identified by the investigators included: recording demographic and clinical data of patients viewing and managing lab results; managing order entries, including prescriptions; and supporting clinical decisions. The statistical analysis presented positive results from the responders using fully functional systems, as compared to those using the basic systems. 20% of the physicians with basic systems expressed concerns about ease of use and reliability of their systems.

Aggelidis & Chatzoglou (2009)

Aggelidis and Chatzoglou tested the applicability and effectiveness of technology acceptance models (TAM) within healthcare in Greece and determined the factors influencing the health

personnel's intent of using these systems. A modified TAM was used to determine the constructs in three different contexts – individual (anxiety, self-efficacy, and computer attitude), technological (perceived usefulness, ease of use) and implementation (subjective norms, facilitating conditions, and training). The paper analyzed twenty-three hypotheses using correlation, exploratory and confirmatory factor analysis. The reliability and validity of the measurement model were determined. Facilitating condition was the key influencer for behavioral intention. Sample included only those personnel who were using IS/IT systems to accomplish their tasks, the majority being administrative personnel and only 25% being medical and nursing personnel. The study found that health organizations must create favorable conditions by providing adequate training for motivating the users to use the system. The authors also recommend that management must encourage the staff to adopt and use the system so as to emphasize the importance and utility of technology in performing daily tasks.

Khalifa & Alswailem (2015)

Khalifa and Alswailem evaluated hospital information systems acceptance and satisfaction by exploring influential factors that may impact the acceptance and satisfaction levels among different healthcare professionals. Constructs were measured using the Technology Acceptance Model (TAM). Computer availability in the hospital was one of the most influential factors. The unavailability of laptops and computers on wheels were found to impact the direct and immediate entry of information and retrieval of records at the point of care. The study also found differences in users' perceptions of the systems – less experienced users found it to be less user friendly and difficult to use as compared to the experienced users. The study also determined the basic requirements for such systems, viz. improving software speed, responsiveness, increased availability of computers, laptops and computers on wheels, and screen designs focusing on sequence and logic of functions, tasks, buttons and font size.

Prasanna & Huggins (2016)

Prasanna and Huggins examined the end user acceptance of information system for emergency operations using a model with features integrated from TAM and UTAUT theories. Information quality was an additional independent variable considered in the research model.
Constructs from TAM – perceived usefulness, and perceived ease of use – were replaced with performance expectancy and effort expectancy from the UTAUT model so as to have a broader representation of user behavior. The research assumed that symbolic adoption was dependent on antecedents of performance expectancy, facilitating conditions, ease of use, information quality, and social influence. Prior research using UTAUT model did not consider mediating factors unlike perceived usefulness, which is a mediator in TAM. The study contradicts the assumption *"that facilitating conditions were insignificant amongst high levels of both performance expectancy and effort expectancy"* used in UTAUT model, since it focused on information systems implemented across various physical locations. The study also investigated the impact of age and gender on the relationships between endogenous and exogenous variables with performance expectancy as a mediator. Authors modified two mediating variables from UTAUT model – experience, and voluntariness of use – to experience of using the system and previous emergency operation center information systems (EOCIS).
The analysis put into perspective the importance of considering performance expectancy as a mediator while using UTAUT for EOCIS by identifying a significant mediation effect. Relationship between information quality and performance expectancy was examined. Significant moderation was found to be attributing to system use, gender and age. Thus, older age less than 50 years, and male users had stronger impact on the relationship, while system

experience had weaker impact. Similar results were observed when the same analysis was used for New Zealand, USA and Australia. Social influence was observed to have positive influence on technology acceptance and adoption. Authors also found that technology acceptance theories were fundamentally incomplete since prior research did not consider the mediation effect in both highly specific and generic context.

Handayani et al. (2017)

Handayani et al. developed a model of hospital information system that considered user acceptance based on human, technological and organizational characteristics to support government eHealth programs. The study used both qualitative and quantitative approaches with case studies for seven hospitals – three general hospitals and four private hospitals. The objective was to determine the obstacles faced by hospitals in Indonesia by identifying suitable user acceptance model based upon user groups in each hospital type. Authors modified TAM model by adding three constructs – human, technology, and organizational characteristics. Measures for these constructs were: human (user self-efficacy, compatibility, information security expectancy, and social influence), technology (information quality, system quality) and organization (management support, facilitating conditions, and user involvement on HIS implementation). The analysis indicated insignificant effect of self-efficacy, information quality and user involvement on perceived usefulness. Social influence was found to have no impact on perceived ease of use and perceived usefulness. Human, technological and organizational constructs were found to influence the acceptance of these systems. System quality and perceived usefulness did not have significant influence.

Aldosari, Al-Mansour, Aldosari, & Alanazi (2018)

In this study, the acceptance level of electronic medical records by the nursing staff was investigated, using TAM model. The study examined the factors impacting the nursing staff's attitude towards implementation and use of electronic medical records. Constructs used in the model were user demographics, top management, IT support, system quality, perceived ease of use, and perceived usefulness. User demographic characteristics, top management, IT support, and system quality were important factors to predict acceptance of EMR by nurses. Intention to use and user satisfaction had a positive impact on system acceptance. To increase the system acceptance, authors recommended full training courses for those nurses who had no formal training on using the system.

DISCUSSION

The aim of this study was to identify the key system requirements that impact the acceptance and adoption of health information systems, based on a review of the relevant literature. Table 5 below provides a summary of the findings from the articles reviewed.

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Table 5: Summary of Findings				
#	CITATION	FINDINGS	IS MODEL USED	TYPE OF STUDY
1	Van der Meijden, Tange, Troost, & Hasman (2003)	Information quality evaluated the most as compared to system and service quality constructs. Article identified system development as one of the indicators that affected evaluations of failed initiatives.	IS Success Model	Literature Review
2	Odhiambo-Otieno (2005)	Identified information needed by system developers for designing the system and users' requirements to using the system. Study results indicated the lack of evaluation criteria in design stage. Focus group which consisted of IS designers and users identified the items that must be addressed during evaluation. Authors recommend including pre-, concurrent, and post-implementation criteria to be used before, during and at the end of implementation stage for assessing the system's viability and ultimate contribution towards DHS (District Health Systems).	None	Case study
3	Mantzana, Themistocleous, Irani, & Morabito (2007)	Proposed IGOHcaps method is useful in understanding the importance and effect of healthcare, identifying the healthcare actors as well as in possibly increasing the adoption of IS in healthcare.	None	Case study
4	Desroches et al. (2008)	Recording demographic and clinical data of patients, viewing and managing lab results, managing order entries including prescriptions, and supporting clinical decisions – determinants of fully functional health record system. Research analysis shows positive results for fully functional systems as compared to the basic systems.		Modified Delphi study
5	Aggelidis & Chatzoglou (2009)	Sample for analysis consisted of personnel using IS/IT systems for accomplishing tasks, mostly administrative and only 25% were medical and nursing personnel. Given the three constructs – individual, technological, and implementation studied, facilitating condition (implementation construct) was identified as the important factor. It was then determined from this study that health organizations must create favorable conditions for training system users so as to emphasize on the importance and utility of technology in performing daily tasks.	Modified TAM	Case study

6	Khalifa & Alswailem (2015)	This study about determining influential factors impacting the acceptance of hospital information systems amongst healthcare professionals identified improving software speed, increased availability of computers, laptops & computers on wheels, screen designs focusing on sequence and logic of functions, tasks, buttons, and font size as the 'basic requirements' for these systems.	TAM	Case study
7	Prasanna & Huggins (2016)	This study analyzed the user acceptance of IS for emergency operations using TAM and UTAUT theories. The integrated research model consisted of mediating variables which were not considered in prior research, suggesting that "to facilitate end-users' acceptance throughout an implementation process, an implementation team should consider the different needs of end-users alongside relevant behavioral implications."	TAM, UTAUT	Case study
8	Handyani et al. (2017)	Human, technological and organizational constructs were found to influence the acceptance of these systems. System quality and perceived usefulness did not have significant influence.	Modified TAM	Case study
9	Aldosari, Al-Mansour, Aldosari, & Alanazi (2018)	User demographic characteristics, top management, IT support, and system quality were important factors to predict acceptance of EMR by nurses. Intention to use and user satisfaction had a positive impact on system acceptance. To increase the system acceptance, authors recommended full training courses for those nurses who had no formal training about using the system.	TAM	Case study

This review resulted in determining the basic system requirements such as screen designs that focus on sequence and logic of functions, buttons, software speed, system responsiveness, high availability of computers, providing adequate training and IT support to end users in hospital and healthcare scenarios. Prasanna & Huggins (2016) determined the impact of gender and age on the end user's acceptance of emergency operation systems. Authors recommend considering these variables while designing similar studies. Handayani et al. (2017) determined factors impacting perceived ease of use and perceived usefulness on the acceptance of healthcare information systems. Aldosari et al. (2018) studied the factors impacting acceptance of electronic medical records for nursing staff. Upon surveying the nursing staff, it was determined that lack of adequate training to use these systems influenced the acceptance and adoption of these systems in addition to system quality, demographic characteristics and IT support.

LIMITATIONS AND FUTURE RESEARCH

The review considered only three IS theories – TAM, UTAUT, and IS success Model for studying the acceptance and adoption of health and hospital information systems as each of

these models keep into consideration different constructs that measure usefulness and quality of systems, service, and information. TAM does not consider other variables that impact perceived ease of use and perceived usefulness constructs. Some studies reviewed had modified TAM to study the impact of such variables.

Our study considered only physicians, nursing staff and emergency operators as the end-users. This was done so as to control the scope of our study. Also, the literature lacks a general definition for health information systems, rather definitions used are specific to research studies, and their findings cannot be generalized.

Future studies may consider multiple IS adoption and acceptance theories in the context of pharmacists, owners and managers of hospitals, and consulting doctors. DeLone and McLean's IS success model has system quality, information quality and service quality as key constructs that influence users to using the system and also determines the net benefits from using the system. Future studies may conceive a new model that includes constructs from the IS success model with respect to other mediating and moderating variables, to better understand the acceptance and adoption of the systems.

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DECISION SCIENCES INSTITUTE
A Study of Informal Efficiency in the Acquisitions of Mobile Applications

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ABSTRACT

Facebook acquired WhatsApp in 2014 for $ 19 billion. Besides the substantial value of the purchase, another instigative fact was the growing performance of the Facebook's stock in relation to the S & P500 on that date. This could support a relationship between announcements of buying apps and market reaction. This paper aims to verify if the acquisition of mobile apps generates abnormal returns in the stock prices of IT companies. We developed an event study analyzing daily and cumulative abnormal returns. The results were sufficient to affirm that the announcement of acquisitions of mobile applications impacted the company value.

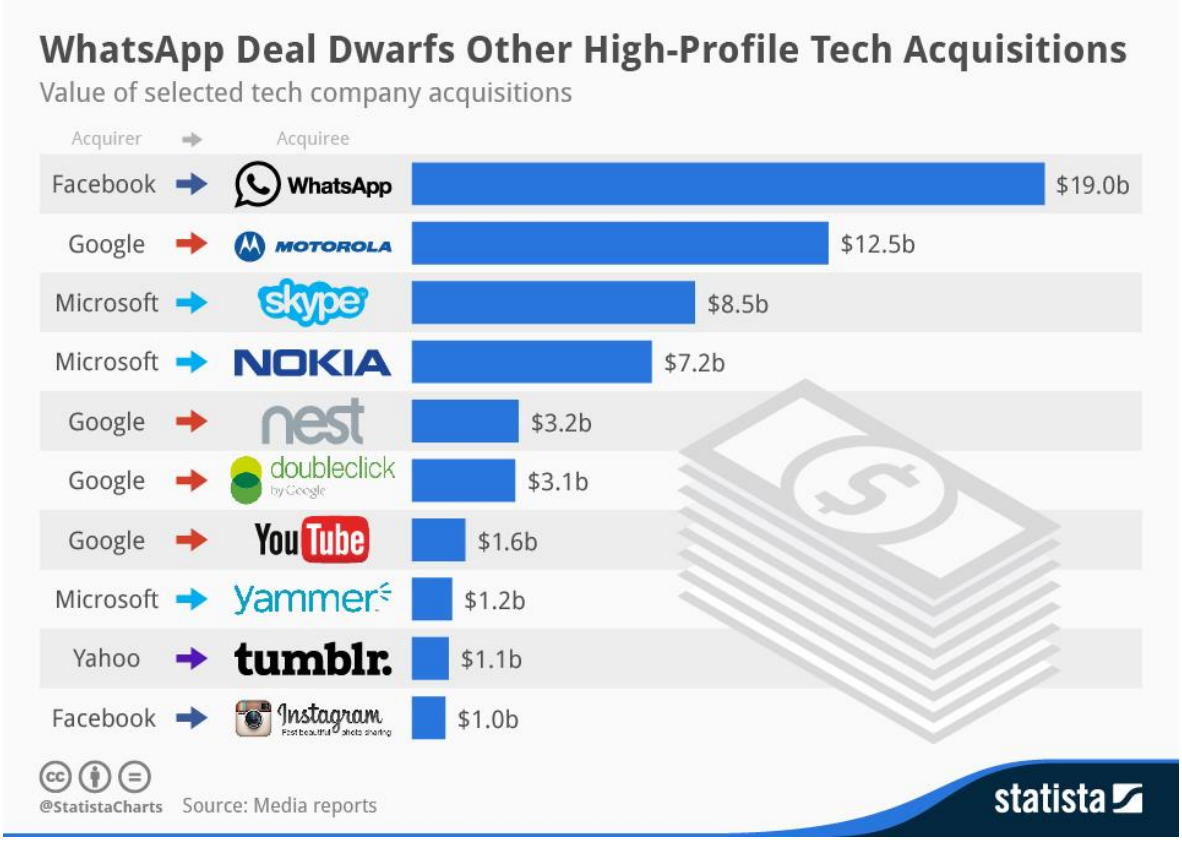
KEYWORDS: Event Study, Mergers & Acquisitions, IT firms, App Mobile.

INTRODUCTION

On February the 19th in 2014 the WhatsApp, the instant messaging service, was acquired by Facebook for $ 19 billion, approximately. This acquisition was reported by leading newspapers around the world. "JPMorgan analysts said the price tag seemed high, but added that mobile messaging was a "crucial part of the social network's core mission of 'connecting the world'" (KUCHLER; BRANDSHAW, 2014). In the following days many comments like this have been published. By 2014, the major indexes, Dow Jones and Nasdaq, as well as the Nasdaq Stock Market (NASDAQ) and the S & P500 had declined (NASDAQ, 2014). Despite the situation in the financial market and comments about the acquisition, Facebook shares registered growth.
The importance of the IT sector to the economy is growing every day, which raises the relevance of a more in-depth study of the sector. According to the PWC's report of Global Top 100 companies in 2016 "technology has overtaken Financials to become the largest sector in terms of market cap ($2,993bn)." (PWC, 2016)
To analyze the impact of this kind of acquisition, it must be remembered of the concept of efficient capital market, according to Ross, Westerfield and Jaffe (2002, p.298) tells us that "in this type of market, the information processed immediately is immediately incorporated into the stock price." The efficient markets hypothesis (EMH) assumes that the stock price reflects all available information (Fama, 1970). Therefore, according to signalization theory, investor can respond to announcements through buying shares, if they see potential or improvement (Asquith e Mullins, 1986). Thus, it is reasonable to think that the announcement of the

acquisition of an essential asset to the development of the company's main activity will change the market value of the company.
As pointed by Qin, Tang, Jang, & Lehto (2017) “the academia is starting to research on issues related to mobile channels.” Also, “studies that evaluate the impacts of mobile distribution are generally scarce”. In response of this, the present research aims to add new findings of this study area. There are some evidences that could support a relationship between announcements of buying an app and market reaction. As tells Kuchler and Brandshaw (2014) "Facebook’s shares fell as much as 3 per cent in after-hours trading after closing at $68.06 in regular hours trading in New York".
Another justify to the study of acquisition on technologies market is the volume that it has been negotiated. It can be seen up down in accord to Richter, 2014 study:

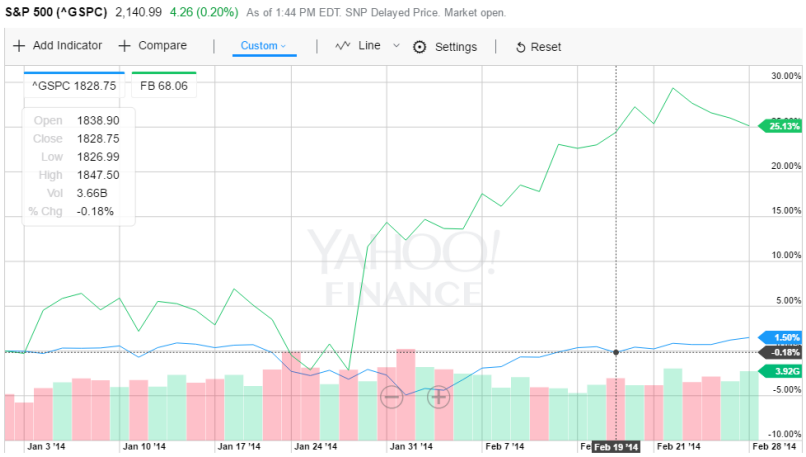
Figure 1: Value of selected tech company acquisitions



Richter (2014)

As mentioned earlier, Facebook acquired WhatsApp in 2014 for $ 19 billion. Besides the monetary representativeness of the purchase, another factor that draws attention is the performance of the action of Facebook in relation to the S & P500 on that date, as highlighted in Figure 2.

Figure 2: Facebook and S&P500’s Stock Quotes



Yahoo Finance (2016)

As can be seen in Figure 2, Facebook's share performance was higher than the US index (S & P500). This fact suggests that the company could create value higher than expected by market levels. According to the literature, intangible assets have played a key role in generating unexpected returns. In this sense, this research seeks to contribute to the discussion regarding the representativeness of intangible assets in the value of organizations.
Furthermore, technological intangible assets are the main asset of technology companies, thus, it is believed that the acquisition of a new app could impact on the byer company's share.
This paper aims to verify if the acquisition of mobile applications generates abnormal returns in the stock prices of technology companies listed on the Nasdaq Stock Market (NASDAQ) buyers. So, it is expected that the acquisition of these assets generates expectations of future value generation, thereby increasing their visibility and negotiability of the securities. Using traditional event-study methodology, this research aim to provide a financial market-based analysis of the impact of acquisition of mobile applications on the market value of buyer firms.

LITERATURE REVIEW

In this section, we discuss the idea of what is Mobile Apps, and how it could be recognized on mergers and acquisitions. Then, we review the theoretical development around efficient markets hypothesis (EMH).

Literature Review of Mobile Apps

Mobile Apps, or as they are popularly known, Apps are extensions that perform specific functions on mobile devices, such as smartphones, and are targeted at the end user (APPLE, 2015). As follows, they meet all criteria for being classified as intangible assets.

> intangibles have several particular characteristics that distinguish them from tangible assets and demand that intangibles be treated differently from tangibles. Three of these supposed distinguishing characteristics are said to be alternative uses, lack of separability, and great uncertainty of recoverability. (HENDRIKSEN and VAN BREDA, 1992, p.635)

There are many ways that Mobile App could improve shareholder value. The recent study by Qin, Tang, Jang, & Lehto (2017) enumerate five: “(1) accessing the booming Millennial market, (2) improving operating efficiency, (3) creating revenue opportunities, (4) reducing distribution cost, and (5) fostering customer loyalty and brand recognition”.

Literature Review of efficient markets hypothesis (EMH)

Hendriksen and Van Breda (1992, p.207) said about agency theory that “principals will always be interested in the outcomes generated by their agents, agency theory provides the underpinning for an important role for accounting in providing information after an event: a so called *postdecisorial* role.”

Fama (1970) states that the capital market is efficient in relation to information, in other words, all information is contained in the share price. This maxim expresses the following implications. First, business managers fail to create value by deceiving investors. Second, investors who use the information the market has should not expect abnormal returns on their investment.

There are three distinct types of efficiency, according to Fama (1991): weak form, the semi-strong form, and the strong form. Efficiency in the weak form assumes that only the set of information contained in the past prices is reflected in the stock price. This translates into some trends from investors who believe in price-value trends, such as head and shoulders. The semi-strong form of efficiency, most likely, indicates that in addition to past price information, the stock price immediately incorporates all available information. This theory is more reasonable since it requires time and knowledge for the analysis of an investment. Strong form of efficiency is considered by many to be utopian, since it assumes that all information, available or not, is immediately incorporated into the price.

Some evidence may suggest from the degree of efficiency of a market. The serial correlation, if there is, indicates a weak form, if it is zero, it can be said that it is a semi-strong form. (Ross, Westerfield, and Jaffe, 2002) Event analysis can prove that a market is semi-strong form when calculating the abnormal return on investments because it analyzes the impact of a disclosure on share price. If the performance of mutual funds is not divergent from common investors, it is also possible to evidence a semi-strong form.

In that way, this research aim to provide a financial market-based analysis of the impact of acquisition of mobile applications on the market value of buyer firms. It was considered a semi-strong form of efficiency.

Previous Studies of Market Reaction over acquisitions and new products

Several studies have already tried to relate market reactions to events that occurred in companies. Following are some studies that, using the methodology of study of events, aimed at demonstrating the creation or destruction of value due to acquisitions or the launching of new products.

Table 1: Previous Studies of Market Reaction			
Author	**Sample Size & Description**	**Sample Period**	**Returns to Acquiring Firm Shareholders**
(Pau Chaney, Devinney, & Winer, 1991)	1,101 announcements of new products and concepts Announced by 231 firms	1975-1984	0.75% over a 3-day period.
(P. Chaney & Dervinney, 1992)	1481 announcements of new products by 263 firms were usable for the empirical analysis	1975-1988	0.60 % over a three-day period centered on the product announcement date.
(Uhlenbruck , Klaus; Hitt, Michael A.; Semadeni, 2006)	1,029 acquisition of online firms by offline firms events	1995-2001	Positive abnormal return on the day of the announcement of 0.93 % for acquisitions of online firms by offline firms
(Sorescu, Shankar, & Kushwaha, 2007)	419 new product preannouncements	1984-2000	Approximately 13% during the one year after the preannouncement or up to introduction, whichever comes first
(Qin et al., 2017)	27 announcements of the mobile application of hotel and airline companies	2009-2011	On average, hotel companies and airlines that introduced mobile apps experienced a gain of 1.32% in abnormal returns on the event day
(Lee & Chen, 2009)	409 new product announcements	1990-1998	On average, the daily excess returns, 3.96% one day before and 1.02 % in the event day.
(Sood & Tellis, 2009)	5,481 announcements related to innovation projects	1977-2006	Average return for any event is 0.6%

These previously studies are evidence that market could react from acquisitions of mobile applications. Following, we present the empirical hypothesis, the methodology, the empirical results and, finally, the discussion and conclusions of this study.

HYPOTHESE

H1: The acquisition of mobile applications generates positive abnormal returns in the stock prices of technology companies listed on the Nasdaq Stock Market (NASDAQ) buyers.

METHODS

This study aims to verify if the acquisition of mobile applications generates abnormal returns in the stock prices of technology companies listed on the Nasdaq Stock Market (NASDAQ) buyers.

Data description

We analyze the Mergers and Aquisitions (M&A) listed on database from Bloomberg, we searched for all M&A from IT firms and Mobile Application. There is no sector defined as Mobile Application, so, to find our population we searched for M&A from IT firms listed on NASDAQ (buyers) and firms or assets categorized as Internet-Software. Also, we selected only M&A with the status of negotiation as completed. After this selection, our population had 823 events. We excluded the M&A which has as buyer multiple acquires (173), shareholders (12) and unnamed buyer (5), after this filter, our sample become with 633 announcements.

This research presents a positivist approach, since it seeks to test the presented hypotheses. The study's characterization in relation to the objective is descriptive-explanatory. Regarding the research problem, the approach is characterized as quantitative. In the present study it is proposed to carry out a research that will allow the ex post facto analysis.

The population of this study consists of technology companies listed on the Nasdaq Stock Market (NASDAQ). For the analysis of the data, the technique of descriptive statistics will be used initially, and then the technique of the event study will be used. In according to Elton and Guber (1995, p.426) who defend that event studies are used to “determine what information is reflected in price and, if its impact is unclear, to determine whether the announcement is good or bad news.”

The benchmark used to calculate abnormal returns is the S&P 500 Index, which includes all companies publicly traded in Nasdaq Stock Market (NASDAQ). These steps limited the number of studied announcements to a final sample of 52 announcements of 35 buyer firms. The complete list of announcements is displayed on appendix.

Table 2: Descriptive statistics of the sample

Panel A: Countries of the sample

Country	**Occurrences (%)**
USA	77%
CANADA	6%
ISRAEL	6%
CHINA	6%
JAPAN	6%

Panel B: Sample buyer firms statistics at the end of the fiscal year of the announcement

Market Value (in millions)	**Total assets (in millions)**	**Revenue (in millions)**	**Net Income (in millions)**	**Transaction Value (in millions)**
Mean	413,121.21	260,433.70	6,056.52	806.81
Median	974,05	486.05	12.60	73.89
Std Deviation	2,010,771.24	1,229,634.47	19,074.79	2,921.21

We found on Bloomberg the date of the announcement, and designated these dates as date zero. The window panel selected was 5 days before and after the announcement. For each of the announcements in the sample, we calculated the return for the buyer firm on each of the days being studied. In sequence, we computed the abnormal return for each of the days being studied for each company in the sample. So, we computed for each day in the event period the average abnormal return for all the firms in the sample.

This study considered the event window begins in March, 27th 2000 and ends in September 20th 2016. We calculate the daily asset return (R_i) and the daily market return (R_{mt}) as fallows:

$$R_i = LN(P_t/P_t\text{-}1) \quad (1)$$
$$R_{mt} = LN(C_t/C_{t-1}) \quad (2)$$

P_t = share price at time t; P_{t-1}= share price at time t-1; C_t= quotation of the Market Portfolio at time t (S&P 500); C_{t-1}= quotation of the Market Portfolio at time t-1 (S&P 500); and LN represents the logarithmic form used to determine the daily returns.

In the sequence, the estimation window analyzed was about 152 before the 5th day before the event. The estimation of expected return occurred besides the application of the method Ordinary Least Squares (OLS) in the form of a simple linear regression commonly called Market Model, which is demonstrate below:

$$R_i = \alpha_i + \beta_i R_{mt} + \varepsilon_i \quad (3)$$

α = parameter estimated from the OLS application, it represents the intercept that, operationally, is the mean difference between the dependent variable (R_i) and the independent variable (R_m), the latter being associated with the slope estimation of the linear model; β = parameter estimated from the OLS application, it is the ratio between the covariance between the observed daily returns (of the stock and the market) and the variance of the daily returns of the market.

The expected daily return would be generated by the estimated parameters (α and β) and by the market daily return on the estimation window. We calculate the expected daily returns ($E(R_i \mid R_m)$) as follows:

$$E(R_i \mid R_m) = \alpha_i + \beta_i R_{mt} \quad (4)$$

Then, we calculate the difference between observed daily returns (R_i) and the expected daily returns ($E(R_i \mid R_m)$). The result is the abnormal daily returns (AR_i):

$$AR_i = LN(P_t/P_{t-1}) - E(R_i \mid R_m) \quad (5)$$

or

$$AR_i = LN(P_t/P_{t-1}) - (\alpha_i + \beta_i R_{mt}) \quad (6)$$

The abnormal daily returns (AR_i) represents the exceed of return in relation to the expected daily return. It can be positive or negative. In this study, we calculate the abnormal daily returns (AR_i) for 11 days on our event window. The event window encompasses the 5 days before the event (5B;4B;3B;2B;1B), the event's day and the 5 days after the event (5A;4A;3A;2A;1A).

After that, we calculate the cumulative abnormal returns (CAR_i), which is the sum of the abnormal returns.

$$CAR_{i\,(t1,\,t2)} = \sum_{t=t_1}^{t_2} AR_i \quad (7)$$

t_1=first day of analysis; t_2=last day of analysis

This study aims to verify if the acquisition of mobile applications generates abnormal returns in the stock prices of technology companies listed on the Nasdaq Stock Market (NASDAQ) buyers, so for the hypothesis test we considerate the null hypothesis bellow:

Null Hypothesis (H0): $AR_i \geqslant 0$

Null Hypothesis (H0): $CAR_i \geqslant 0$

The ordinary t-statistic is calculated as follows:

$$t = AR_i / \sigma(AR_i) / \sqrt{n} \quad (8)$$

$\sigma(AR_i)$ =the cross-sectional abnormal return sample standard deviation.

Empirical Results

In this section, we analyze the short-term effects of an acquisition announcement on stock prices.

Table 3: Regression's standard error for each of sample which present significant abnormal return

Date	Ticket Buyer	Regression's standard error
27/03/2000	LBTE	0.088808166
09/08/2000	GEC	0.078894463
05/09/2000	NTAP	0.061838551
21/03/2001	DRIV	0.076574529
17/07/2001	INKT	0.096080921
16/12/2004	0772374D	0.016413772
27/09/2005	ENGH	0.017678379
02/11/2006	ORCL	0.014469937
01/05/2007	1015837D	0.032834005
03/05/2007	ESIC	0.037009669
05/10/2009	KITDQ	0.031349644
16/07/2010	CALL	0.036750073
02/11/2010	ORCL	0.012502044
08/11/2010	INSG	0.024324281
01/02/2011	MS	0.014603826
24/02/2011	VOCS	0.025528945
24/02/2012	VOCS	0.026425271

08/11/2012	PERI	0.021802441
13/12/2012	ORCL	0.00907841
03/07/2013	YHOO	0.012988963
16/09/2013	PERI	0.033149639
14/10/2013	FB	0.028764143
19/12/2013	TRAK	0.016696116
15/04/2014	BV	0.036696725
10/11/2014	LIOX	0.027374154
30/09/2015	FB	0.012534801
01/12/2015	PERI	0.024925447

From this table 3 with the following tables, we are able to calculate the *t* and, then, calculate the significance of the abnormal daily returns.

Table 4: Results of the daily abnormal returns for the assets which present significant abnormal return

Ticket Buyer ORD	**5B**	**4B**	**3B**	**2B**	**1B**	**Event**	**1A**	**2[a]**	**3[a]**	**4A**	**5A**
LBTE[1]	-0.10	-0.10	0.12	-0.02	-0.02	-0.07	-0.07	0.03	-0.04	-0.16a	-0.12
GEC[2]	0.02	-0.04	-0.03	-0.04	0.00	0.17b	0.13a	-0.14a	-0.06	0.00	-0.00
NTAP[3]	0.01	0.06	0.03	0.02	-0.02	-0.00	-0.08	0.11a	-0.01	-0.02	-0.00
DRIV[7]	-0.00	0.08	-0.02	-0.07	-0.01	0.00	0.18b	-0.07	-0.05	-0.08	0.03
INKT[9]	-0.01	-0.10	0.07	-0.07	-0.01	-0.05	-0.21b	-0.14	0.08	0.14	0.06
077237 4D[10]	-0.00	0.02	-0.02	-0.01	-0.00	-0.01	0.03b	-0.01	-0.01	-0.01	0.01
ENGH 13	-0.01	0.00	0.03	0.00	-0.01	0.04b	0.05c	0.00	-0.02	0.04b	-0.04b
ORCL 15	-0.00	-0.03a	0.02	-0.00	0.01	-0.01	-0.03a	0.01	0.00	0.01	0.01
101583 7D[18]	0.00	-0.03	0.01	-0.00	-0.01	-0.00	0.04	0.05	0.03	-0.06a	-0.01
ESIC[19]	-0.02	-0.00	-0.01	-0.00	-0.02	0.03	0.06a	0.05	-0.01	0.03	0.02
KITDQ 20	0.04	0.04	-0.02	0.04	0.01	-0.08b	0.15c	0.02	-0.04	0.04	-0.02
CALL[21]	0.06	0.08b	-0.00	-0.08b	0.00	0.93c	-0.17c	0.03	0.13c	-0.04	0.12c
ORCL 24	-0.01	0.00	0.02a	0.00	-0.01	0.01	-0.02	-0.01	-0.01	-0.01	-0.00
INSG[25]	0.06b	-0.00	-0.04	-0.03	-0.07c	0.02	-0.01	0.00	-0.01	-0.03	-0.03
MS[26]	-0.01	-0.02	0.03a	-0.00	0.00	-0.00	-0.01	0.00	-0.00	0.01	0.00
VOCS 27	-0.01	-0.03	-0.06b	0.01	-0.00	0.02	-0.00	-0.02	-0.00	0.01	-0.01
VOCS 31	-0.03	0.01	-0.03	-0.01	0.03	-0.03	0.01	-0.02	-0.5c	-0.02	0.02

PERI[34]	0.03	0.02	0.01	0.01	-0.03	0.15c	-0.03	0.05b	-0.01	-0.01	-0.02
ORCL[35]	-0.00	-0.01	0.00	0.00	-0.01	-0.00	0.01a	-0.00	0.00	0.04c	-0.01
YHOO[36]	0.00	0.00	-0.01	-0.00	-0.01	0.02a	-0.01	-0.01	0.03c	-0.01	0.00
PERI[38]	0.06a	-0.02	-0.00	0.00	0.03	-0.12c	0.05	-0.00	0.03	-0.01	-0.01
FB[39]	-0.01	-0.06b	-0.01	0.03	-0.01	0.00	0.00	0.02	0.01	0.03	-0.01
TRAK[40]	-0.01	-0.02	0.00	0.01	-0.01	-0.01	0.11c	-0.02	0.00	-0.01	-0.01
BV[42]	0.01	0.077b	-0.04	0.00	-0.01	-0.01	-0.01	0.00	-0.00	0.01	-0.03
LIOX[45]	-0.02	0.02	-0.01	0.01	-0.02	0.15c	-0.02	0.00	-0.03	0.00	-0.05b
FB[47]	0.01	0.01	-0.02	-0.01	-0.03b	0.01	0.01	-0.01	-0.00	-0.01	-0.02
PERI[48]	0.07c	0.12c	0.09c	-0.04	-0.00	0.00	0.02	0.02	0.05a	0.09c	0.11c

a= significance level of 10%
b= significance level of 5%
c= significance level of 1%

As could be seen, the ticker PERI[48] had a significant (level of 1%) abnormal daily return on the 5th, 4th and 3th day before the event also on the 4th and 5th day after de event. The ticker INSG[25] had a significant (level of 1%) abnormal daily return on the day before the event. On the event day, tickers CALL[21], PERI[34], PERI[38] and LIOX[45] had a significant (level of 1%) abnormal daily return. Also, the tickers PERI[38] and KITQ[20] presented negative and significant abnormal return, on the date of the announcement, which means rejects the null hypothesis. Four tickers had a significant (level of 1%) abnormal daily return on the first date after the event.

Briefly, on the event day, only 8 companies presented significant abnormal return, being 6 positive and 2 negative. Over the 5 days after through 27 analyzed events, in 26 days was there an significant abnormal return, in other words, in 19,25% of the days had significant abnormal returns. About the 5 days before the announcement, only 13 days had significant abnormal returns.

Next, we calculate de accumulated abnormal returns (CARi) until the event day, as presented in table 5:

Table 5: Cumulative abnormal returns (CARi)

Ticket Buyer	**[-5;0]**	**[-4;0]**	**[-3;0]**	**[-2;0]**	**[-1;0]**
LBTE[1]	-0.186b	-0.085	0.011	-0.108	-0.092
GEC[2]	0.090	0.073	0.111	0.138b	0.175a
NTAP[3]	0.092	0.079	0.024	-0.005	-0.023
DRIV[7]	-0.024	-0.020	-0.096	-0.073	-0.004
INKT[9]	-0.177	-0.167	-0.065	-0.136	-0.066
0772374D[10]	-0.023	-0.019	-0.036b	-0.021	-0.011
ENGH[13]	0.064c	0.070c	0.066c	0.040b	0.039b
ORCL[15]	-0.019	-0.017	0.010	-0.011	-0.007

1015837D[18]	-0.026	-0.030	-0.002	-0.009	-0.007
ESIC[19]	-0.021	-0.003	-0.002	0.005	0.009
KITDQ[20]	0.031	-0.007	-0.043	-0.023	-0.065b
CALL[21]	0.992c	0.937c	0.854c	0.856c	0.933c
ORCL[24]	0.014	0.022a	0.017	-0.004	-0.004
INSG[25]	-0.069c	-0.124c	-0.123c	-0.084c	-0.054b
MS[26]	-0.009	0.005	0.021	-0.005	-0.001
VOCS[27]	-0.071c	-0.065b	-0.034	0.024	0.015
VOCS[31]	-0.056b	-0.030	-0.039	-0.006	0.007
PERI[34]	0.194c	0.163c	0.144c	0.137c	0.123c
ORCL[35]	-0.024c	-0.021b	-0.013	-0.017	-0.017
YHOO[36]	0.001	-0.001	-0.001	0.009	0.011
PERI[38]	-0.062	-0.119c	-0.096c	-0.093c	-0.094c
FB[39]	-0.060b	-0.052	0.011	0.023	-0.005
TRAK[40]	-0.020	-0.015	0.000	-0.004	-0.010
BV[42]	0.032	0.019	-0.058	-0.015	-0.017
LIOX[45]	0.139c	0.157c	0.140c	0.145c	0.138c
FB[47]	-0.032b	-0.043c	-0.049c	-0.030b	-0.018
PERI[48]	0.243c	0.168c	0.050b	-0.036	-0.002

Additionally,, the ticker PERI[48] had a significant (level of 1%) cumulative abnormal return on the 5 and 4 accumulated days before the event. , 4th and 3th day before the event also on the 4th and 5th day after de event. The tickers ENGH[13], INSG[25], CALL[21], PERI[34], PERI[38] and LIOX[45] had a significant cumulative abnormal return in every accumulated days before the event. Unlike the daily analysis, FB[47] presented a significant cumulative abnormal return 5, 4, 3 and 2 days before the announcement.

DISCUSSION AND CONCLUSIONS

This study aimed to verify if the acquisition of mobile applications generates abnormal returns in the stock prices of technology companies listed on the Nasdaq Stock Market (NASDAQ) buyers. To test the abnormal returns we used the methodology of study of events, aimed at demonstrating the creation or destruction of value due to acquisitions of mobile applications

We expected that, based on a semi-strong form of market efficiency, will have abnormal returns as a demonstration of market reaction. Through daily analysis, we found 47 abnormal daily returns in 270 daily returns. Mostly of these, was during the announcement day or after that. That result is evidence that market see the relevance of the announcement.

Additionally, we analyzed the cumulative abnormal returns and we found 48 significant cumulative abnormal returns, from 135 observations. The combination of daily (ARi) and cumulative (CARi) results is sufficient to affirm that the announcement of acquisitions of mobile applications create or destroyed value of buyer company.

As Pau Chaney, Devinney, & Winer (1991) brought up there are many event study's limitations. They pointed some:

> First, stock prices are naturally noisy, implying that an event must trigger a reaction that is significant enough to be seen above the normal background noise. Second, most events have no true event date. That is, although a public announcement may exist, it is next to impossible to find out precisely when information has been incorporated into the stock price; hence there is a tendency to see abnormal returns prior to public announcements. Third, many events have a tendency to cluster. For example, firms use stockholders' meetings to announce earnings and major changes. Also, managers have the incentive to attempt to counter bad information, such as low quarterly earnings, with potentially good information, for example, the signing of a government contract or other corporate developments. Fourth, many events do not have a clear impact on the firm. The market reaction is an aggregate expectation. Events without clear consistent expectational effect may appear to be nonsignificant when only stock prices are examined.

As a suggestion for future studies we propose analyze as event date not the official announcement but the public announcement of intention of investment. The market may have a delayed reaction, or even the date considered as disclosure in Bloomberg may not be the date investors were aware of. In the case of a strong market, the information would be absorbed when the purchase intention arose.

APPENDIX

Order	Announcement date	Target-Company	Buyer	Ticket Buyer
1	27/03/2000	MoreCom Inc	Liberate Technologies	LBTE US Equity
2	09/08/2000	Software.Com Inc	Great Elm Capital Group Inc	GEC US Equity
3	05/09/2000	WebManage Technologies Inc	NetApp Inc	NTAP US Equity
4	11/09/2000	Janna Systems Inc	Siebel Systems Inc	SEBL US Equity
5	18/09/2000	Servicesoft Inc	Broadbase Software Inc	BBSW US Equity
6	14/02/2001	TradeCast Ltd	TD Ameritrade Holding Corp	AMTD US Equity
7	21/03/2001	Market Maker business	Digital River Inc	DRIV US Equity
8	02/05/2001	Tidestone Technologies Inc	Actuate Corp	BIRT US Index
9	17/07/2001	eScene Networks Inc	Inktomi Corp	INKT US Equity
10	16/04/2002	Cybrant Corp	Blue Martini Software Inc	723068Q US equity
11	16/12/2004	Dralasoft Inc	Verity Inc	0772374D US Equity
12	02/08/2005	ContextMedia Inc	Oracle Corp	ORCL US Equity
13	27/09/2005	Apropos Technology	Enghouse Systems	ENGH CN Index

		Inc	Ltd	
14	12/04/2006	Portal Software Inc	Oracle Corp	ORCL US Equity
15	02/11/2006	Stellent Inc	Oracle Corp	ORCL US Equity
16	22/12/2006	Bizchord Ltd	Perion Network Ltd	PERI US Equity
17	07/02/2007	Visual Web Solutions Inc	ACI Worldwide Inc	ACIW US Equity
18	01/05/2007	Beanstream Internet Commerce Inc	LML Payment Systems Inc	1015837D US Equity
19	03/05/2007	EasyLink Services Corp	EasyLink Services International Corp	ESIC US Equity
20	05/10/2009	FeedRoom Inc/The	Piksel Inc	KITDQ US Equity
21	16/07/2010	YMax Corp	magicJack VocalTec Ltd	CALL US Equity
22	28/07/2010	Day Software Holding AG	Adobe Systems Inc	ADBE UW Equity
23	24/09/2010	Brickbox Digital Media SRO	Piksel Inc	KITDQ US Equity
24	02/11/2010	Art Technology Group Inc	Oracle Corp	ORCL US Equity
25	08/11/2010	Enfora Inc	Inseego Corp	INSG US Equity
26	01/02/2011	Zynga Inc	Morgan Stanley	MS US Equity
27	24/02/2011	North Social	Vocus Inc	VOCS US Equity
28	16/05/2011	eLong Inc	Tencent Holdings Ltd	SEBL US Equity
29	12/07/2011	PopCap Games LLC	Electronic Arts Inc	EA US Equity
30	03/01/2012	LeadFormix Inc	Callidus Software Inc	CALD US Equity
31	24/02/2012	iContact Corp	Vocus Inc	VOCS US Equity
32	11/04/2012	Conduit Ltd	JPMorgan Chase & Co	JPM US Equity
33	02/07/2012	Gaikai Inc	Sony Corp	SNE US Equity
34	08/11/2012	SweetIM Technologies Ltd	Perion Network Ltd	PERI US Equity
35	13/12/2012	DataRaker Inc	Oracle Corp	ORCL US Equity
36	03/07/2013	Xobni Corp	Yahoo! Inc	YHOO US Equity
37	26/08/2013	Luma/US	Facebook Inc	FB UW Equity
38	16/09/2013	Conduit Client connect businsess	Perion Network Ltd	PERI US Equity
39	14/10/2013	Onavo Mobile Ltd	Facebook Inc	FB UW Equity
40	19/12/2013	Dealer Dot Com Inc	Dealertrack Technologies Inc	TRAK US Equity
41	19/02/2014	WhatsApp Inc	Facebook Inc	FB UW Equity
42	15/04/2014	FeedMagnet Inc	Bazaarvoice Inc	BV US Equity
43	27/06/2014	58.com Inc	Tencent Holdings Ltd	TCEHY US Equity
44	05/11/2014	Contact At Once!	LivePerson Inc	LPSN US Equity

		LLC		
45	10/11/2014	CLS Communication AG	Lionbridge Technologies Inc	LIOX US Equity
46	11/02/2015	Make Me Reach SAS	Perion Network Ltd	PERI US Equity
47	30/09/2015	Offerpop Corp	Facebook Inc	FB UW Equity
48	01/12/2015	Undertone Networks	Perion Network Ltd	PERI US Equity
49	09/03/2016	Masquerade Technologies Inc	Facebook Inc	FB UW Equity
50	28/04/2016	Textura Corp	Oracle Corp	ORCL US Equity
51	03/05/2016	Livefyre Inc	Adobe Systems Inc	ADBE UW Equity
52	20/09/2016	InvestCloud Inc	JPMorgan Chase & Co	JPM US Equity

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DECISION SCIENCES INSTITUTE
A Survey of Techniques and Tools for Big Data Mining: the High Performance Analytics

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ABSTRACT

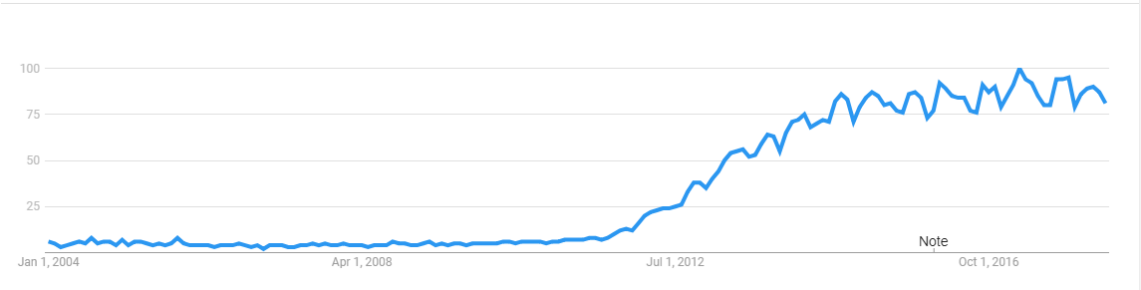
Big Data Mining extracts meaningful insight, hidden pattern, and useful information to support various decision making through analyzing structured and unstructured data. Handling big data is always a challenging task, especially in a distributed environment. To realize high performance computing and analysis, it is necessary to match suitable methods for particular Big Data Mining tasks. In this paper, we investigated data mining techniques, tools, and procedures to shed lights for future research; identified six distributed data mining environment; proposed a conceptual framework of Big Data Mining.

KEYWORDS: Business analytics, Big data, Data mining, Decision support

INTRODUCTION

The term ‘Big Data’ first discussed by John Mashey in 1998 and the first paper including ‘Big Data’ in title occurred around 2000 by Diehold (Fan & Bifet, 2013). Using Google searching term “Big Data” in May 2018, we can locate 136 million results, including 11 million news, 21 million videos, and 680 thousand books. The volume, velocity, variety, and value of data have grown unprecedentedly in recent years. Google Trend shows big data topic sustain a high popularity since 2013 (Figure 1). In today’s world, trillion terabytes of data are produced and 90 percent of the data today were generated in the last two years (IBM, 2018). Industries are facing unprecedented challenges to process and analyze tremendous amount of data to gain information and knowledge. Decision making process driven by data requires more analysis instead of intuition.

Figure 1: Google Trend for term “Big Data” (from 01/04/2004-05/22/2018)



Data is complex but important to business success. The structured and unstructured data are becoming valuable information as the Data Analytics methodologies and techniques make it possible for people to extract value from data. Data Mining is a computational process of extracting valuable information from given data to conduct predictions and supporting decision-making. Its major tasks include patterns and rule finding, clustering, classification, regression, dimensionality reduction, outlier detection and so on. The common data mining process includes three steps: harvesting and cleaning data (or data ETL), modeling, and deployment

(Hashmi & Ahmad, 2016). The final goal of the process is to identify valuable information and insight for better decision making in high speed.

In order to support data mining and business analytics, effective high-performance computing environment and infrastructure are required, which apply systematic designs to unleash the full power of the Big Data (Wu, Zhu, Wu, & Ding, 2014). Meanwhile, effective data analysis and prediction techniques are developed accordingly. There are many data mining applications in business world, such as customer profile, churn forecast, fraud detection, risk factor extraction, and health monitor and diagnosis (Fan & Bifet, 2013). Business giants, such as Google, Facebook, and Walmart have developed multiple initiatives to ensure effective and efficient services and responses to their customers (Wu, Zhu, Wu, & Ding, 2014). Many researches are available now to provide proposals and solutions to industries for handling big data challenges.

In this study, we investigate emerging tools, computing techniques, algorithms and procedures to shed some light to future researches. The paper proceeds as follows. In section 2, 3, 4, 5, we discuss important aspects, programming frameworks, system environment, algorithms, and procedures of Big Data mining and their recent development. Base on the surveyed components, we propose a conceptual framework for Big Data Mining with 4 primary layers and 2 support layers. Section 7 provides a conclusion of the study and potential future research fields.

BIG DATA PROGRAMMING FRAMEWORK

In most occasions, a single computer, which equipped with hard drive, memory and CPU, is adequate for small data analysis and miming project. But in Big Data scenario, data scale is more beyond the capacity that a PC can process. The most recent Big Data processing frameworks utilize cluster computers with a high-performance computing capability, supporting by parallel programming and data mining features.

Traditionally, companies have been making business decisions based on transactional data stored in relational databases. Big Data, such as system logs, tweets, e-documents, sensors data, images, is forcing companies to rethink their mining approaches for extracting more useful information, new insights, and hidden relationships from these unstructured data (Wu, Zhu, Wu, & Ding, 2014). There are many big data tools to support the mining works. Some of them are Apache Mahout, MOA, and Vowpal Wabbit (Fan & Bifet, 2013).The most popular Big Data programming model on parallel programming is MapReduce (Wu, Zhu, Wu, & Ding, 2014).

MapReduce's capability in the real-time and large-scale data processing has attracted extensive attention. As a batch-oriented parallel computing model, MapReduce provides a constructive solution for big data challenges. Data mining tasks usually have to walk through the training data to get statistics and ensure model parameters. Accessing to large-scale data is recurrent and numerous (Wu, Zhu, Wu, & Ding, 2014). In the data processing procedure, the Map executes filtering and sorting and the Reduce transact a summary, which makes it fit many descriptive and predictive algorithms. The down side of the MapReduce is the higher communication or I/O cost. Data process speed is slow due to constraints of replication and disk storage.

Recently, Apache Spark is emerging and joins the mainstream of processing and mining big data. It applies a programming language to a distributed collection data structure "Resilient distributed datasets" (RDDs). Through the collections of objects (RDDs), users can execute partitioning, storage allocation (memory, disk etc.), and parallel transformations (map, filter etc.) across a cluster. During the process, master node assigns jobs to worker nodes, which read data stored in HDFS or in local machine (Bharill, Tiwari, & Malviya, 2016).

As the most popular open source and large scale data processing engine, Apache Spark is broadly adopted in Big Data mining and advanced analytics projects. The advantages of the Spark makes it fit to various environments (e. g. Hadoop, Mesos, standalone, or in the cloud). By using the Spark, people can read data from various data sources (e.g. HDFS, Cassandra, HBase, and S3), interact with varied applications, and work with major programing languages, including Scala, Java, Python, and R (The Apache Software Foundation,2017).

Simply speaking, Spark can run traditional and streaming ETL, interactive or Spark-type SQL, advanced analytics (Machine Learning), graph processing (Graph X/Graph Frames), and Streaming (Structured Streaming) within the same engine. Compared to MapReduce, Spark is 100 times faster than MapReduce through data caching (Hashmi & Ahmad, 2016). It is suitable for fast data processing/in-memory processing, iterative processing, near real-time processing, graph processing, machine learning, and joining datasets (Bekker, 2017).

Although MapReduce has dominated big data processing for a long time and utilized by several companies and organizations, it would be replaced by Spark or other programming models or tools in the near future because of latter's multiple advantages. Besides MapReduce and Spark, there are some other high level programming tool and language are being developed such as Pig, Hive, and Scope (Chen, Mao & Liu, 2014).

BIG DATA MINING SETTINGS

With the businesses spread across the world, current dataset may not be stored in one centralized server. The data sources are often scattered in multiple places. Distributed data mining is designed to handle the distributed data and involving the application of particular algorithms in multiple environments and technique constraints. It is in high demand because of fast growing data volume and speed, storage locations, bandwidth limitation and privacy concerns (Zeng, Li, Duan, Lu, Shi, Wang, & Luo, 2012). It is hard to provide a unified framework for algorithms and there is no "One-Size-Fits-All" algorithm or solution. To deploy a data mining algorithm, a user should firstly consider to identify particular type of computing environments in which certain algorithms can fit.

Communicating among multiple process nodes, distributed data mining commonly utilizes the suitable algorithms to tackle local data and then combine the local pattern and information into a global solution. Srimathi et al. (2014) classified distributed data mining into three groups: DDM based parallel data mining agent, DDM based on mete learning, DDM based on Grid. Based on the summarizations of Zeng et al. (2012), Srimathi et al. (2014), and other most recent studies, we identified six types of distributed data mining setting:

Multi-core Supercomputers

Under this setting, all the computing units share the same memory and the communication cost among computing units is tiny. The disadvantage of such type devices are very obvious: expensive. People only consider this setting when the cost of data mining computation is very expensive and the algorithm can only be rewritten as an efficient fine grained parallel algorithm. Graphics Processing Unit (GPU) is a new type of setting under this category. Equipped with GPU with massive number of cores, supercomputers can now handle and accelerate data mining workload. When the data mining relates to simple and repeat operations, e.g. matrix operation, counting occurrence of item from a bitmap, or search K-nearest neighbors, the GPU can speed up the process significantly.

One of the success GPU-based data mining framework is Three Components Framework: a CPU-based storage and buffer manager is used to manage the whole program flow and data transferring between CPU and GPU; a GPU-CPU co-processing mining module; and a GPU-

based visualization module. Successful implementations include k-means clustering and the Apriori frequent item set mining.

Peer-to-Peer Based

Peer-to-Peer (P2P) environment does not depend on a central server, and each site gets the data and performs its own task. The nature of the peer-to-peer system is decentralization and each site has limited view to the entire system. This limit actually provides better security since sites do not need to observe irrelevant surroundings. P2P networks overcome constrains of communication bottlenecks or messages failure and provide an efficient platform for the distributed big data mining. One of example of P2P system is An extendible multi-agent data miner system (EMADS), comprising a set of peer agents in a set of containers, such as data agents, user agents, task agents, mining agents, and housekeeping agents. A big data mining task is accomplished under the cooperation of multiple agents.

Typical examples of P2P distributed data mining include distributed association rule mining, distributed decision tree. A few researchers proposed other solutions:

(1) Collective data mining. The approach vertically divides data and joins up-to-date results from local sources.

(2) Model to calculate the mean value and data mining application over distributed data and P2P networks.

(3) Ensembles of models, such as Bayesian model averaging for regression models, and partition learning.

Internet and Grid Computing Based

Internet generates huge amount of distributed data and various distributed computing resources. Internet computing maneuvers idle terminals and PCs to build robust distributed computing systems with a global reach. With the assistance of internet computing, we are able to begin many sound projects, which previously required participation of supercomputer, in an economy way. Most recent internet distributed data mining projects include:

(1) Models@Home for distributed computing in bioinformatics.

(2) SETI@Home for distributed computing to detect intelligent life in outer space.

Geographically distributed and users access through a single interface, a grid incorporates a group of similar machines to execute large-scale resource sharing, innovative applications, high-performance orientation, and data processing. Two examples of grid base data mining techniques compose of:

(1) Three layers Data Mining Grid. According to different functions, three layers accomplish grid software, data, and hardware resources management, middleware function, job scheduling, and security support, and results summarization.

(2) Grid-enable Weka. Weka is a broadly used software for machine learning and predictive modeling. In Grid-enable Weka, the machine learning tasks can be split across computers and accomplish producing, testing, and cross-validating a classifier on a remote machine.

Cloud Based

One of the major challenges to the big data mining is the parallelized use calculation power to save the time and reduce the communication cost. Cloud computing implies powerful interconnected servers with multi-core processors to process huge amount of data without physically running process in individual user's environment. Through the concentrated management and colossal storage resources, cloud technique can provide big data processing and storage with fine-grained computing capacity (Chen, Mao & Liu, 2014).

As the newest promising technology for IT industry. Cloud computing exploits the global memory and computing capabilities of computers and servers via a network, usually the Internet, providing us a flexible and considerable computing support and solution. This technique is becoming a business. Othmane and Hebri (2012) proposed an Agent-Based

Systems on the Cloud to handle distributed data mining. The system include following components: User Interface, Task Agent, Data Agent, Cloud Temporary Storage, Mining Agent, Process Agent, Visualization Agent. Through the approach, people can use the parallelism over the cloud platform and shorten the response time, as well decrease the communication costs.

Internet of Things

The Internet of Things (IoT) is the network embedded with software, electronics, sensors, and actuators. These devices generates large quantity of data that needs to be processed in a timely manner. Even though, it may be possible to send all data to a central serve for processing, that would introduce network delay and possibly overwhelm a centralized system because of large number of devices involved. Many businesses realized that data may need to be processed at the Edge, closer to the Things. Compared to a centralize setup, the Edge setup could be smaller and more nimble. By conducting data analytics on the Edge, the business can mine data in real time and make decisions in real time. The intelligence gained on the Edge can be pushed upstream to the centralized system for further processing and analysis. Highly optimized models built on intelligence from many Edge systems can be then deployed to Edge systems. The combination of edge computing and centralized data mining can offer powerful benefits to many IoT deployments.

The IoT is still at early development stage. The major issues of research focus more on efficiency of data processing and then on effectiveness of knowledge mining (Tsai et al., 2014). Chen et al. (2015) proposed an architecture for IoT and big data mining system, which includes five layers: devices, raw data, data gather, data processing, service, and security/privacy/standard. Through the architecture, the data from sensor, camera, RFID, and other IoT devices can be processed by multiple open source solutions, such as Hadoop, HDFS, Storm, and Oozie. The service layer provides data mining functions for extracting information, insights, and values.

BlockChain

Proposed by Nakamoto (2008), blockchain establishes a distributed system which secures and accelerates the online transactions without central authority and intermediaries (Tapscott & Tapscott, 2017). In the system, computers are chained each other in a sequence, no one can manipulate the data without agreement of majority users due to every block keeping a history of transactions. The timestamp and hashing function make the data change verifiable, trackable, and auditable across the block (Di Pierro, 2017). Through the mechanism of smart contracts, the blockchain platform can authenticate private, public and personal records (Treleaven, Brown, & Yang, 2017). Some researchers believe that the technology will transform the business to a low costs, better service, and effective value delivering model (Tapscott & Tapscott, 2017). While, most importantly, the blockchain provides a high-quality and adequate data to the data analysis, predictive modeling, and machine learning. The noise and error of data will be reduced significantly in the data mining process.

The data in blockchain is streaming and high-dimensional. To mining the data across blockchain, an effective mechanism is to connect the transaction flow of the blocks with the corresponding information across the member nodes. Meanwhile, one of significant challenges is extracting features of classification learning (Chen, 2018). Big data mining technique application in blockchain is scarce. Recently, Chen (2018) proposed a deep learning approach, akagi–Sugeno Fuzzy cognitive maps ANN, to fast make traceability decisions. His experiment shows that the method outperforms the consensus algorithm in speed and accuracy.

The quality of distributed data mining is partially hard to measure due to influence factors of data partitioning, assignment scheduling, and global integrating. As supplement of the distributed data mining, the parallel data mining could discover the same valuable information

through global, parallel, and sequential algorithm on full dataset. The precision may be somewhat promised, comparing to the distributed data mining (Zeng, Li, Duan, Lu, Shi, Wang, & Luo, 2012). In the near future, the parallel data mining algorithm will more and more be applied in different environment settings.

In practice, there is not a single best setting for each organization. The final solution depends on organization's decision according to its objective, resource, capability, status quo of systems, and management requirements.

BIG DATA MINING ALGORITHMS AND TECHNIQUES

The common task of analytics and data mining is prediction (Phillips-Wren & Hoskisson, 2015). Statistical models and machine learning algorithms are broadly applied in data mining projects (Hashmi & Ahmad, 2016). Commonly, data mining models can be divided into two categories: supervised and unsupervised mining.

(1) Supervised mining deals with training the model with existed data and making prediction or label new input observations. The typical models for supervised mining include: Regression, Naïve Bayes, Decision trees, Perceptron, and Support Vector Machines. For their importance to data mining tasks we describe each model as following Table 1.

Techniques	Description
Logistic Regression	Applied to predict the probability of a dependent variable (and thus classify the outcome based on that probability) through a logistic function.
Decision Tree	A flowchart-like structure where the final outcome relies on the rules across the internal path and nodes.
Neural Networks	In the system of Interconnected layers and nodes, outputs is calculated through the weighted sum of the values of the nodes activation function to that weighted sum.
Support Vector Machine	By given labeled training data, the discriminative algorithm produces an optimal hyperplane which can categorize new data.
Naïve Bayes	Based on applying Bayes' theorem with the assumption of independence between features.

Table 1: A Description of Typical Supervised Mining Models

(2) Unsupervised mining is concerned to extract patterns or clusters by giving data without a label. The algorithms for frequent pattern mining commonly include: Apriori algorithm, FP-Growth algorithm, Eclat, etc. Related techniques such as dimensionality reduction, ensemble learning, Outlier detection, and Machine Learned Ranking are also broadly discussed. For clustering, the popular algorithms accommodate: k-means, fuzzy cmeans (centroid models), BIRCH (hierarchical models), DBScan, OPTICS (density models). Other widely discussed techniques for clustering consist of Expectation-Maximization and Self-Organizing Maps (Hashmi & Ahmad, 2016).

With the fast increasing streaming data from multiple sources, streaming data mining models now are in high demand. To handle the streaming data, a good model should be capable of synchronizing and combine them efficiently and effectively. To harvest useful information from the streaming data, traditional existing models need to be transformed to handle the new

situation. Current available models, which can be deployed to process and analyze streaming data, incorporate following (Hashmi & Ahmad, 2016):
(1) For clustering of a streaming data , there are BIRCH, Scalable k-means, Single-pass k-means , Stream, Stream LSearch, CluStream, ODAC, DenStream, D-Stream, SWClustering , ClusTree , DGClust , StreamKM++ , SOMKE.
(2) For classification of streaming data, available algorithms/models can be categorized into two groups: incremental learning and ensemble learning. The classical algorithms for incremental learning include Incremental Bayesian algorithm, Incremental SVM, VFDT (Hoeffding Tree), and CVFDT; Streaming Ensemble Algorithm (SEA), Accuracy-Weighted Ensemble (AWE), and Dynamic Weighted Majority (DWM) are well-known ensemble learning algorithms.
(3) For regression and pattern mining, the most notable models are Hoeffding-based Regression trees,estDec FP Stream , Moment , IncMine, and CloStream.
In unstructured text, web, multimedia, and network task, besides some of techniques discussed above, other typical techniques (Chen, Mao & Liu, 2014) include:
(1) Information extraction, topic models, text summarization, classification, clustering, question answering, and opinion mining.
(2) Information retrieval, Page Rank, and CLEVER.
(3) Multimedia summarization, multimedia annotation, multimedia index and retrieval, multimedia suggestion, and multimedia event detection, and topic-oriented multimedia summarization system (TOMS).
(4) Link-based structural analysis and content-based analysis.

BIG DATA MINING PROCEDURE

Data mining follows certain steps to obtain optimal solutions. One of the most high-profile data mining process models is CRISP-DM (Kumari, Nandal, & Kataria, 2017), which include six major phases: business understanding, data understanding, data preparation, modeling, evaluation, and deployment. The procedure can be applied in big data tasks as well. Carrying the mechanism in the head can organize our thinking about big data mining tasks and problems (Provost & Fawcett, 2013).

We describe each step and specific big data mining tasks and considerations as follow:

(1) Business understanding. This initial phase focuses on understanding the problem under a business landscape, and then transferring business requirements and information into a big data mining project. During the business understanding step, an initial plan needs to be formed to ensure the achievement of business goals and missions.

(2) Data understanding. Data sources can be varied in today's digital world. Big data status quo makes data understanding more challenge and complicated than ever before. The data distributed geographically force us to recognize and understand it carefully. The data understanding phase starts from data harvest from multiple sources and environment, and data glimpse to figure out data quality problems, to identify initial knowledge from the data, and to identify meaningful sample data to form a hypotheses testing or experiment design.

(3) Data preparation. It should never be ignored to preprocess the data to ensure a high quality input before miming. The data preparation step is expected to generate the final dataset from "dirty" data. Data preparation tasks cannot be accomplished in one shot in a predefined order. The process is iterative and requires multiple tries. In this step, tasks like table and record manipulation, feature selection, data transformation, data filter, and data cleaning primarily serve to the future modeling task.

(4) Modeling. In this step, we utilize appropriate model and tune their parameters to seek optimal solutions. Commonly, people can try multiple techniques for one problem. Particular

requirements and data quality will sometime limit the performance of a certain technique. Returning to the former step, especially the data preparation phase, is necessary and often needed. For static and dynamic data, we should consider different algorithms according to our previous discussions.

(5) Evaluation. It is crucial to assess the quality and performance of model and review the procedure ran to produce the candidate model. We need to guarantee that the model can appropriately support us to reach particular business mission. One of the key issues is to check if business issue is ignored in whole or missed partially. During this process, we need to make a decision whether or not to implement the data mining results in the future.

(6) Deployment. Following the model creation and evaluation, we need to applied data mining experiment and project results to gain and add more business value to organization and stakeholders. We need to make sure the knowledge we obtain from data modeling can benefit organization and customers in an organized, understandable and applicable way. Producing a report, carrying out a repeatable data scoring, or embedding an autonomous process into current information system could be one of the data mining deliverables. Commonly, outside customer and inside decision makers are end users of created data miming products or services which we developed from above multiple phases.

CONCEPTUAL FRAMEWORK OF BIG DATA MINING

Base on the all components surveyed and discussed previously, we develop a conceptual framework for Big Data Mining. In this framework as show in Figure 2, it includes 4 primary layers and 2 support layers:

Primary layers are:

(1) Data source. Various data sources generate structured and unstructured data.

(2) Computing Environment. Data mining function and algorithms run on certain computing environment according to the characteristics of big data and business status quo.

(3) Algorithm. Due to requirements of different data-driven analysis, certain mining algorithm can be utilized. Major categories include supervised, unsupervised, streaming, and unstructured data mining methods.

(4)Product and Service. The final objective of big data mining is to provide business a better solution. The product and service from the data mining process improve and optimize business decision making.

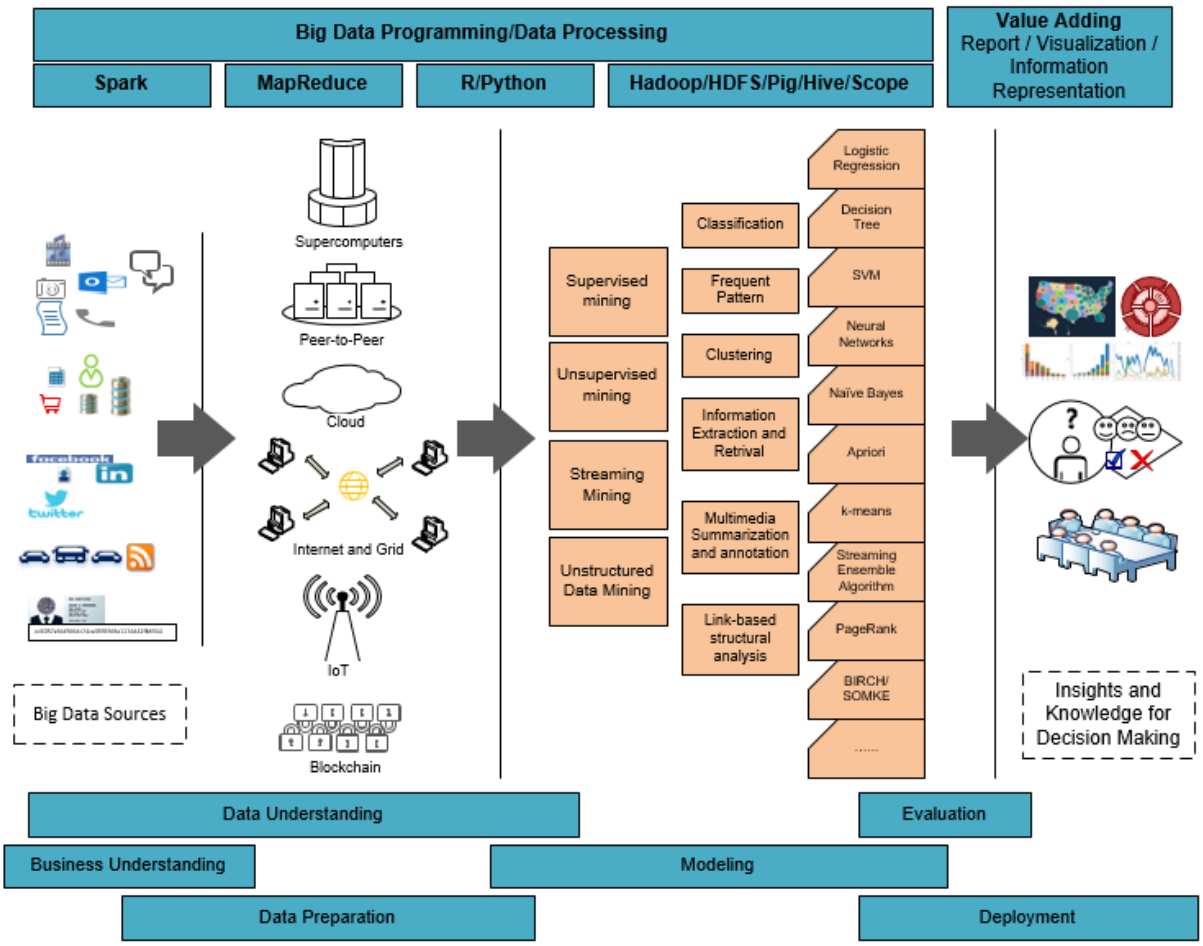
Support layers include:

(1) Big Data Processing and Value Adding. Based on data analysis supported by multiple tools, big data mining add value to business through methods of report, visualization, and information representation.

(2) Big Data Mining Procedure. Six continuous and overlapped steps guarantee a seamless pipeline for data-driven decision making.

There is not an exhaustive framework for big data mining because fast changing business environment. When new problem occurs and novel technology becomes mature, we need to reconsider their old works and then make updates and optimize the previous process and solutions.

Figure 2: Conceptual Framework of Big Data Mining



CONCLUSION AND FUTURE RESEARCH

Efficient data processing and analysis are major research areas in Big Data Mining. In this survey, we investigate previous researches and studies on tools, techniques and frameworks on Big Data Mining. In term of contribution, we state several challenges across big data mining process including analytics architecture, and distributed data mining settings and methods. We summarized centralized and decentralized data mining tools and algorithms which can handle big data problems. We also discuss major models and procedures to run a big data mining project. Our proposed framework consolidates and conceptualizes the big data mining life cycle and technique details. The framework could strength researchers and managers to better understand Big Data Mining and high performance analytics.

Big data technologies bring us beneficial and desired outcomes (Power, 2014). To choose decent programming tools, settings, technique, and model are very crucial for project and business success. Industry and academic researchers should study the upcoming and implemented evolving technologies like Hadoop, Spark, distributed computing, machine learning, deep learning and their use cases. Through the survey, we can find that there is not "One-Size-Fits-All" solution for processing big data and handle big data problems due to its

characteristics. An organization needs to select the best solution according to its tasks, ability and capability.

To expand our understanding of Big Data Mining, future research should consider following issues:

(1) Data quality and security. Big data is large scale, noisy, various, uncertain, incomplete, and sensitive. Effective processing mechanism of data cleaning, transforming, and dimensionality reduction should be studied and explored. Researchers need to consider the standard to protect data from breach.

(2) Efficient processing framework. Research effort is needed to improve the distributed and parallel programming framework. The potential problems include energy efficiency, dynamic resource allocation, processing big data in cloud computing, load balance, and real time processing (Hashem, Anuar, Gani, Yaqoob, Xia, & Khan, 2016). The use case of Spark and other big data mining platform should be identified and developed to stimulate broad application.

(3) Effective algorithms. As a new development of machine learning, deep learning is proving to be powerful in big data analytics, especially in identifying language, image and audio pattern (Najafabadi, Villanustre, Khoshgoftaar, Seliya, Wald, & Muharemagic, 2015). The approach applies to multiple big data projects across the industry and academia. However, deep learning with streaming, high-dimensional data, distributed computing, and IoT needs further investigation.

(4) Blockchain mining. Blockchain provides a quality data solution for big data mining. It will become a game changer for the business and regulation. The new research can address program framework and machine learning on specific block, segment, and whole chain. Machine learning execution with smart contract will be an interest topic.

(5) Data Visualization. In the data mining process, visualization strengthens the power of big data mining. Interdisciplinary studies like computer science, psychology, art, and statistics should be further explored to enhance the performance of descriptive and predictive data analysis, insights and knowledge presentation, and business storytelling.

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DECISION SCIENCES INSTITUTE
Alliance Partner Selection and Firm Value: An Event Study

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ABSTRACT

This study links an important phenomenon in alliance formation – partner selection – to alliance performance. Particularly we study how exploration in partner selection, as characterized by forming relationships with new partners from new industries, affects the value of an alliance. We find that generally exploration has a negative impact on the value of the alliance. However, after considering some contingency factors such as the industry environment we find that the relationship actually becomes positive in a dynamic environment. These findings suggest that the exploration choice in partner selection needs to fit certain contextual conditions to add value to the firm. The main effect of the choice and the contingent effect of the context provide important implications for alliance managers and corporate executives when they weigh the choice of selecting a value-adding partner.

KEYWORDS: Event study, Alliance partner selection, Exploration, Exploitation

INTRODUCTION

The abundant research on alliances has shed light on a typical alliance life cycle consisting of stages such as partner selection, alliance negotiation, contract formulation, and partnership termination (Kale, Dyer, & Singh, 2002). Although the importance of partner selection has long been recognized by strategy researchers (Harrigan, 1985), the question of partner selection has remained as an under-researched topic in the literature (Rothaermel & Boeker, 2008). The question of "who allies with whom" has been found to be related to issues such as dyadic complementarities or strategic interdependence (Rothaermel & Boeker, 2008; Gulati, 1995; Shah & Swaminathan, 2008), status similarities (Podolny, 1994) or technological similarities (Rothaermel & Boeker, 2008), trust and commitment (Shah & Swaminathan, 2008), the potential partner's status and reputation (Stern, Dukerich, & Zajac, 2014) and social structure such as repeated ties (Gulati, 1995). As the need for novel knowledge and new capabilities through alliances often drives the decision of partner selection, the issues above usually affect the incentive of learning, the efficiency of the learning process, and hence alliance performance.

Depending on the extent of learning, firms may engage in exploration and exploitation when forming alliances. Exploration involves experimentation with new knowledge domains. In the context of partner selection, this may require forming relationships with partners who can bring in new capabilities and resources. Exploitation, on the contrary, takes advantage of existing competence and knowledge. Hence exploitation in partner selection is more like forming relationships with partners whom the firm has been interacting with or been familiar with. In reality, firms often face the exploration-exploitation dilemma when choosing alliance partners. On the one side, choosing a partner who has existing relationships with the focal firm, which is often viewed as a form of exploitation, may ease the knowledge transfer process and enhance the efficiency of collaboration (Lavie & Rosenkopf, 2006). But the same relationship, sometimes characterized as a repeated or strong tie, may also restrict the firm's search for and access to non-redundant and novel information and knowledge, which sustain the growth and renewal of

the organization. On the other side, forming relationships with new partners, as a form of exploration, offers new growth opportunities for the focal firm. The knowledge obtained from such relationships, however, is likely to be very different from what the firm gained from past relationships, therefore represents a challenge in the knowledge assimilation process. Moreover, due to lack of familiarity and trust with the partner, the collaborative relationship may also be endangered by potential opportunistic behaviors and distrust between allying firms.

The dilemma is rooted in the well-established belief that exploration and exploitation lead to different performance outcomes – exploitation produces positive performance effects in the short run whereas exploration is more likely to pay off in the long run. The choice of partner selection, therefore, should determine the potential value of the relationship, which can be captured by the unusual movement of the firm's share price. Unfortunately research that links partner selection to alliance performance has been scarce. Recently there have been studies looking at the relationship between partner choice and performance at the firm level (Goerzen, 2007; Lin, Yang, & Demirkan, 2007), but very few studies have looked at the relationship at the alliance level. Previous research has shown that stock market investor-shareholders respond differently to R&D announcements with varied focus on exploration and exploitation, because investors perceive different value potentials in the two types of R&D projects (McNamara & Baden-Fuller, 2007). But will they also respond differently to choices of partners, which vary in the focus of exploration versus exploitation? The research needed to answer the question is hardly existent.

The main task of this study is then to investigate how the choice of partner selection, in terms of the focus on exploration versus exploitation, affects the market valuation of the firm's common shares. We agree with Lavie & Rosenkopf (2006) that there are domains where firms may tune this focus when forming an alliance, probably due to the different types of learning involved in the alliance. More importantly, theory explaining the difference in value creation will be incomplete without considering certain contingency factors. Because either choice of partners incurs some benefits and costs in alliance management, the value of the alliance is most likely to depend on factors that may change the balance. Combining March's (1991) exploration-exploitation framework with social network theory advanced by Granovetter (1973; 1983), we explore factors such as environmental dynamism and munificence with respect to their contingent effects on the value of the alliance. These factors influence the relative weights of the costs and benefits associated with exploration and exploitation in partner selection, and hence the economic value that can be expected from the alliance.

EXPLORATION VS. EXPPLOITATION IN PARTNER SELECTION

March's (1991) seminal work on exploration and exploitation has spawned a large number of studies applying the dual concepts to analyze a variety of phenomena such as organizational innovation, organizational adaptation, organizational learning, and competitive advantage. Exploration refers mainly to learning and innovation, i.e. the pursuit and acquisition of new knowledge (Gupta, Smith, & Shalley, 2006). By contrast, exploitation represents the refinement and extension of existing competencies, technologies, and paradigms (March, 1991). A key difference in the exploration-exploitation dichotomy is the level of learning involved in each type of activities (Gupta, Smith, & Shalley, 2006). As March theorized, both exploration and exploitation are of critical importance to organizations, but the two are fundamentally incompatible. The incompatibility comes from the competition for scarce organizational resources such that the interplay between exploration and exploitation occurs in the form of a zero-sum game (Gupta, Smith, & Shalley, 2006). Moreover, "failure trap" and "success trap" may yield self-reinforcing effects for both types of activities (March, 1991).

Alliances are often viewed as an interorganizational vehicle for learning new and external knowledge (Lavie, 2006). Given the involvement of learning in both exploration and exploitation, it is not surprising that the exploration-exploitation framework has been widely applied in the alliance research. Koza & Lewin (1998, p. 257) defined an exploitation alliance as "the joint maximization of complementary assets" and often takes the form of equity-based joint venture. On the contrary, an exploration alliance is likely driven by "a desire to discover new opportunities" (Koza & Lewin, 1998, p. 257). Other alliance researchers have linked the type of alliances to the different stages in the product development process (Rothaermel, 2001; Rothaermel & Deeds, 2004; Lavie & Rosenkopf, 2006; Stettner & Lavie, 2014). Some of these authors refer to exploration alliances as those that focus on upstream activities of the value chain such as drug discovery, development, and manufacturing, whereas exploitation alliances have a focus on downstream activities such as marketing and sales.

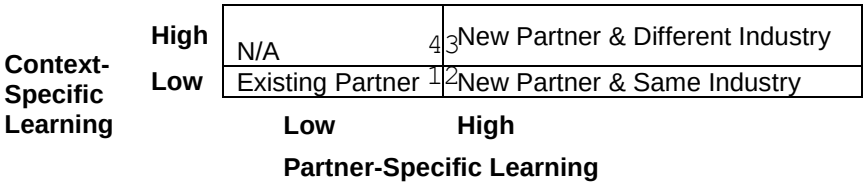
Lavie & Rosenkopf (2006) generalized three domains of exploration and exploitation in alliance formation: the function domain, the structure domain, and the attribute domain. Alliances can serve different value chain functions which exemplify the distinction of exploration and exploitation. The function-based differentiation is consistent with the conceptualization of Koza & Lewin (1998) and the operationalization of Rothaermel (2001) and Rothaermel & Deeds (2004). The structure domain considers the network positions of the firm's partners and differentiates between recurrent alliances and new alliances. The last domain taps into the difference in the organizational attributes of a firm's partners over time. The conceptualization by Lavie & Rosenkopf (2006) is interesting and allows the test of the ambidexterity hypothesis across different domains. Recent studies on exploration and exploitation in alliance formation have been focused on the structure-based distinction (Lin, Yang, & Demirkan, 2007; Goerzen, 2007), looking at the impact of repeated ties versus new ties.

In this study we build upon the previous conceptualization of the exploration-exploitation dichotomy in alliance formation with a focus on the choice of partner selection. Particularly we define exploration and exploitation based on the firm's choice of partner in the present alliance as opposed to in the previous alliances. We focus on whether an alliance represents a new tie to the firm, which would mean that the firm has no prior relationship with the partner. Forging relationships with existing partners is viewed as a form of exploitation in partner selection. The difference in the level of learning is evident across the two choices, i.e. a new tie or a recurrent tie. A new tie, which means exploration in partner selection, often leads to significantly more learning involved in the relationship. This type of learning taps into the knowledge about the partner, regarding various aspects such as its location, size, technology, structure, culture, and the like. Each time the firm forms a new tie, it needs to undertake such partner-specific learning in the entire alliance life cycle. When forming a relationship with an existing partner, on the other hand, chances are the firm has already possessed the relevant knowledge about the partner, which would largely reduce the effort of learning in the alliance. Moreover the mutual trust built through previous relationships may also reduce the likelihood of partners' opportunistic behavior (Lioukas & Reuer, 2015).

Besides partner-specific learning, firms may also engage in context-specific learning as a result of their partner choice. The term context refers to the technological environment in which a firm operates (Rosenkopf & Almeida, 2003). On the one hand, the firm may choose a partner with the same technological background as its previous partners, which may incur less learning regarding the context. As a firm's technology is often determined by its industry, the choice of a partner from the same industry as the previous partners represents a form of exploitation in partner selection. On the other hand, the choice of a partner from a different industry may

demand a significant level of learning about the partner's technological background, therefore can be viewed as a form of exploration in partner selection. Partner-specific learning thus intertwines with context-specific learning in the choice of partner selection. By combining these two types of learning, we can create a full spectrum of partner choice ranging from exploration to exploitation. Figure 1 uses a two by two matrix to illustrate the different learning activities involved in partner selection. The level of learning increases monotonically from Cell 1 to Cell 3 via Cell 2, indicating a distinction between exploitation and exploration.

Figure 1: Partner Selection and Learning Activities



PARTNER SELECTION AND ALLIANCE PERFORMANCE

Exploration activities and exploitation activities entail different performance implications due to the difference in the amount/level of learning involved in each type of activities. March (1991) argues that exploration activities such as basic research produce less certain results and last over longer time periods as they often involve a large amount of learning. Because of uncertainty in the scope of possible outcomes, exploration often leads to failure or at least its performance effect is hard to be captured by short-horizon measures. In contrast, exploitation has a quick self-correction mechanism as it uses knowledge that is most proximate and hence represents a closer feedback system. As a result, exploitation activities are more likely to yield positive returns in the near term (Levinthal & March, 1993). It is apparent then that exploration and exploitation will have different effects on a particular performance metric.

In the alliance literature, no research has been done on the relationship between exploration-exploitation in partner selection and alliance performance. At the firm level, there has been some empirical evidence that exploitation in alliance formation may have adverse effects on firm performance. Goerzen (2007), for example, reported that firms with a greater propensity to enter into repeated partnerships experienced inferior economic performance. There is also conjecture that both exploration and exploitation are important for the firm. For example, Lin et al. (2007) tested the ambidexterity hypothesis, which argues that firms pursuing exploration and exploitation simultaneously in alliance formation will outperform those who do not. Their empirical findings, however, failed to support the ambidexterity hypothesis but identified a set of boundary conditions of the hypothesis. Despite the scarcity of research on the relationship between partner selection and alliance performance, many studies have suggested that partner characteristics impact alliance performance (Afuah, 2000; Stuart, 2000; Zaheer & Bell, 2005; Lavie, 2007). These findings highlight the importance and need of studying a firm's choice of alliance partners and its performance implications.

So far there seems to be neither complete nor consistent empirical research regarding the economic impact of exploration versus exploitation in partner selection. Furthermore, none of the extant studies has been done at the alliance level. To link partner selection to alliance performance, we employ a market-based measure for the economic value of alliances, abnormal stock market returns during the announcement period of an alliance. Compared with conventional performance such as ROA, excess returns reflect the investor-shareholders'

evaluation of the potential value attributed to a particular event, which separate from the focal event other factors that might affect alliance performance. It is therefore a “cleaner” measure of alliance performance. In addition, there has been evidence that the stock market not merely reacts to the event itself, but also gathers all relevant information available in the market and uses it to adjust the assessment of value creation. For instance, investor-shareholders are found to respond differently to project announcements at various stages in the R&D process that are used to construct the exploration-exploitation dichotomy (McNamara & Baden-Fuller, 2007). Given these properties of abnormal stock market returns, we believe that they are appropriate measures for capturing the economic value that can be attributed to exploration and exploitation in partner selection.

The stock market will generally favor exploitation in partner selection as this choice reduces the need to learn about the partner and improves the alliance management process. Exploitation takes advantage of the past relationships between the firm and the partner. Choosing an existing partner may reflect the managerial intention to leverage the firm’s knowledge about the partner, maintain a long-term collaborative relationship, and most importantly streamline the transactions involved in the new partnership. Such information is often highlighted in the announcement of the alliance, producing some strong signals to the stock market that the firm probably will do well in managing the new partnership. As a result, investors and analysts will generally react favorably to exploitation in partner selection. On the contrary, exploration in partner selection produces some risks and uncertainty to shareholders. Lack of knowledge about the partner and lack of expertise in the technology to be tapped in the alliance create some serious challenge for managing the relationship and assimilating the partner’s knowledge. Such information can be easily picked out by investors and analysts and used against the valuation. Furthermore, the informational advantage of exploration is subject to information asymmetry between the managers and the shareholders, which might not be communicated well enough to the stock market upon the announcement of the alliance. Hence long-term benefits through allying with a new partner can be overshadowed, at least temporarily, by the difficulty in managing the relationship. Consequently, exploration in partner will generally incur less favorable market responses.

H1: Exploration in partner selection is negatively associated with abnormal stock market returns during the announcement of an alliance.

Value Contingency

Note that H1 does not imply that exploration in partner selection will cause negative abnormal stock market returns. Since on average alliances create value for the firm (Chan, Kensinger, Keown, & Martin, 1997), H1 suggests that on average exploration creates less value than exploitation in partner selection, all other things being equal. While there has been evidence that investors emphasize long-term growth potentials such as those stemming from R&D (Hansen & Hill, 1991), given the difficulty in assessing the outcome of these activities, it is likely that the valuation effect will be contingent. For instance, it was found that exploration in R&D was favored by investors in small firms (McNamara & Baden-Fuller, 2007), suggesting some contingent effect in value creation. Therefore it should be reasonable to argue that when evaluating a strategic move by the firm such as forming an alliance, investors and analysts will factor the contextual elements into their consideration. Given that the relative importance of the argued benefits and costs probably varies under different circumstances, we postulate that the value of the alliance will also depend on certain contextual factors. To be more specific we submit that it is the fit between the choice of the partner and the attribute of the context that determines how much value can accrue to shareholders. In other words, the alliance will have a

higher value if the partner choice in terms of exploration and exploitation is compatible with the circumstance. We label these contextual factors as value contingency.

Environmental Dynamism and Munificence

We are especially interested in contextual factors that may change the relative importance of the benefits and costs associated with exploration and exploitation in partner selection. It has been argued previously that in fast-changing environments the incidence of both exploration and exploitation alliances will be greater than in stable environments (Koza & Lewin, 1998). Thus environmental dynamism represents an important contingency factor that determines value creation in alliances. In fact many studies on exploration-exploitation in alliance formation incorporate environmental uncertainty in their analysis (Goerzen, 2007; Lin, Yang, & Demirkan, 2007). Environmental dynamism, also known as environmental turbulence or uncertainty (Dess & Beard, 1984), is characterized by the rate of change and innovation in the industry as well as uncertainty or unpredictability of the actions of competitors and customers (Miller & Friesen, 1983).

We argue that a dynamic industry environment will enhance the benefits of exploration in partner selection. Previous studies have shown that entrepreneurial strategic postures characterized by risk-taking, innovative, and proactive organizational behaviors are compatible with a dynamic environment (Miller, 1987; Miller & Friesen, 1983; Miles, Govin, & Heeley, 2000). Rowley, Behrens, & Krackhardt (2000) reported that dynamic environments favor a high level of investment in exploration alliances. It is also argued that to cope with uncertainty firms should connect themselves to non-redundant partners in an attempt to gain new information and knowledge (Goerzen, 2007). Fast technological change, therefore, drives the need for distant search (exploration) to maintain competitive advantage (Rosenkopf & Almeida, 2003). In such an environment, uncertainty in the outcome of exploration becomes less important compared to greater uncertainty imposed by the environment, whereas the informational advantage of exploration is likely to be even greater as the ability to quickly respond to changing market needs is crucial for superior firm performance. Moreover incremental performance enhancement through exploitation becomes short-lived in dynamic environments, whereas the informational disadvantage of exploitation exacerbates the challenge faced by the firm and might even endanger the firm's survival. All the above arguments suggest that in a dynamic environment, the value of exploration in partner selection may exceed the value of exploitation. Hence we hypothesize that,

H2: Exploration in partner selection is positively associated with abnormal stock market returns in industries of which competitive environments are changing fast.

A second contextual factor we are interested in is environmental munificence, defined as the extent to which a business environment supports sustained growth (Dess & Beard, 1984). Environments that are mature or shrinking are normally characterized as having low levels of munificence, whereas rapidly growing markets are typically associated with a high degree of munificence. Like environmental dynamism, environmental munificence influences organizational behaviors and outcomes. Specifically, it is argued that a munificent environment provides the needed resources to develop capabilities for managing an exploration strategy (Bierly & Daly, 2007). In hostile or less munificent environments, the scarcity of resources requires firms to avoid excessive risk-taking and pay greater attention to the conservation of resources (Goll & Rasheed, 1997). As such organizations respond to hostile environments through strategy-making characterized by greater analytical efforts and reduced innovation (Miller & Friesen, 1983). High uncertainty in the outcome of exploration becomes even more

costly to the firm in the presence of resource scarcity, causing the value of the alliance to decrease. In such an environment, incremental improvement through exploitation may represent a more viable strategy for the firm.

On the other hand, munificent environments invite extensive risk-taking, forceful proactiveness, and an emphasis on novelty in strategies since fast-growing markets often lack established standards, require new technologies, and allow innovation failures. This makes exploration in partner selection a promising strategy. Moreover, the profitable industry environment allows the firm to use slack resources toward exploration efforts, creating necessary in-house competencies to manage relationships with new partners. As the outcome uncertainty in exploration is reduced by better management and execution, the value of exploration will rise accordingly. Meanwhile, the effect of munificence on exploitation is at best minimal because the latter consumes limited organizational resources and often leads to predictable results. Hence it is reasonable to anticipate that as the level of environmental munificence increases, the value of exploration in partner selection will eventually surpass the value of exploitation, and building new ties become a more attractive strategy for the firm. As such we argue that,

H3: Exploration in partner selection is positively associated with abnormal stock market returns in industries of which competitive environments are munificent.

METHODOLOGY

Data

We collected the data on alliances from the Mergers, Acquisitions, and Alliances' database of the Securities Data Company (SDC). We chose a time period from 1997 to 2003, a period for which we believe SDC has the most comprehensive coverage. We collected alliance data for U.S. manufacturing industries (SIC 2000 – 3999). There are certain reasons for choosing the manufacturing division. First of all, a large number of manufacturing firms, such as those in the automobile, chemicals, computer equipment, electronic components, pharmaceuticals, and telecommunications equipment industries, have long-lasting tradition of using alliances for growth and success. Alliances are an important element in their corporate strategy. Second, restricting our sample to the manufacturing industries will reduce cross-industry differences in the purpose, management, and assessment of alliances, while at the same time will allow sufficient variance in some of our variables across these industries. For example, it has been reported that there was significant variance in the task environmental dimensions across the U.S. manufacturing industries (Dess & Beard, 1984).

As the term "alliance" often takes a vast array of organizational forms, ranging from licensing agreements to joint ventures (JVs), we restricted our sample to equity-based joint ventures, also in an attempt to controlling for differences in the management and assessment of alliances across different forms. We excluded joint ventures which involved more than two participants (including the focal firm). Since we needed to compare the firm's present partner with the past partners to get the measure for exploration in partner selection, it became difficult to measure the variable if more than one partner was involved in the joint venture. We also excluded announcing firms with only one alliance (not necessarily joint ventures) during the sample time period for the same reason. We compiled data from Compustat database as well, from which we obtained the measures for firm size, primary industry, and environmental characteristics. We also used the geography data published by the U.S. Census Bureau to calculate the variable of geographic distance. The final data set after excluding observations with missing data consisted of 1061 joint ventures made by 367 firms in the seven-year period (1997-2003).

Dependent Variable

Abnormal stock market returns

To measure the economic value that an alliance can add to the firm, we used the event study methodology to compute abnormal stock market returns following new alliance announcements. Finance and accounting researchers employ a standard asset pricing model to predict firms' stock returns and use the residuals obtained from the model as a proxy for firms' excess returns. Standard event study methodology uses daily data on the stock market returns of each publicly traded firm in the sample over a pre-event estimation period to estimate the following market model (Brown & Warner, 1985; Fama, 1976):

$$r_{it} = \alpha_i + \beta_i r_{mt} + \epsilon_{it}$$

In the above equation rit denotes the daily returns of firm i on day t, r_{mt} denotes the corresponding daily returns on the value-weighted market returns, αi and βi are firm specific parameters, and ϵ_{it} is distributed i.i.d. normal. The methodology then uses the estimated firm specific parameters $\hat{\alpha}_i$and $\hat{\beta}_i$ to predict the daily returns for each firm over a chosen event window surrounding the event day, using the following equation:

$$\hat{r}_{it} = \hat{\alpha}_i + \hat{\beta}_i r_{mt}$$

where $\hat{r}_{it}$ is the predicted daily return. The daily excess return for firm i can be calculated using the following equation:

$$\hat{\epsilon}_{it} = r_{it} - \hat{r}_{it}$$

However, a strong assumption of this approach is that there is no other event in the estimation period. When one or more events fall into the estimation period, they will confound the calculation of the expected normal returns$\hat{r}_{it}$. An alternative proxy for the expected normal returns, as suggested by previous research, is the value-weighted market returns or the equally-weighted market returns (Haleblian & Finkelstein, 1999; Brown & Warner, 1985). As our sample includes firms that had multiple alliances within the same year, we chose to use the value-weighted market returns as the expected normal returns. The equation to compute daily access returns then becomes

$$\hat{\epsilon}_{it} = r_{it} - r_{mt}$$

Brown and Warner (1985) have shown that the approach of standard OLS market model and the approach of using market adjusted returns have similar statistical power to detect abnormal market movements. The excess returns thus reflect the daily unanticipated movements in the stock price for each firm over the event period. To capture any information leakage or information lagging effects while simultaneously avoid the influence of other firm events that possibly occurred within the event window, we adopted a relatively small window to calculate the cumulative stock market abnormal returns (CARs). The window we used was a three-day period starting from one day before the event day and one day after the event day, i.e., day -1 through day 1. Regarding the use of abnormal returns to represent value gains from a strategic move such as forming an alliance, researchers have expressed concerns that the stock market reaction might not reflect the actual success of the implementation of the strategy. Past empirical research, however, has revealed that stock market-based measures such as abnormal returns and perceptual measures such as managerial assessment of alliance success are highly correlated (Kale, Dyer, & Singh, 2002; Koh & Venkatraman, 1991).

Independent Variables

Exploration in partner selection We measured exploration in partner selection in a two-step procedure. First, we compared the present partner with the firm's previous partners within one

year prior to the announcement date of the joint venture. For example, if the firm announced a joint venture on January 1, 1998, we then checked whether the firm had any previous alliance relationships with the same partner (not necessarily joint ventures) within the period from January 1, 1997 to December 31, 1997. If we found any such relationships, the new joint venture would be taken as a repeated tie and the variable of exploration in partner selection would have a value of zero, since this actually indicated exploitation in partner selection. If not, the new joint venture would be taken as a new tie to the firm. Then we compared the present partner's primary industry with the previous partner's primary industries, also dated back one year from the announcement day. If we could not find any previous partner with the same industry as the present partner (New Partner & Different Industry in Figure 1), the variable of exploration in partner would have a value of one. Otherwise the variable would have a value of 0.5, as it implied high partner-specific learning while low context-specific learning (New Partner & Same Industry in Figure 1). To summarize, if the present partner was an existing partner, the choice involved low partner-specific learning and low context-specific learning, and the variable was given the low end value zero. If the present partner and its industry were both new to the firm, which indicated high partner-specific learning and high context-specific learning, the variable was given the high end value one. If it was a new partner from an existing industry, the variable was given the middle value 0.5.

Environmental dynamism and munificence We focused on the announcing firm's primary industry and adopted the operationalizations by Dess and Beard (1984) for measuring the two environmental variables. According to the authors, the indicator for dynamism should reflect the volatility or unpredictability of the firm's dominant industry environment, whereas the indicator for munificence needs to reflect growth in the same environment. While Dess and Beard (1984) used the data obtained from the U.S. Census Bureau, we used the data from Compustat and followed a similar approach used by Keats and Hitt (1988). Specifically, we first aggregated annual net sales across all firms in each relevant manufacturing industry at the three-digit SIC code level by using the Compustat data. Then we constructed a time-series regression equation in which the dependent variable was the natural logarithm of the aggregated net sales and the independent variable was time as measured by year. For example, if the joint venture was announced in 1998, we used the industry sales data from 1994 to 1998 and the time variable to build the following equation:

$$Y_T = b_0 + b_1 T + \varepsilon$$

where Y is the natural logarithm of industry sales, T is year (1994~1998), and ε is residual. There were five data points in the regression above and the regression was run for each three-digit SIC industry in the sample. The measure for dynamism was the antilog of the standard error of slope b_1, reflecting the volatility in the growth rate for a particular industry. The measure for munificence was the antilog of b_1, indicating the average growth rate over the period.

Control variables

Alliance experience Like previous research on alliance experience, the announcing firm's alliance experience was measured by counting the number of each firm's alliances starting from January 1, 1997 to the event day when the firm announced the new joint venture (excluding the new joint venture). The data on alliances was obtained from the SDC database. When we collected the alliance data we read through the summary description of each alliance and removed any duplicate records. We also referred to other data sources such as the LexisNexis Academic database to verify the announcement dates reported by the SDC database. In case there was a discrepancy about the date we resolved the inconsistencies by referring to other news and wire sources. The accurate announcement dates would ensure the measurement reliability in both abnormal returns and alliance experience.

Firm size Like many previous studies that used abnormal returns to capture the value of an alliance, we controlled for firm size measured by the natural logarithm of total assets of the firm.

Partner relatedness Past alliance research has suggested that similarity or complementarity in partners' resources affects alliance outcomes (Lavie, 2006; Sampson, 2007). Hence we controlled for the relatedness in partners' industries by using a dummy variable, which was set to the value of 1 if the two partners had the same four-digit SIC code and 0 otherwise.

Foreign partnership Since our sample included joint ventures with foreign firms, we created a dummy variable named foreign partnership which was equal to one if the joint venture was a cross-border alliance.

Industry and year effects We also controlled for industry effects by using industry dummies at the two-digit SIC code level. Year dummies were included to control for potential time effects.

Alliance type The type of alliances was also controlled for by using dummy variables representing licensing services, R&D services, marketing services, manufacturing services, and supply services. Table 1 provides the descriptive statistics and the correlation matrix for all the key variables.

Table 1: Descriptive Statistics and Correlation Matrix

		Mean	S.D.	1	2	3	4	5	6	7	8
1	CAR (in percentage)	0.61	5.63	1.00							
2	Exploration in Partner Selection	0.85	0.30	-0.01	1.00						
3	Environmental Dynamism	1.03	0.04	-0.04	0.04	1.00					
4	Environmental Munificence	1.07	0.12	-0.02	-0.05	0.40***	1.00				
5	Alliance Experience	21.59	35.84	-0.01	-0.19***	0.01	0.04	1.00			
6	Assets (in billion dollars)	48.03	98.09	-0.05	-0.15***	0.13***	0.15***	0.37***	1.00		
7	Related Alliance Dummy	0.16	0.36	0.02	-0.18***	-0.07	-0.07**	0.04	0.03	1.00	
8	Foreign Partner Dummy	0.68	0.47	0.01	-0.06**	-0.0**	-0.05*	0.07**	0.04	0.05*	1.00

DATA ANALYSIS AND RESULTS

Our dataset consists of 1061 events over seven years and across 367 firms. We used ordinary least squares (OLS) regression for the pooled data. As we mentioned earlier, our sample included firms that made multiple announcements over the seven-year time period. Including firms with multiple events (records) may violate the homoskedasticity assumption of OLS, resulting in biased estimates of standard errors. To correct for this bias we ran the analysis with Huber-White standard errors clustering on firms, which will produce a robust estimation of standard errors given the presence of arbitrary correlations in error terms within the cluster. This method, also called Rogers standard errors (Rogers, 1993), is robust to different specifications of the dependence in error terms within a cluster.

Table 3 reports the results of regression analysis using the firm's cumulative abnormal returns (CARs) as the dependent variable. Model I includes only the main explanatory variable, exploration in partner selection, together with the control variables. The coefficient on exploration in partner selection is negative and significant at the 5% level, suggesting that forming a joint venture with a new partner from a new industry lowers the CAR by almost 1%, compared to forming a joint venture with an existing partner. This result is consistent with H1, which states that exploration in partner selection is negatively related to the value of an alliance. However, we realize that there could be self-selection bias by which the firm self-selected itself with respect to the partner choice based on other firm attributes. Without controlling for self-selection, the estimated coefficient of the choice variable is likely to be biased. To correct for self-selection bias, we employed Heckman selection model. Heckman model estimates two regression equations. The first is a probit model that estimates the impact of firm heterogeneities on the choice variable. The second is a regular regression model that estimates the impact on the dependent variable of the explanatory variables plus an additional parameter λ that measures self-selection bias. λ is obtained from the first equation.

Table 2: Regression analysis examining the relationship between abnormal stock market returns and exploration in partner selection

	I	**II**	**III**	**IV**
Exploration in Partner Selection	-0.986** (-2.06)	-0.943* (-1.96)	-0.963** (-1.98)	-0.894* (-1.77)
Environmental Dynamism			-1.251 (-0.30)	-3.514 (-0.90)
Environmental Munificence			-0.133 (-0.11)	0.217 (0.19)
Alliance Experience			0.006 (1.27)	0.008* (1.67)
Exploration × Dynamism				26.586* (1.69)
Exploration × Munificence				-7.092* (-1.87)
Firm Size	-0.247** (-2.16)	-0.260** (-2.13)	-0.281** (-2.16)	-0.290** (-2.22)
Related Alliance Dummy	-0.138 (-0.28)	-0.142 (-0.29)	-0.422 (-0.77)	-0.423 (-0.78)
Foreign Partnership Dummy	-0.051 (-0.14)	-0.135 (-0.33)	-0.050 (-0.13)	-0.013 (-0.04)
λ (Self-selection Bias)		1.864 (0.53)		
Year Fixed Effects:				
Year 1998	-3.67e-4 (-0.00)	-0.011 (-0.02)	-0.057 (-0.12)	-0.105 (-0.23)
Year 1999	-0.116 (-0.24)	-0.146 (-0.30)	-0.210 (-0.41)	-0.209 (-0.41)
Year 2000	-0.086 (-0.14)	-0.113 (-0.19)	-0.254 (-0.40)	-0.231 (-0.37)
Year 2001	-1.708*** (-2.64)	-1.732*** (-2.65)	-1.824*** (-2.72)	-1.886*** (-2.81)
Year 2002	-0.140 (-0.23)	-0.159 (-0.25)	-0.358 (-0.51)	-0.346 (-0.49)
Year 2003	-0.319 (-0.48)	-0.350 (-0.52)	-0.502 (-0.71)	-0.519 (-0.72)
Industry Fixed Effects:				
SIC 22	-0.856	-0.848	-2.321	-2.275

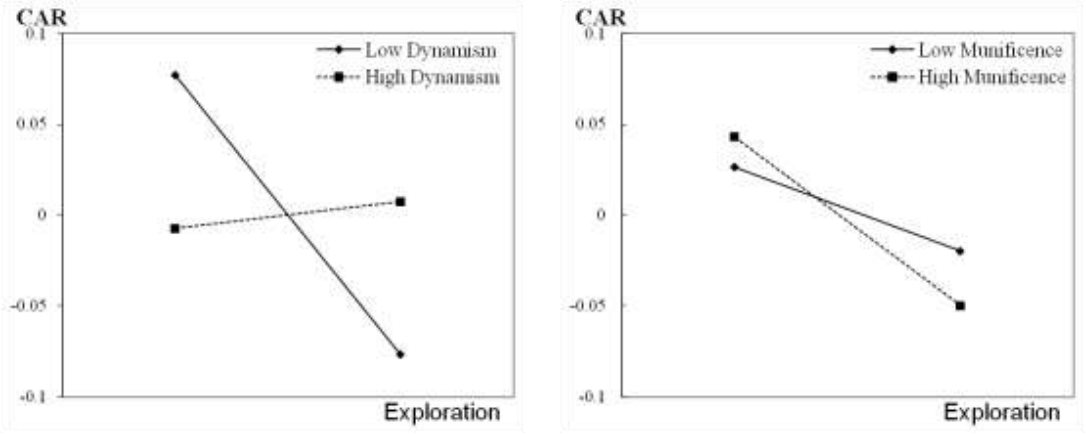
	I	II	III	IV
	(-0.54)	(-0.53)	(-1.28)	(-1.25)
SIC 23	0.816	0.775	-0.428	-0.372
	(0.76)	(0.72)	(-0.31)	(-0.27)
SIC 24	2.780***	2.763***	1.219	1.232
	(2.77)	(2.72)	(0.82)	(0.83)
SIC 25	4.905***	4.911***	3.700***	3.711***
	(6.73)	(6.71)	(3.04)	(3.07)
SIC 26	0.011	-0.006	-1.446	-1.436
	(0.01)	(-0.01)	(-0.95)	(-0.95)
SIC 27	-0.067	-0.118	-1.430	-1.648
	(-0.03)	(-0.05)	(-0.54)	(-0.60)
SIC 28	0.778	0.757	-0.472	-0.462
	(1.25)	(1.21)	(-0.44)	(-0.43)
SIC 29	1.345	1.360	0.418	0.441
	(0.97)	(0.99)	(0.22)	(0.23)
SIC 30	2.369*	2.357**	1.106	1.048
	(2.04)	(2.04)	(0.70)	(0.65)
SIC 31	3.431***	3.346***	1.735	1.754
	(3.91)	(3.67)	(1.33)	(1.36)
SIC 32	-0.930	-0.949	-1.236	-1.207
	(-0.95)	(-0.96)	(-1.24)	(-1.20)
SIC 33	0.674	0.674	-0.608	-0.614
	(0.52)	(0.51)	(-0.38)	(-0.38)
SIC 34	0.510	0.507	-0.613	-0.651
	(0.43)	(0.42)	(-0.41)	(-0.44)
SIC 35	0.887	0.808	-0.489	-0.498
	(1.41)	(1.28)	(-0.44)	(-0.45)
SIC 36	0.886	0.034	0.770	0.778
	(1.15)	(1.08)	(1.04)	(1.03)
SIC 37	1.188*	1.175*	-0.111	0.144
	(1.84)	(1.82)	(-0.10)	(-0.13)
SIC 38	0.226	0.217	-0.959	-0.964
	(0.26)	(0.25)	(-0.78)	(-0.78)
SIC 39	-0.764	-0.821	-2.395	-2.446
	(-0.34)	(-0.36)	(-1.00)	(-1.03)
Alliance Type Fixed Effects:				
Licensing	2.177	2.222	2.010	1.924
	(0.93)	(0.95)	(0.85)	(0.80)
Manufacturing	-0.196	-0.183	-0.178	-0.118
	(-0.58)	(-0.54)	(-0.52)	(-0.34)
Marketing	-0.304	-0.304	-0.327	-0.310
	(-0.62)	(-0.62)	(-0.66)	(-0.63)
Research & Development	0.680	0.702	0.636	0.622
	(1.09)	(1.11)	(1.01)	(0.99)
Supply	-1.148	-1.122	-1.177	-1.117
	(-1.48)	(-1.44)	(-1.49)	(-1.41)
Constant	3.888**	3.748**	6.256	8.171*
	(2.25)	(2.15)	(1.34)	(1.81)
Observations	1061	1061	1061	1061
R-squared	4.60%	4.63%	4.96%	5.29%

Model II includes λ as an additional variable and re-estimates the impact of exploration in partner selection on abnormal returns. We suspected that the choice variable might be affected by factors such as environmental conditions, the type of the alliance, and alliance experience.

As such we included these factors in the first equation of Heckman selection model. The results are not reported here but we found a positive effect of environmental dynamism on the choice variable and a negative effect of alliance experience on the choice variable. We report the results of the second equation in Table 3 under Model II. After controlling for self-selection bias, exploration still has a negative and significant effect on abnormal returns ($b = 0.943$, $p < 0.05$). The coefficient for self-selection bias is not significant.

Model III includes the major contingency variables into the regression model, namely, environmental dynamism and munificence and Model IV adds the two interaction terms between exploration and the two contingency variables, all centered before entering the regression. H2 states that exploration in partner will be positively related to abnormal returns in a dynamic industry environment. The exploration-dynamism interaction has a positive and significant coefficient ($b = 26.586$, $p < 0.05$), suggesting that at a high level of environmental dynamism, the negative relationship between exploration and abnormal returns can become positive. To illustrate this interaction effect, we plotted the relationship between exploration and CAR at low and high levels of environmental dynamism (Figure 2, left). At the low level of dynamism, the line has a negative slope, whereas at the high level of dynamism the slope turns positive, indicating a positive relationship between exploration and CAR. The result here supports H2. H3 proposes that at a high level of environmental munificence there will be a positive relationship between exploration in partner selection and abnormal returns. This prediction, however, is not supported by the result. The exploration-munificence interaction has a negative and significant coefficient ($b = -7.092$, $p < 0.05$), making the negative exploration-CAR relationship even stronger at a high level of environmental munificence. The interaction effect is depicted by drawing the line at different levels of munificence (Figure 2, right).

Figure 2: The Moderating Effects of Environmental Dynamism and Munificence



DISCUSSION

So far our empirical analysis has revealed some interesting findings, as well as some surprising results. We expected that exploration in partner selection would be positively related to abnormal returns, a proxy for the value of the alliance, in a munificent industry environment. Surprisingly, the empirical results revealed the opposite effect. The negative interaction effect of exploration-munificence can be interpreted in a different way, i.e. the positive relationship between exploitation in partner selection becomes stronger in a munificent environment. We suspect two possible reasons for this finding. First, firms may not choose exploration in a munificent environment. Exploration is usually driven by long-term objectives, often at the expense of short-term efficiency. In partner selection, exploration aims at accessing non-

redundant knowledge and seeking future growth opportunities through forming new ties. In a munificent environment, although firms can afford sacrificing short-term gains, they probably do not perceive the exploration option to be the optimal choice as competitive advantage can be well sustained. Exploitation, instead, is often initiated by short-term goals, such as capitalizing on excess production capacities or advantageous market conditions. Therefore, in a munificent environment, incremental improvement enabled by exploitation may be preferred by firms. The descriptive statistics provide some preliminary evidence that there is probably a negative relationship between exploration and munificence. Second, a munificent environment is often characterized by a high rate of growth. One implication of the high growth rate is that firms need to enhance their functional competencies, including those in procurement, manufacturing, marketing, sales, and logistics, to meet the market demand for their products. Under such circumstances, the strategic focus is the speed to market rather than the novelty or innovativeness provided by the product. To meet the need for speed, firms should formulate strategies that can produce certain and quick outcomes. Exploitation, as a result, may satisfy such needs and enhance the value of the alliance.

The alliance literature has called upon research on the important decision-making problem pertaining to partner selection. After reviewing the past research on partner selection, we found that antecedents to partner selection such as complementarity, similarity, or relational capital all can be linked to the learning activities involved in an alliance. This observation motivated us to adopt the perspective of organizational learning and use March's exploration-exploitation dichotomy to conceptualize the alliance partner selection decision. We defined exploration and exploitation based on the choice of the partner, with a significant difference existing in the level of learning in each of the choices. It should be noted that in our conceptualization, exploration and exploitation are mutually exclusive. We also found that the literature is short of studies on the relationship between partner selection and value creation in alliances. To address this research gap, we built a model linking exploration and exploitation in partner selection to the value of the alliance. We found that the choice of the partner has a direct impact on the value of the alliance, as measured by excess returns during the announcement period of the alliance. This finding should complete the existing alliance literature on partner selection. For example, using a similar argument, Yamakawa et al (2011) found that a higher ratio of exploration alliances in a firm's alliance portfolio were negatively associated with firm performance measured by return on assets (ROA). Our findings seem to suggest that the stock market reacts in a similar manner to such alliances.

While a choice of the alliance partner may be under managerial discretion, such a choice may also be affected by the environment, or at least the outcome of the choice would be affected by varied environmental conditions. We considered two environmental variables and found that the one that reflects the change and innovation has a positive moderating effect on the exploration in partner selection. In a dynamic industry environment, the negative relationship between exploration and value creation becomes positive, as the firm needs to continuously innovate to cope with uncertainty imposed by the environment. In other words, exploration in partner selection is more likely to add value to the firm in a dynamic environment than in a stable environment. In terms of the negative moderating effect of munificence, a recent study by (Jensen, Simsek, & Cao, 2012) suggested that resource munificence could mitigate resource constraints associated with ambidextrous activities, defined as pursuing both exploratory and exploitative activities simultaneously, and enhance the positive effect of such activities on unit performance. As a result, merely seeking exploration in partner selection under munificent environments may not yield the best anticipated value from such an alliance, thus deepening the negative effect of such a choice.

Managerial Implications

Our empirical findings should have important implications for managers, especially for those who make the decision as to "with whom we should ally". The negative relationship between exploration in partner selection and abnormal returns highlights the need to communicate critical information to outside shareholders and other investors. Exploration is often a decision made by managers, who as insiders may have some proprietary information about the importance of the partner choice, which might not be well conveyed to the stock market. The finding that exploration generally decreases shareholder value reflects not only the investors' concern as to forming a relationship with a partner unknown to them, but also to some extent the management's inability to release some critical transactional information into the market, such as the strategic benefits and importance of choosing a new partner. If the management can do a better job in reducing information asymmetry between shareholders and them, the market reaction to exploration selection might change in a way that is favorable to them.

The effects of the contingent factors are also important for decision makers in the firm. Managers need to be aware that dynamic environments require a proactive and forward-looking strategy, such as choosing a partner that can bring in new knowledge and capabilities. Exploration in partner selection therefore is a more viable strategy in a dynamic environment than in a stable environment. Also in a dynamic environment, exploration can create greater value than exploitation. Exploitation aims at short-term efficiencies and incremental improvement, which tend to be short-lived when the environmental conditions change rapidly. As such managers probably should avoid forming too many repeated ties with existing partners in such environments as they provide little value to the firm. Actually one study has shown that in the presence of technological instability, the effect of repeated ties is negative on economic performance at the corporate level (Goerzen, 2007). This suggestion demands managers' attention as they usually have positive attitude to partners with whom they have had relationships (Zollo, Reuer, & Singh, 2002). As managers choose to ally with new partners, they also need to work hard to take advantage of the ties to cope with environmental uncertainty. Extra coordination and collaboration efforts are probably required in such partnerships.

LIMITATIONS AND FUTURE RESEARCH

The first limitation pertains to the sample we used. We chose joint ventures that were formed by US manufacturing firms. This limitation may restrict the generalizability of our results to other industry sectors or other types of alliances. But as we mentioned earlier, restricting the sample to certain industries and a specific form of alliance should help minimize cross-industry and cross-type differences in the intention, governance, and evaluation of alliances, hence increasing internal validity of our model. Secondly, we used the partner's primary industry to approximate the technological background of the partner when constructing the measure for exploration in partner selection. This could overestimate the similarity between the partner and the previous partners. To address this issue, future researchers should consider some continuous measure such as a "technological distance" measure that captures the difference between the present partner and previous partners. The patent portfolio of the firm can be used to calculate this distance measure. Thirdly, there is a legitimate concern that our sample could be overrepresented by alliances with an exploration focus, as it has been found that recurrent alliance relationships are less likely to be equity-based (Gulati, 1995). Although it is not very clear how this limitation would affect our results, we conducted a preliminary t test of the exploration variable between a group of joint ventures and a group of non-JV type alliances. The results (not reported) showed that there was no significant difference in the mean across the two groups.

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DECISION SCIENCES INSTITUTE
Allocation Decision: A Teaching Case for Accounting Classes

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ABSTRACT

This paper presents a teaching case for use in several possible accounting classes. The case deals with the allocation of investment income among different segments of a nonprofit entity. Students are given the opportunity to determine if a proposed allocation is appropriate or to suggest a different allocation. In either case, students are expected to justify their response. This case allows students to do some allocation calculations and to think critically to evaluate the proposed or alternative allocations.

KEYWORDS: Allocation Decision, Revenue Allocation, Accounting Allocation, Allocation Base, Teaching Case

INTRODUCTION

In many accounting contexts, allocations are made (Zimmerman, 1995). Some of the common allocations include the following: (1) allocation of service department costs to the departments using those services (Anthony and Young, 1994; Garrison, et. al., 2015), (2) allocation of the cost of an asset over its useful life through depreciation, amortization, or depletion (Spiceland, et. al., 2018), (3) allocation of overhead costs to different activities or products in a production setting (Garrison, et. al., 2015), (4) allocation of joint costs to the multiple products produced from a common process (Garrison, et. al, 2015), (5) intraperiod tax allocation (Spiceland, et. al., 2018), and (6) allocation of revenues or expenses among different segments of an organization.

This teaching case focuses on the last of these items—the allocation of investment income among the various segments of a nonprofit association. It is loosely based on a real-life situation, but the names and numbers are disguised as they are presented in the case. It could be used in any of several classes, depending on the objective(s) to be met by the instructor. It could be used in an auditing class to discuss how an auditor should work with a client that has made allocations in the process of preparing the financial statements. It could be used in a governmental/nonprofit accounting class, as it relates to a nonprofit organization that will report net assets rather than stockholders' equity. It could be used in a managerial accounting class when different allocation methods are discussed. It could also be used in a financial accounting class as a discussion of how investment revenue should be allocated among the sub-entities of an organization.

Students will be given a suggested allocation of investment income from pooled investment funds across the segments of the organization. The students are then asked to either justify the allocation method used or to suggest a different allocation method. If a different allocation method is chosen, it should be justified with appropriate reasoning. This case allows students to not only work with specific allocation concepts and calculations, but it also allows the students to think critically about why an allocation method is appropriate or not.

CASE MATERIAL

The Humanities Professors Association (HPA) is a nonprofit academic organization of college and university humanities professors organized to provide a forum for the exchange of ideas related to teaching and research. It started many years ago as a small group of professors from a few institutions that were geographically close to each other. However, it has grown over time. It has become a national organization, consisting of humanities professors from around the United States. It even includes some members from other countries.

The HPA is led by a Board of Directors elected by the membership of the HPA. Board members are faculty members from various institutions who serve in rotating officer positions, finally serving as the HPA president for one year and then as the past president for one year before their board membership is concluded. These officer positions are non-paid positions, and the officers get financial support from their colleges or universities for the travel and meeting attendance costs involved in their service.

To provide continuity and administrative support for these volunteer officers, a home office has been established at Eastern State University (ESU). Four employees at the home office provide ongoing marketing, administrative, technology, and bookkeeping support for the organization. One of these employees is hired as the Executive Director who is a non-voting member of the Board of Directors. The employees are treated as employees of ESU, but the HPA reimburses ESU for the compensation and benefits paid to these individuals. Because the HPA objectives are consistent with the ESU mission, ESU provides facilities and equipment to support HPA operations. The HPA pays a set annual amount to ESU as a partial reimbursement for this support. As needed, the home office contracts with lawyers and CPAs for legal and accounting expertise.

From its inception, HPA has held an annual meeting where humanities professors can come and share their teaching ideas and their research. This meeting provides a networking opportunity for college and university professors to improve the humanities curriculum and teaching methods. It also provides an outlet for professors to share and get feedback on their research. In fact, over time, HPA began publishing an academic journal six times per year as an outlet for excellent research in this academic area.

The success of the annual meetings coupled with the inability of some faculty to get funding to attend when the meetings are far away and more expensive led to the creation of regional affiliates to the national organization. These regional affiliates are part of the national organization, but they hold regional conferences annually within the geographic area of the region. To date, three regions have been created and have actively sponsored annual regional meetings: Eastern Region (EHPA), Midwest Region (MHPA) and Western Region (WHPA). These regions each have a Board of Directors, faculty elected by members and who volunteer their time to help organize the regional annual meetings. Because these regional officers are not simultaneously members of the HPA Board of Directors, they do not make decisions for the national organization, but they do make decisions for the region in which they serve.

Each region has significant autonomy in choosing the venue for its regional meeting, determining an appropriate conference registration fee, and budgeting to ensure that the meeting revenues will cover the meeting costs. The regional officers contract with a hotel in the desired location to host the meeting and provide the food and beverage for functions that are included in the meeting registration fee. This usually requires the regions to commit to a certain number of room nights that meeting attendees will utilize during the meeting. It also requires

the region to commit to a certain minimum food and beverage cost that will generate additional revenue for the hotel property. By guaranteeing a specific number of room nights along with a food and beverage minimum, regions generally get a concession from the hotels that there will be no rental charges for the meeting rooms, as the hotel is already guaranteed to earn adequate revenue from the meeting through the occupied room nights and the food and beverage guarantee.

From time to time, a region may find that a specific meeting was not as successful as anticipated and meeting attendees do not fill the contracted hotel room block. This can result in a financial penalty to the region. In addition, once the contract has been signed with the hotel, if meeting attendance is lower than expected, resulting in less than the budgeted revenue, the food and beverage minimum must still be met. Therefore, regions can have losses in some years. To plan for the risk of losses, regions often set the meeting registration fee above the amount that would provide an expected breakeven for the meeting. Thus, the regions typically have a positive amount of net assets on their balance sheets, as they cannot expect the national organization to step in and subsidize them. Over time, each region, as well as the national organization, has increased its net asset balance, providing a safety net for the risk of an unsuccessful meeting and to provide funds for ongoing disbursements.

Over a period of years, HPA officers have improved in budgeting for meetings and contracting with hotels. As net assets grew, the home office began investing some of the cash in investment accounts with a major national investment company to earn a return on these assets. Other funds had been kept in non-interest bearing checking accounts. Regions have also pooled some of their net assets into these investment funds, with the understanding that a larger investment pool would result in a lower expense ratio and provide for better investment opportunities. With input from the regions, the HPA Board has decided to invest approximately 60% of the invested balance in equities and the remaining 40% in bonds. Since the investment funds have typically been growing, this was determined to be an appropriate diversification to provide an appropriate return without excessive risk. The national and regional boards each determine how much to invest in the pooled funds and how much they want to keep in non-interest bearing checking accounts. Purposes for amounts in the checking accounts would be to provide for ongoing transactions, to provide a safety net of easily accessible funds, and to avoid investment risk in the pooled investment funds. For at least the last two years, no withdrawals have been made from the investment funds, and no deposits have been made except the reinvested interest and dividends earned on the existing fund balance. Per Generally Accepted Accounting Principles (GAAP), the investment fund balance is listed at fair value at each reporting date, so unrealized gains are also reflected in the fund balance.

Meeting registration fees are collected by the home office, even for the regional meetings. All expense disbursements are made by the home office, with the regional expenses first being approved by regional officers. The annual financial statements are prepared by the home office. The statements are prepared with separate columns for the national organization and each of the regions. The home office contracts with a CPA firm for the annual audit of the financial statements.

The most recent financial statements have been prepared and were recently sent out to the regional officers. Exhibit 1 shows the Statements of Financial Position for 20X5 and 20X4. Exhibit 2 shows an abbreviated Statement of Activities for 20X5. Because the HPA is a service organization mainly providing an annual meeting for attendees, general teaching and research support for academics, and a journal, the types of assets and liabilities are very limited. Office supplies are immaterial, and space and office equipment are provided by ESU. Operating

revenues for the home office include mostly membership dues and meeting registration fees. Expenses are those related to meeting costs, journal publication, general support of members, and office employee costs. Since the regions have no employees, their operating revenues and expenses relate only to meeting registration fees and meeting costs.

Exhibit 1					
Humanities Professors Association (HPA)					
Statements of Financial Position as of December 31, 20X5 and 20X4					
	20X5				
	Home Office	Eastern Region	Midwest Region	Western Region	
	HPA	EHPA	MHPA	WHPA	Total
ASSETS					
Cash	$752,000	$37,000	$31,500	$27,500	$848,000
Investments	$1,200,608	$228,899	$64,926	$43,567	$1,538,000
Total Assets	$1,952,608	$265,899	$96,426	$71,067	$2,386,000
LIABILITIES AND NET ASSETS					
Liabilities					
Accounts Payable	$27,000	$4,000	$1,500	$500	$33,000
Compensation Payable	$23,000				$23,000
Net Assets					
Unrestricted	$1,902,608	$261,899	$94,926	$70,567	$2,330,000
Total Liabilities and Net Assets	$1,952,608	$265,899	$96,426	$71,067	$2,386,000
	20X4				
	Home Office	Eastern Region	Midwest Region	Western Region	
	HPA	EHPA	MHPA	WHPA	Total
ASSETS					
Cash	$700,000	$30,000	$25,000	$20,000	$775,000
Investments	$1,100,000	$215,000	$60,000	$40,000	$1,415,000
Total Assets	$1,800,000	$245,000	$85,000	$60,000	$2,190,000
LIABILITIES AND NET ASSETS					
Liabilities					
Accounts Payable	$30,000	$2,000	$1,000	$1,000	$34,000
Compensation Payable	$18,000				$18,000
Net Assets					
Unrestricted	$1,752,000	$243,000	$84,000	$59,000	$2,138,000
Total Liabilities and Net Assets	$1,800,000	$245,000	$85,000	$60,000	$2,190,000

Exhibit 2					
Humanities Professors Association (HPA)					
Statement of Activities for the year ended December 31, 20X5					
(abbreviated)					
	20X5				
	Home	Eastern	Midwest	Western	
	Office	Region	Region	Region	
	HPA	EHPA	MHPA	WHPA	Total
Revenues					
Operating Revenues	$1,100,000	$120,000	$75,000	$65,000	$1,360,000
Investment Income	$100,608	$13,899	$4,926	$3,567	$123,000
Less: Expenses	($1,050,000)	($115,000)	($69,000)	($57,000)	($1,291,000)
Change in Net Assets	$150,608	$18,899	$10,926	$11,567	$192,000
Net assets, beginning of year	$1,752,000	$243,000	$84,000	$59,000	$2,138,000
Net assets, end of year	$1,902,608	$261,899	$94,926	$70,567	$2,330,000

Amy Jackson is the newly elected treasurer of the EHPA. She looked through the statements to make sure they reflected the appropriate revenues for the regional meeting and the approved expenses for the region. She wondered about the allocation of the investment income among the different segments of the organization. After inquiring further, she was able to obtain the spreadsheet which was used to allocate the investment income. This spreadsheet is provided in Exhibit 3; Exhibit 4 shows the formulas used in this spreadsheet. Since Amy is a humanities professor, she does not have much business or accounting background. However, she is very intelligent, and she is a clear thinker. She would like your input into the allocation method used to divide the investment income.

Exhibit 3					
Humanities Professors Association (HPA)					
Allocation of 20X5 Investment Income					
(Interest and Dividends, which were reinvested plus unrealized increase in fair value)					
	20X5				
	Home	Eastern	Midwest	Western	
	Office	Region	Region	Region	
	HPA	EHPA	MHPA	WHPA	Total
Net assets, beginning of year	$1,752,000	$243,000	$84,000	$59,000	$2,138,000
20X5 Operating Revenues less Expenses	$50,000	$5,000	$6,000	$8,000	$69,000
Net assets, end of year, before					
investment income allocation	$1,802,000	$248,000	$90,000	$67,000	$2,207,000
Average net assets for 20X5, before					
investment income allocation					
((beg. bal. + end. bal.)/2)	$1,777,000	$245,500	$87,000	$63,000	$2,172,500
Percentage of investment income					
(Average net assets (per column)/					
Total average net assets)	81.80%	11.30%	4.00%	2.90%	100.00%
Investment Income	$100,608	$13,899	$4,926	$3,567	$123,000
Investment balance, beginning of year					
at fair value	$1,415,000				
Investment balance, end of year					
at fair value (including reinvested					
interest and dividends--no additional)					
investments or withdrawals were					
made during the year)	$1,538,000				
Investment Income	$123,000				

	A	B	C	D	E	F
1	Exhibit 4					
2						
3	Humanities Professors Association (HPA)					
4						
5	Allocation of 20X5 Investment Income					
6	(Interest and Dividends, which were reinvested plus unrealized increase in fair value)					
7						
8		20X5				
9		Home	Eastern	Midwest	Western	
10		Office	Region	Region	Region	
11		HPA	EHPA	MHPA	WHPA	Total
12	Net assets, beginning of year	1752000	243000	84000	59000	=E12+D12+C12+B12
13						
14	20X5 Operating Revenues less Expenses	50000	5000	6000	8000	=E14+D14+C14+B14
15						
16	Net assets, end of year, before					
17	investment income allocation	=B12+B14	=C12+C14	=D12+D14	=E12+E14	=E17+D17+C17+B17
18						
19	Average net assets for 20X5, before					
20	investment income allocation					
21	((beg. bal. + end. bal.)/2)	=(B17+B12)/2	=(C17+C12)/2	=(D17+D12)/2	=(E17+E12)/2	=E21+D21+C21+B21
22						
23	Percentage of investment income					
24	(Average net assets (per column)/					
25	Total average net assets)	=B21/$F$21	=C21/$F$21	=D21/$F$21	=E21/$F$21	=E25+D25+C25+B25
26						
27	Investment Income	=B25*$B$36	=C25*$B$36	=D25*$B$36	=E25*$B$36	=E27+D27+C27+B27
28						
29	Investment balance, beginning of year					
30	at fair value	1415000				
31	Investment balance, end of year					
32	at fair value (including reinvested					
33	interest and dividends--no additional)					
34	investments or withdrawals were					
35	made during the year)	1538000				
36	Investment Income	=B35-B30				

CASE REQUIREMENTS FOR STUDENTS

Look at the allocation of investment income among the different segments of the HPA. Analyze how the allocation was made and determine whether you feel the allocation is appropriate or not. If you feel it is appropriate, provide reasons to justify why you feel this way. If you feel there is a better way to allocate this income, provide calculations showing your preferred method and provide reasons to justify your preference. Present your justifications in a way that you think will make sense to Amy Jackson.

TEACHERS' NOTE

This case is not very long. The students could be given the case in advance and asked to read it. Either on their own or in groups, they could consider the appropriateness of the proposed allocation of investment income or present an alternative. The case discussion in class should easily fit within one class period. It is important to allow the students to think critically about the allocation process and make their arguments supporting either the proposed allocation method or their alternative. The allocation of expenses or revenues can have different objectives, so it will be informative to allow students to express their thoughts before leading them in a specific direction.

Hopefully, students will bring up the allocation base used in the proposed allocation—the average net assets of each segment—and determine that this might not be the best allocation for this situation. Since each segment can choose how much to put at risk compared to how much it holds in non-interest bearing checking accounts, it would seem to make more sense in this case to allocate the investment income over the average investment account balance for each segment. Since no additional investments or withdrawals were made during the year, an easy allocation could simply divide up the investment increase proportionately over the beginning investment account balances for each segment. Using this simple allocation, the investment income would be allocated as follows:

Home Office	($1,100,000/$1,415,000) x $123,000 = $95,618
Eastern Region	($215,000/$1,415,000) x $123,000 = $18,689
Midwest Region	($60,000/$1,415,000) x $123,000 = $5,216
Western Region	($40,000/$1,415,000) x $123,000 = $3,477

If a comparison is made between these two different allocation methods, it becomes obvious that the proposed allocation gives the Home Office and WHPA more and EHPA and MHPA less than the allocation based on investment account amounts.

	Proposed Allocation	Improved Allocation	Difference	Difference as Percent of Proposed Allocation
Home Office	$100,608	$ 95,618	$4,990	5.0%
Eastern Region	$ 13,899	$ 18,689	($4,790)	(34.5%)
Midwest Region	$ 4,926	$ 5,216	($ 290)	(5.9%)
Western Region	$ 3,567	$ 3,477	$ 90	2.5%
Total	$123,000	$123,000	$ 0	

This is because the Home Office and WHPA have a much higher percentage of their net assets in non-interest bearing checking accounts compared to EHPA and MHPA, which have a much higher percentage of their net assets in the pooled investment funds. If the percent difference is also examined, it becomes obvious why Amy Jackson may have initially been wondering about

the allocation proposed. While the differences may not seem material, percentage-wise, for the home office and the other regions, the percentage difference for EHPA is quite large.

An analogy to this situation could be raised. What if an employer has a defined contribution pension plan and contributes a specific amount each month for each employee. The employees can choose how the contributions for them will be invested among the different fund options—more in risky funds or more in less risky funds—depending on their risk tolerance. However, at the end of each period, the investment company takes the total returns and divides them equally across all funds regardless of individual fund risk or return. How would you feel if you were willing to bear more risk but got the same rate of return as those who were unwilling to bear risk? How would you feel if you chose less risky funds but ended up with an investment loss because the riskier funds you avoided lost value?

In fact, in the proposed allocation, think about what could happen if there are losses in the investment account. If the board members of one region anticipated the losses and withdrew that region's money from the investment funds and put it into their checking account to avoid the market risk, that region could still be allocated a loss if the loss is allocated across average net assets rather than on the average amount invested. Although that region wanted to avoid risk, it was unable to do so, because the allocation method was not consistent with the risk choices made by that region. In a risk-return tradeoff situation, the returns should be allocated where the risk lies, not in some other fashion.

The proposed allocation may also produce counterintuitive results or gamesmanship that may actually be detrimental to the organization. If segment leaders become aware of this allocation based on average net assets, they may intentionally keep more funds in the non-interest bearing checking accounts, thinking they will share in the investment gains anyway. However, as more and more funds are shifted to checking accounts, the investment account balance will become smaller, reducing possible investment income available to allocate.

In the case given, no investments or withdrawals were made to or from the investment funds. If investments or withdrawals occurred during the year, it would be better to use some average investment balance, either a simple average or a weighted average, depending on the amounts and timing of the deposits and withdrawals (and perhaps on the timing of the investment account increases, both realized and unrealized).

It may also be interesting to discuss why the auditors would have approved the allocation in the proposed method. Are there any reasons why or situations in which the proposed allocation might be appropriate?

FUTURE RESEARCH

This case is in its formative stages and has not yet been tested in a classroom situation. Future research will provide feedback from students after they worked with this specific case. Student perceptions of the case will be used to improve it over time.

CONCLUSION

Although it will likely be obvious to the students that the numbers in this case are disguised, they may find the case more interesting knowing that it is based on a real-life situation for a nonprofit entity. This case gives students an opportunity to evaluate a proposed method for allocating investment income among segments of a nonprofit entity. They can think about an

appropriate allocation base and use critical thinking skills to provide justification for either the proposed allocation method or an alternative method.

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DECISION SCIENCES INSTITUTE
An analysis of classroom collusion using Latent Dirichlet Allocation

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ABSTRACT

In this study, we use Latent Dirichlet Allocation to explore the reflections of students who faced a demanding classroom challenge, to which some responded by colluding. Our five-topic LDA solution describes the cheating event in terms of the nature of the course assignment itself, teams as a resource and support mechanism, the repercussions of cheating, and differences between majors or course tracks. The most relevant topics were the differences between the tracks and the repercussions of cheating. Teams and teammates also play a large role in the students' reflections. We conclude with the implications of these topics in future research.

KEYWORDS: Cheating, Collusion, Latent, Dirichlet, Allocation

INTRODUCTION

In late 2017, The *Washington Post* reported that over 80 marketing students were accused of cheating at a major Midwestern university (Bever, 2017). The accused students used a group-messaging application to share answers pertaining to classroom assignments. Unfortunately, cheating is not a rare occurrence. Business educators view cheating by college students as constituting a long-standing problem that is serious and widespread at both the graduate and undergraduate level (e.g., Cronan, Mullins & Douglas, 2018; McCabe & Trevino, 1996; Simha & Cullen, 2012; Simkin & McLeod, 2010; Wright, 2004; Klein, Levenburg, McKendall & Mothersell, 2007; McCabe, Butterfield & Trevino, 2006). Evidence suggests that the problem is worldwide (Ismail & Yussof, 2016). Cheating in business schools appears to occur no more or less than in other academic disciplines, however, business student attitudes toward what constitutes cheating has been found to be relatively more lax (Klein, Levenburg, McKendall, & Mothersell, 2007).

Cheating is most often defined as either purposefully obtaining access to another person's work without authorization, or as unpermitted collaboration on exams or collusion on assignments (Burrus, McGoldrick & Schuhmann, 2007; McCabe & Trevino, 1996; Sierra & Hyman, 2008) with intent to gain advantage over others (Cronan et al, 2018). Business school administrators and faculties have developed a heightened interest in cheating by students and in business in general (McCabe & Trevino, 2002; Lawson, 2004; Ballantine, Guo, & Larres, 2016). However, efforts to come to grips with classroom cheating have been inconclusive in part because of a lack of contextual studies and studies examining actual cheating behavior.

In an attempt to better understand the phenomenon of cheating, we examine a situation that captures students' guided reflections on an occurrence of classroom collusion in two

sections of an accounting course. Here, we define collusion as secretly sharing information without permission in order to obtain an advantage in the classroom. Ariely (2012) calls this collaborative cheating- where cheating takes place in context of a team. We use Latent Dirichlet Allocation to examine interviews of business students directly involved in a classroom situation where actual student collusion occurred on a relatively large scale. By studying this naturally occurring situation (i.e., where actual collusion has taken place) our results enrich a research stream based predominantly on self-reports of cheating behavior.

LITERATURE REVIEW

The context and morality of cheating and collusion

Most previous research studies have dealt with either the context for cheating or the morality of cheating. For example, McCabe and Trevino (1996: pg. 30) state, "the climate or culture of academic integrity found on campus may be the most important determinant of the level of student cheating on that campus." These authors found that both peer pressure and technology increased the variety of classroom cheating (McCabe & Trevino, 1996). Subsequent papers by McCabe, Trevino, and their colleagues support this conclusion. McCabe and Trevino (1997) also found that peer influence is among the strongest demographic and contextual factors affecting the level of cheating among students. Moreover, at the graduate level, McCabe, Butterfield, and Trevino, (2006) found that perceptions of unethical peer behavior were a justification students often gave for cheating.

Other researchers have also examined the context of student cheating. For example, Kaufmann, West, Ravenscroft, and Shrader (2005) found that students demonstrated immature ethical reasoning and rationalization when they believed peer behavior and the classroom environment encouraged cheating. In responding to open-ended questions about a cheating incident, students revealed both concern with following their perceived norms governing classroom expectations and an ability subsequently to rationalize their behavior. "When everybody cheats, it's okay to join the bandwagon." Another student said, "Coursework is based on the idea of working in teams efficiently and effectively. WE [sic] are so used to this that what others consider 'cheating' to us is 'teamwork'." At the same time, students were not amoral and tried to rationalize their behavior by distinguishing what they had done from what they considered to be more serious, actual cheating behavior. Both the line of reasoning articulated in the studies above and the quotes from Kaufmann et al (2005) suggest that when students perceive an ethical climate in the classroom that is dissonant from their pre-existing moral beliefs or other training, they may behave in ways that are not consonant with these pre-existing beliefs about what is ethically right and wrong.

Another line of research deals with individual understanding of morality and cheating. In the accounting ethics education literature linking moral judgments to actual behavior, Ponemon (1993) describes an extensive effort to teach accounting ethics over a year-long period. Ponemon found that the ethics intervention, as extensive as it was, had little effect on moral reasoning. More interestingly, however, he found free-riding (i.e. not paying the complete cost for study materials) was highest when the moral reasoning scores on the Defining Issues Test were the lowest. Woodbine and Aamirthalingam (2013) also found that Master's of accounting students exhibit very opportunistic behavior and relatively lax attitudes toward cheating when given the opportunity to cheat and advance test scores.

The influence of peer pressure and the moral intensity (Jones, 1991) of the situation may entice students into behaving in ways that others see as unethical (Peterson, 2002; Sierra & Hyman, 2008). As an example, Premeaux (2005) found differences between students at expensive schools with high entrance requirements (tier 1) compared to tier 2 schools. Students at tier 1 schools experience relatively more cheating on written assignments and

attached more significant social stigmas to cheating, while tier 2 students, attending local institutions, reported more cheating on exams were more accepting of the notion that even moral people cheat. Similarly, an organizational culture that tolerates widespread sharing of work may precipitate academically dishonest actions. Citing an example where cheating was observed firsthand, Flynn (2003) states that 'displaying concern for one's classmates and seeking to encourage them during an examination… was only natural for someone reared in a culture that emphasized the well-being of the group (pg. 438).' Consequently, organizational cultures may foster divergent attitudes toward cheating, and these different attitudes may create difficulties for course instructors. Such results highlight the importance of student perceptions of classroom context or climate. Therefore, both context and morality affect cheating. Morality effects are nuanced and related to instrumentality. Context effects appear to be somewhat more direct, that is, students respond to the situation at hand.

The point is that students do not always understand the line of demarcation between cheating and formally assigned group work (Ariely, 2012; Shrader et al, 2012). The widespread use of teams and group assignments may be adding to the level of general confusion about what kinds of sharing are permitted and what constitutes cheating (Kaufmann et al, 2005). For example, a student quoted in the Washington Post article mentioned above (Bever, 2017) said, "I think it [cheating] is not right, but collaboration is required for a lot of classes… so as long as you don't cross this boundary, I think it is good to use it." This statement is fascinating in that it recognizes both context and morality. Some might say it convolutes context and morality. In either case, it indicates that student perceptions of morality and context are important in understanding the phenomena of cheating and collusion (Briggs, Workman, & York, 2013).

Most previous research has examined cheating from an institutional level or has employed survey research to tap into student perceptions. Few have looked at actual situations where students were deeply involved with a particular cheating episode. The purpose of this paper is to present a unique form of analysis of a classroom event where collusion actually took place. In two sections of an advanced accounting course, students were given the assignment of preparing for two sides of a classroom debate. However, some students colluded in an attempt to reduce the amount of work and uncertainty associated with the assignment. We interview the actual students involved with the goal of trying to understand how they viewed the classroom where they either took part in or watched collusion take place. Our purpose here is to seek understanding of this decision to collude by examining what students had to say about the actual situation. Our goal, through the application of latent Dirichlet analysis (LDA), is to identify the underlying structure of words and topics students used to describe their experience. LDA offers the means to explore and provide unbiased insights into the way students actually talk about collusion.

THEORETICAL DEVELOPMENT/MODEL

Study Method

Academic collusion and cheating present researchers with a rather delicate set of research ethics challenges. It would not be ethical for researchers to entrap students into collusion. Moreover, researchers should be extremely cautious about even creating situations where students might be encouraged to collude. Yet few studies examine the background motivations and thought processes of students that collude. The infrequency of actual studies dealing with context belies the fact that collusion seems to occur regularly.

Researchers have relied on a variety of data ranging from student self-reports of cheating behavior (McCabe & Trevino, 1993) to hard evidence such as discarded cheat sheets (Pullen, Ortloff, Casey & Payne, 2000) in order to better understand student cheating. The focal point of these studies varies from the thought process of students who cheated in a particular

setting (e.g., Briggss et al, 2013; Kaufmann et al, 2005; West, Ravenscroft, & Shrader 2004; Shrader, Ravenscroft, Kaufmann, & West, 2012), to comparisons between spontaneous and intended cheating (Genereux & McLeod, 1995), to the role of new cheating technologies (D'Souza & Siegfelt, 2017; McCabe & Trevino, 1996).

Notwithstanding the focus or data source, previous studies have come to the general conclusion that cheating behavior is common (Lawson, 2004). More disturbing for those of us who teach in business schools, however, are the comparative studies that have found business students to be among the most prominent among the cheaters (McCabe & Trevino, 1993). For example, in a two-university study involving four hundred students across disciplines, Roig and Ballew (1994) found that students majoring in accounting and finance held the most lenient attitudes toward cheating among all students in their sample. Compounding this is the finding by Bloodgood, Turnley and Mudrack (2010) that merely taking a business ethics course does not seem to have a much influence on students' views regarding cheating.

Self-reported surveys of attitudes toward cheating, of intentions to cheat, of past cheating, and of reasons for cheating represent the dominant form of data on cheating (Spiller & Crown, 1995; Cizek, 1999, Cronan et al, 2018). While surveys are convenient and useful, and establish the seriousness of the collusion question, they do raise some doubts. There may be a wide gap between how students respond to a survey and how they may actually reflect and respond to questions about their own behavior (Scheers & Dayton, 1987; Karlins et al, 1988; Miceli et al, 1991; Nowell & Laufer, 1997). Consequently, actual behavior provides more validity than self-reports, but presents researchers with ethical challenges because of faculty members' obligation not to encourage collusion.

In this paper, we employ an objective and powerful form of analysis to explore a classroom event where collusion actually took place. We interview the actual students involved in order to tap into their firsthand observations of the classroom dynamics. The sample group is rather small but it represents a major portion of the universe of students involved in the situation. Our intent and method are exploratory. We are not trying to predict collusion. We already know it happened and are now using a powerful form of text analysis to delve into the verbal reasoning of the students about the context. Both colluders and non-colluders were interviewed.

Latent Dirichlet Allocation, Topic Modeling and Words

Current advances in machine learning have led to methods that can be used to uncover hidden or latent relationships present in large data sets. The main difference between these methods and traditional statistical methods is that they make no *a priori* assumptions about relationships present in the data. Latent Dirichlet Allocation (LDA), the topic modeling method used in this paper, is an unstructured machine-learning algorithm that uses probabilistic topic modeling to estimate the likelihood that words are grouped in similar topic areas (Zupic & Cater, 2015). LDA is an analytic technique where observations in a large set of data are explained by similarities in otherwise unclassified groups (Blei, Ng, & Jordan (2003). LDA extracts patterns from a large set of data without a priori assumptions so it is not designed to answer specific pre-formulated hypothese (Schwab & Zhang, 2018). Instead, it is an exploratory technique, one that provides fundamental word-level observations on basic language structure found in a large volume of text. In this way, LDA opens up large data sets to unrestrained discovery. It is a method of discovery that Moro, Cortez and Rita (2015) claim is useful for conducting progressive and relevant research in any disciplinary field. Implementations of LDA and its variants are available from data analytics firms, academic software repositories, or from open source software such as Github.

As an unstructured machine-learning algorithm, LDA makes no assumptions in terms of how information sorts into silos. A researcher inputs textual data to the algorithm, which

produces words and topics from the data. The richness of LDA is that it recognizes that there can be many probabilistic topics and that words are independently distributed among topics (Sugimoto et al, 2011). In our exploratory study, student interviews are the corpus (data set) from which we specify words based on probability distributions called topics.

The basic unit of modeling is the topic. Topics are combinations of words. A topic is a distribution of words over the entire set of words in a corpus (Sievert & Shirley, 2014). Most LDA applications focus on textual data because LDA is able to analyze the underlying structure of large amounts of text (Sugimoto et al, 2011). It is the most widely used topic modeling method because it allows researchers to extract a parsimonious set of an optimum number of latent dimensions or topics in collections of data (Sugimoto, Li, Russell, Finlay, & Ding, 2011; Tirunillai & Tellis, 2014). Dyer, Lang, and Stice-Lawrence (2017) use LDA to ascertain exactly "what is being said" in corporate reports. We use LDA in this study to look for the most referred words in a set of student interviews. In LDA, a 'word' is the basic unit of discrete data (Blei et al, 2003). A 'document' or interview is a sequence of words, and a 'corpus' is a collection of interviews. Specifically, we employed LDAvis (Sievert & Shirley, 2014), an LDA-based data visualization method, to analyze our data. LDAvis allows us to examine how different words contribute to the meaning of each topic, how different topics relate to each other, and the prevalence of each topic. Our corpus is the entire set of comments transcribed from the interviews with the students involved in the colluding and non-colluding class sections. The corpus includes the text from twenty-six student interviews.

In effect, LDA helps discover underlying themes in a set of data by generating key words. Words are allocated to topics in the analysis. As domain experts, the researchers in effect, interpret the topic results. In our study, the domain experts are both the authors and the LDA administrators. Therefore, a topic is a cluster of words specified by the domain experts. Unimportant words (e.g. a, and, are, is, the etc.) are often ignored or reduced in the analysis. Rather, the important key words, words that are idiosyncratic and exclusive to a topic, are identified and emphasized.

LDA does not create new words or concepts as with factor analysis or content analysis; rather topics in a set of data are represented by existing key words (Moro et al, 2015). In a well-formed topic model, certain topics will generate words from one conceptual area more than from another - for example, "repercussion-related" and "team-related" topics, where the former is more likely to generate words like "caught", "colluded", "decision", "fail' and "trust", and the latter words like "sharing" and "teammates." Therefore, if an interview contains primarily important words, the model will classify them by topic. For each interview, LDAvis determines the probability of the set of words in each interview belonging to a topic, and then it matches the words with topics. The LDAvis relevance metric sets the weight given to the probability of a word belonging to a topic (Sievert & Shirley, 2014). An interview may represent different topics. Topics are based on probabilities assigned by the LDA software.

In LDA, the administrator determines the number of topics. The appropriate number of topics is determined in many ways (Chen & Wang, 2018). Too many topics dilutes the meaning of each topic and too few is not discrete and does not separate ideas and words from each other. The appropriate number of topics for our dataset was determined by comparing the intra-topic similarity with inter-topic dissimilarity. We ran five, ten, and fifteen topic solutions. and chose a result that maximized the difference between topics (Chen & Wang, 2018). We determined the optimum number of topics to be five and the most illustrative relevance metric to be .6 (as recommended by Sievert & Shirley, 2014). Our LDA produced for each of the five topics a list of the most relevant words. Relevance of the word w to topic k given λ is defined as:

$$r(w,k/\lambda)=\lambda \log(\varphi_{kw}) + 1-\lambda \log(\varphi_{kw} / p_w) \quad (1)$$

where φ_{kw} is the probability that word w belongs to topic k and p_w is the marginal probability of word w being in the corpus. Lambda can be set to values between 0 to 1. A lambda of 0 would

equate relevance to exclusivity – where the top words would be the ones whose probability of being in the whole corpus and of being in the topic are the same or very close. A lambda of 1 equates relevance to the probability of being in that topic, which is the frequency of the words divided by all the total number of words in the topic. As recommended by Sievert and Shirley (2014) who developed the relevance measure, we use a lambda of 0.6 as noted above.

Based on each topic's most relevant words, we decided on topic names. We labelled topics by determining the mix between the probability and relevance of words belonging to topics (Sievert & Shirley, 2014). Our topic results and labels are based on output directly from the analysis, and represent the underlying themes students use to describe their personal experiences with collusion. Therefore, LDA emphasizes topics and words. Words structure the topics. We focus on words in particular because words represent the most subtle and yet critically important way to delve into the understanding and assumptions that made their way into student thought and action. Words provide a glimpse into the mind and will of the students as they describe the collusion incident.

Prior to performing this analysis, we had information that separated colluders from non-colluders. In the interviews, we expected that there would be clear differences in the question responses between colluders and non-colluders. However, our objective in using LDA was to engage in a more granular examination of the language or topic differences, if any, between the two groups. Therefore, we ran the analysis of the entire set of interviews as one corpus. We considered the colluders and non-colluders responses together in order to objectively examine the language. LDA is bias free in terms of caring what a colluder or non-colluder says. It simply accumulates words into clusters or topics and provides for a visualization of the differences. As part of this analysis, we attempt to examine the topic differences among individuals. We trace individuals to topics in an attempt to understand how colluders and non-colluders might be different.

Zupic and Cater (2015) state that LDA holds tremendous potential for "expanding the scope of mapping the management and organization domain (pg. 457)." In order to make wide application of LDA available in organization research, Zupic and Cater indicate that ethics scholars can either wait for new software to be developed or collaborate with information scientists. In our case, we interacted with technical experts from a data analytics firm- Kingland Systems. Kingland, headquartered in Clear Lake, Iowa, provides information technology and financial services to manage compliance and risk for firms. Company clients include some of the world's largest banks, financial services firms, and insurance companies. We worked directly with Kingland analysts, providing them the raw data, or corpus, and then collaborated with them to interpret LDA results.

Data for this study are derived from the complete set of interviews for all student participating in the interviews. We base our LDA on the analysis of the entire interview text, including the initial greeting, general conventions of opening a dialog, and the entire set of responses to the questions posed in Appendix A. This method is analogous to the corporate implementations of LDA used by our partner, Kingland Systems. For example, Kingland provides their clients full-text analysis of formal corporate reports and compliance documents. The authors of this paper interviewed the students and generated the transcripts. Kingland analyzed the transcripts and produced the LDAvis results. The Kingland experts directly helped the authors ascertain the number of LDA topics to best analyze the corpus and they offered advice on the relevance metric to best identify topic words. We use all the text of the interviews in our analysis, thus providing a complete unbiased corpus for analysis.

Sample- The Collusion Incident

A strength of this study is the sample. It is in effect, a naturally occurring filed experiment. We did not manipulate a cheating or collusion intervention. It would unethical to do so. The

collusion occurred naturally. Therefore, the strength or external validity of the experimental effect is greater than would normally be expected with a lab experiment or from a survey. We were able to obtain access to the students involved through the course instructor.

The incident we discuss and analyze occurred in a graduate-level course on accounting professionalism and leadership, taught at a large, public university in the Midwest. Most of the graduate students in the section were accounting/tax majors. A major, multi-part assignment of the course was a debate tournament. The faculty member involved professionals from the nearby metropolitan area to observe the debates and to offer their evaluation of the students' performance. While their presence added a connection to the "real world", the professionals added to the anxiety students felt about doing well on this assignment. The degree program the students were enrolled in is known to be intense and this course was considered very time-consuming.

The debate assignment was designed to develop multiple skills. Research and critical thinking and analysis were required to formulate a strong response to the ambiguous and technical accounting questions. Additionally, the professor wanted students to practice speaking publicly after having carefully prepared their main arguments, but also facing the challenge of speaking extemporaneously if the opposing side created new arguments or offered new evidence. Of course students could mitigate the likelihood of encountering new evidence or novel arguments by preparing very intensively themselves. To ensure students understood the issues thoroughly, the debate process required that teams flip a coin before each debate and the winning team could select the side of the issue they preferred. That uncertainty about which side they would be arguing caused students to spend even more time preparing.

Students did know which team they would be arguing against before the coin toss. However, they were told explicitly not to collude with their opponent to predetermine debate sides. The University has an honor code that mandates both that students refrain from cheating and that they disclose incidents of cheating which they observe. The instructor represented to the external judges that groups would not know which side they would debate until the coin toss.

Before the last round of the debate, the instructor became aware that some teams had colluded with the opposing team to predetermine which side each would argue. The professor overheard two teams deciding, despite the professor’s proscription, to work together and collude to pre-determine which side they would argue. After the debates concluded, a student (who had explicitly declined the possibility of collusion) reported to the professor that the collusion was more widespread than he had first thought.

The professor reacted strongly to the collusion for several reasons. Because of the collusion, he felt he had misrepresented the debate to the professionals who had volunteered their time and expertise. He believed (as did the students involved) that colluding provided a competitive advantage over teams that did not collude. More importantly, collusion was blatantly unfair and constituted a form of academic dishonesty and violation of the school’s honor code. On a personal level, he felt disrespected; furthermore his goals for the class had been stymied and the deep rapport he thought he had with the students was dissipated. However, he wanted to understand why some students had chosen this path, and he wanted the students to learn from the experience. Therefore, after confronting the class, he approached us about interviewing them about the incident.

Table 1 includes student comments made directly to the instructor regarding the collusion incident. In these comments can be seen some of the word topic themes that appear in our formal analysis. Student acknowledged that they felt team and peer pressure to collude. There also appear to be comments related to the idea that the students understood that they were being dishonest and that there would be repercussions for their actions. A majority seems to be remorseful for their behavior. However, the students also offer rationalizations that collusion helped lighten the perceived high-pressure workload. The corpus for analysis includes

the text from twenty-six student interviews. The twenty-six students volunteered to be interviewed - no one was compelled. Eighteen interviews were with non-colluders and eight were with colluders. Of the students interviewed, 12 were female. Of the eight colluders, three were female. Therefore, there was gender balance in the sample.

Interviews

The interviews produced 524 pages of text, and while not large by typical LDA standards, it does represent the entire set of comments about this incident. There were 167 pages of text collected from the colluders, 339 for non-colluders and 18 for the outside observer. This means that each colluder provided approximately 21 pages of text and each non-colluder provided approximately 20 pages.

Student subjects were interviewed via telephone by the study authors. Each interview was conducted with permission of the respondent and the home university's Institutional Review Board. The interviews were immediately transcribed by an independent service and the text of the interviews constitutes the corpus for this research. We asked each respondent a similar set of questions about the collusion incident. The questions are presented in appendix A.

We examined the complete text of all interviews that included 11,125 paragraphs and 218,993 words. There were 65,439 total words for the colluders and 153,554 words for the non-colluders. This results in approximately 8180 words per colluder and 8531 per non-colluder. Given that the responses were freely offered and not constrained, non-colluders were slightly more verbose. Non-colluders talked more about the experience.

Results

The results indicate the words most associated with the five interview topics. Topics in this case represent the substance of the interviews. The two visual features in figure 1 provide overall perspective on these five topics. Circles identify the topics plotted in terms of multidimensional scaling using LDAvis. The size or area of each circle indicates the proportional prevalence of topics in the corpus (Sievert & Shirley, 2014). Three topics (2, 4, and 5) are overlapped and comprise 76.1% of the entire corpus. Overlap simply means the topics are related. Topic 4 is the most prevalent in the corpus (40.7%). Topics 3 (19.1%) and 5 (23.9%) are also prevalent. Topic 3 is interesting. It is not overlapped but is near the other overlapped topics. It is rather important, however, in that it represents 19.1% of the corpus.

The other visual feature in figure 1 lists the top most probable or most salient terms or words from each topic cluster. The topic clusters all contain non-specific and common words, such as 'yeah', 'like', and 'okay.' This is an expected outcome of LDA. Each topic, however, also contains words that are more idiosyncratic or unique to the topic made manifest through the relevance metric. These words cluster to a given topic exclusively compared with the more common terms. We used the word clusters to describe each topic in Table 2 following convention practiced elsewhere in the LDA literature (e.g. Sugimoto et al, 2011; Lash & Zhao, 2017). A complete set of LDAvis diagrams is presented in appendix B.

Table 2 includes the topic description, percent of the corpus represented by each topic, and the most relevant and unique words. The authors determined the topic descriptions based upon relevant words and our understanding of the situation. These relevant words provide the bulk of our analysis. As noted above, relevant words are prevalent in the topic within and throughout the corpus. Unique words are those prevalent in one topic at the exclusion of others. Uniqueness was determined simply as the percent of a word in a topic, that is, the prevalence of a word in a topic divided by the prevalence of the word in the entire corpus. For example, in

Table 1	Sample post-collusion student comments made directly to instructor regarding the collusion
Student #1	“I wanted to inform you about my side of the collusion mishap. For the third debate only, about an hour before class, I was approached and asked if my team would take the Con side because one of my opponents was not prepared. I said yes because I felt bad and I didn't want my friends to be embarrassed. I realize that it was a bad decision and I wasn't happy about it at the time. I made a bad decision due to pressure and stress. Although it is not an excuse, my team was fully prepared on both sides of the debate. I am taking this situation as a learning experience about how easy it is to fall into unethical situations.”
Student #2	“I would like to tell you that my group only talked with the other groups about what side they preferred and then we flipped a coin to find out who would debate on what side. After that we parted our separate ways and didn't speak any more about the debate, the contentions or the evidence. Nonetheless, we still researched both sides of the issue, and prepared good contentions as well as provided strong evidence to support them. If you would like I can send you our contentions as well as our evidence to support them for both sides. It was never our or my intent to be disrespectful to you, the guest judges, or other members of the class. I feel that I learned a lot from this experience and will be more thoughtful about my actions when working on projects.”
Student #3	“First off, I know without a doubt that I was one of the people you overheard conversing with my opponent the day of the debate. As I look back, you probably watched me do it. On the final debate, there was an arrangement with our opponent that we would take the con side if we won the toss, and our opponent would take the pro side. What I am most ashamed of is that I knew it was wrong, but I did nothing to stop it. It is also wrong to rationalize it. I'm not going to blame my partner or say, "Well the other teams are doing it". Yes, it was a difficult week and I had a lot on my plate, but there is no excuse for what I did.”
Student #4	“The bottom line is that I panicked about 1 hour before the debates. I was personally extremely well prepared for both sides (seriously, I'll show you an epic amount of research organized in two folders pro and con), but my partner was not. I knew most teams strongly favored the con side, so I pushed him to focus on the pro. Additionally, in previous rounds I had been approached by other teams to pick a side days before, and I declined.”
Student #5	“I was a participant in the collusion! To be honest, I am pretty embarrassed about the situation. I took the approach to work smarter, not longer or harder during that week. Not very proud of it, but I cannot go back and change it.”
Student #6	“I am sorry to say that my team had our side predetermined in the final debate. Although we did not end up debating, I definitely regretted my decision after realizing the magnitude of what we did. I apologize for destroying the whole point of the debate, and I have no excuse that would validate it.”
Student #7	“I am responding to your message because member of my team was involved in the collusion. I had mentioned some of this in my final memo so part may seem repetitive if you have already read it. He made an arrangement with one member of the team we were supposed to face. He then sent a text stating

	what he had done. It was done without my knowledge or approval. I believe he did it to spite you or the debate. I think it was like you said in the email, he was overwhelmed by the work load and was doing what he could to make the work load manageable."
Student #8	**"** With heavy heart, I am admitting that group one participated in the collusion. We flipped the coin the day before debate. As ashamed as I and my teammates are, I don't feel it is appropriate at this point to try and justify our actions besides agreeing with what you put in your email. I am truly sorry for the disrespect, and for letting you down."

Figure 1- Topic map of student interviews
file:///C:/Users/cshrader/AppData/Local/Temp/Temp1_averaged.zip/averaged/5_topics_updated.html

topic 1, the word 'interview' has a uniqueness score of 99. This means that even though the word can appear elsewhere in the corpus, there is a 99% probability it will be associated with topic 1 in the LDA.

Evidence from the other high-loading relevant words reveal substantive topics dealing with the nature of the course assignment (topic 2), class teams (topic 3), repercussions of being caught (topic 4), and differences between the auditing and tax tracks in the accounting major (topic 5). Topics 2, 3, and 5 constitute over half of the corpus (55.4%). These topics include words related to taking sides in the debate, teams, and the differences between the auditing and tax majors. Therefore, in effect, students talk most about the immediate classroom situation when describing collusion. Topics 2, 4, and 5 cluster together and deal with class competition, taking sides, repercussions, and differences between majors. Topics 2, 3, and 5 deal with

Table 2 – Extended latent Dirichlet allocation results for student interviews

Topics and Words

	Topic 1	**Topic 2**	**Topic 3**	**Topic 4**	**Topic 5**	
Percent of Corpus	4.8%	11.5%	19.1%	40.7%	23.9%	Total = 100%
Topic Label	General context- honor code, starting the interview, naming important actors	Nature of class assignment itself	Teams - a resource and support mechanism	Repercussions of being caught	Tax and Audit class section ethical differences	
Important Words	Relevant words (LDAvis) thank interview code phone yeah hi hello	Relevant words (LDAvis) like going just really said article prepared	Relevant words (LDAvis) team did debate remember know teams groups	Relevant words (LDAvis) think class people know students caught colluded	Relevant words (LDAvis) think ethics just people know tax audit	

	Unique words (% of word unique to topic)	Unique words (% of word unique to topic)	Unique words (% of word unique to topic)	Unique words (% of word unique to topic)	Unique words (% of word unique to topic)	
	interview (99) code (99) honor (99) hello (96) codes (94) interviewer (93) honor (93)	confident (99) article (98) argument (97) argue (97) articles (96) pros (96) cons (90)	sources (99) shared (98) competing (98) agreement (95) teams (94) teammate (80) team (67)	dishonest (99) fail (98) recommend (98) hiring (98) failed (97) determining (97) probability (96) failing (95) stupid (93) caught (92)	ethics (99) tax (99) emphasis (99) engaging (98) preconceived (98) culture (96) curriculum (96)	

things more internal to the particular collusion incident while topic 4 deals with the external view of the reputation of the school. This appears to be evidence that internal course context has a lot to do with collusion. Table 3 provides samples of student interview comments that reflect the topic categories.

Topic 1 – General context, honor code and greeting

As evident in table 2, the relevant (common) words for topic 1 are thank, interview, code, phone, yeah, hi and hello. Words unique to the topic include interview, code, codes, interviewer, honor, thank and hello. Therefore, topic 1 captures language regarding the basic greeting and simple pleasantries associated with opening the dialog between interviewer and interviewee. It is also quite separate from the other topics on the inter-topic distance map and is much less prevalent than the others (4.8%). Along with this, it also appears to deal with the school code of ethics or honor code. This school did indeed, have an honor code and the interviewees seem to mention it as part of the general context of the situation. McCabe and Trevino (2002) argue that academic integrity is enhanced through a visible honor code. Here we find the code to be visible and part of a general context. The word ‘code’ does not figure heavily in the more prevalent topics.

Topic 2 - Nature of course assignment

Topic 2 is the second least prevalent topic in the corpus. The most relevant words are: like, going, just, really, said, article and prepared. When combined with unique topic words such as: confident, article, argument, argue, articles, pros, and cons, it is clear that this topic deals with the course assignment of developing an argument for the debate.

Topic		**Table 3 - Sample student interview comments**
Repercussion	Non-colluder	“Before the debates started, the professor was very adamant to our class that it was not an option and if we were caught-- I don't know if he said the consequences would be bad, but it was one of those things where it would not be tolerated and personally to him, he would be very disappointed in us.”
	Colluder	“I'm aware that we're cheating and being dishonest, so trusting people to keep their mouth shut is a little difficult. If they're dishonest on one thing, who's to say they're not going to be dishonest on another thing?”
Team	non-colluder	“I just think our class had a lot of students that were very talented, and I think we had people that wanted to succeed and were competitive. I think when you combine how you have a lot of talented and competitive people then it brings everyone up to that level of wanting to compete. There was definitely some rivalries between students as well; there was one team that me and some people that I knew in the class were really wanting-- hoping they would lose.”
	Colluder	“Teams would give other teams the references and show them where to find the things. I was thinking that we have to trust each other and we have to be quiet about it.”
Nature of assignment	Non-colluder	“Yeah I think there is a little difference. It's based on the seriousness of the debate compared to just one homework assignment.”
	Colluder	“We were in front of our classmates, we didn't want to look stupid. When the third one came around, we were just so exhausted from everything, we thought it was actually our right to cheat or make it a little easier for us to fix the third debate. We felt we had so much on our table that it was justified to just pick one side, because we have to do the debate anyway.”
Audit and Tax section differences	Non-colluder	“As weird as this is going to sound, the class that I was in consisted most of auditors, and we have skeptical minds to begin with, so we are a little more distrusting with each other. One of my concerns with even colluding would have been, "Hey, are they going to come back and throw me under the bus? If I say I'm going to be pro and they're going to be con, are they going to pick pro and I'm not going to have anything to argue with?" For our class we have a more competitive mindset than the other class. We're very close and talked about a lot of [?] and just-- they worked together on a lot of things. We were a way more competitive group than they were.”
	Colluder	“Tax is the outcast of the accounting program. Usually people go into audit where it's more regulatory stuff. The tax people are sort of-- I don't know, it's different. Everything in the audit program is very structured and you have to say the right words, or it doesn't

		make sense. They do more writing things and analysis. The tax people are more transactional. We have to be more outgoing with clients. We actually have to talk to our clients, and the work that we do is start to finish. We start a tax return, we finish it. An audit, you're auditing cash. You're only one segment of the big picture. It seems like tax people are more lawyers, we deal more with like cases and interpretation. Whereas an audit, it's more concrete and it's not just the same. Honestly, personality decides who's going to be an auditor and who's going to be a tax person."

Topic 3 – Teams

Topic 3, which deals with the team aspect of the course, appears to be somewhat independent of, but related to, the other main collusion topics in terms of the distance map. This may mean that the team aspect itself has a lot to do with the decision to collude, or at least teams create relevant context for the decision. The finding that 'teams' is a topic unto its own illustrates the importance of teams and teamwork in understanding cheating and collusion. Important relevant and unique words include- shared, agreement, sources, teams, competing, teammate, team, remember, and groups. These words clearly highlight the salience of the team concept in this situation.

Topic 4 – Repercussions of Collusion

The most prevalent single topic in the corpus (39.3%) is topic 4. The words fail, failed, failing and caught all led us to describe this topic as having to do with the repercussions of collusion. Both the immediate repercussions (fail and caught) and future consequences (future, recommend, and hiring) appear to be important considerations to the students. What is interesting is that even though repercussions of being caught are prevalent, many students were still willing to take the risk. This result follows that of West et al. (2005) who found students to become very instrumentally focused when faced with opportunities to cheat. In other words, when the payoff is large enough, even severe consequences many not deter the colluder.

Topic 5- Difference between audit and tax classes

The words 'tax' and 'audit' are both prevalent and unique in topic five. These words describe the nature of accounting majors in different sections of the course- one populated by tax majors and the other audit majors. Other important words are ethics, curriculum, engaging, emphasis, and culture. The collusion incident happened in a section populated by tax majors. It is clear that these students perceive the audit and tax people to be different. In this instance, the audit class did not have a problem with collusion. One explanation for why auditing students may be less susceptible to collusion is found in the work of Ballentine, Guo, and Larres (2018) who demonstrated that less cheating was found in instances where students were involved in deep and strategic approaches to the material. Tax laws and rules may concomitantly reflect what Ballentine et al, term surface learning approaches- requiring memorization without deep understanding. Whatever the reason, it is clear that in this situation involving collusion that the audit and tax sections were seen as different, and though surface versus strategic learning are not part of our research, the conditions appear to be consistent with our findings.

Colluders, non-colluders, and topics

We also extend the LDA results to individual students. Table 4 presents information linking individual students to LDA topics. The general pattern reflects the topic relevance in the

corpus as expected. Concern regarding repercussions, topic 4, was the most relevant topic for a vast majority of those interviewed. Topic 4 was not the most relevant topic for only two of the student respondents. There were only subtle differences between colluders and non-colluders in terms of relevant topics overall. However, according to the Kingland LDA experts, 'even subtle differences are important and interesting.' The difference between the audit and tax majors and the nature of the class assignment were slightly more relevant to colluders than non-colluders, while teams were marginally more relevant to non-colluders. Also, any names appearing in the list of terms are disguised and, therefore, do not violate anonymity.

Table 4- Extended LDA results
Most Relevant Topics by Individual Colluder/Non-Colluder

Colluder/Non-colluder	Most Relevant Topic	Second Most Relevant Topic	Third Most Relevant Topic	Fourth Most Relevant Topic	Fifth Most Relevant Topic
Colluder 1	4	5	3	1	2
Colluder 2	4	5*	3*	2	1
Colluder 3	3	4	5	2	1
Colluder 4	4	5	3	2	1
Colluder 5	4	5	3	2	1
Colluder 6	4	5	3	2	1
Colluder 7	4	3	5	2	1
Colluder 8	4	5	2	3	1
Non-Colluder 1	4	3	5	2	1
Non-Colluder 2	4	3	5	1	2
Non-Colluder 3	4	3	5	2	1
Non-Colluder 4	4	3	5	1	2
Non-Colluder 5	3	5	4	1	2
Non-colluder 6	4	5	3	1	2
Non-Colluder 7	4	5	3	2	1
Non-Colluder 8	4	3	5	1	2
Non-Colluder 9	4	5	3	1	2
Non-Colluder 10	4	5	3	2	1
Non-Colluder 11	4	5	3	1	2
Non-Colluder 12	4	3*	5*	1	2
Non-Colluder 13	4	3	5	2	1
Non-Colluder 14	4	5	3	2	1
Non-Colluder 15	4	3	5	2	1
Non-Colluder 16	4	5	3	2	1

Non-Colluder 17	4	5	3	1	2
Non-Colluder 18	4	5	3	2	1

**topics tied for this individual*

Conclusion and Discussion

To our knowledge, this is the first time LDA has been applied to a dataset to examine cheating or collusion. Evidence from our LDA suggests that a significant portion of the language used to describe collusion is manifested by four major topics. Students see repercussions of being caught, teams and class teamwork, course assignment structure and content, and class section differences to be important factors in the context of collusion. Indeed, the most salient topic in this research deals with repercussions. Our LDA results align closely with those of Briggs et al, (2013) indicating that collusion is a rational assessment on the part of students guided by the expectation that other teams will collude and fear of exclusion on an assignment, even when harsh repercussion may be applied. The discussion also centers on differences between auditor and tax functions in accounting. Taking the repercussion and auditing difference topics together coincides with previous research that finds auditor moral reasoning to be influenced by the potential for penalties (Jeffrey, Dilla, & Weatherholt, 2004). Repercussions as an assessment of the instrumental nature of decisions to cheat are common elsewhere in the literature (West et al, 2004).

Another of the topics resulting from our analysis centers on teams and teamwork. Our results suggest that collusion may be associated with team assignments. These results also confirm the survey results of Shrader et al. (2012) that teams and peers may put unintentional pressure on students to collude on class assignments. Teams were part of the class structure in this incident as they are in many business classrooms today. In business schools, we often use teams to teach consensus building and appreciation of diversity. Instructors place students in teams hoping to maximize individual performance and enhance inclusion. However, teams also can create blurred lines. Teams often result in shared work- both when desired and when not permitted. Team assignments may lead to free riders both within the team and including the whole team. Team based learning is a popular teaching technique, but using teams in the classroom requires careful structuring of activity and the team itself in order to be effective (Koppenhaver & Shrader 2003). It appears that whenever teams are formed there is an enhanced opportunity for students to use the team in an instrumental way to lighten the workload. As Ariely notes: “Some…forces might make it easy for group-based processes to turn collaborations into cheating opportunities in which individuals cheat to a higher degree because they realize that their actions can benefit people they like and care about (2012, pg. 222).” Ariely claims that under conditions where teammates perceive they can all benefit from the opportunity, the level of collaborative cheating tends to increase. The implication for future research is that team context must be considered because of its powerful effect on class assignments. The widespread use of classroom teams for presentations and debates may be creating confusion (or opportunity) in terms of what is allowed collaboration and what is illegal collusion. Forming classroom teams without providing team training and time for team development may be doing as much harm as good. Certainly team-based learning is more effective if teams operate as planned. One of the central issues of team-based learning is the degree to which the instructor may have influence on the teams. However, collusion and the subsequent conflict that commonly occurs is likely to have a negative impact on learning, and can minimize the effectiveness of classroom team assignments.

Our results also show that those who chose to collude and those who did not described the incident in similar terms. When asked a battery of detailed questions, there was no glaring difference in terms of how students described the incident. Often students may not see the line

of demarcation between cheating and formally assigned group work (Shrader et al, 2012). The widespread use of teams and group assignments may be adding to the level of general confusion about those specific instances when sharing is permitted (Kaufmann et al, 2005). For example, the student quoted in the Washington Post article mentioned above (Bever, 2017) sees no problem with taking advantage of opportunities to collude when not expressly prohibited.

One fundamental aspect of this paper is that we demonstrate the value of large data processing techniques such as LDA and LDAvis. LDA provides an objective and consistent means of examining large amounts of text. It allows the identification of underlying content and discloses words and topics to make the content interpretable. Our colleagues at Kingland use it to analyze volumes of corporate annual reports and technical documents. It is well suited to this task. However, to our knowledge, this is the first LDA study to examine the language of students who are actually involved in a classroom collusion incident. Moreover, even though not large, our sample represent the universe of data available on this particular collusion incident. Therefore, there is clearly an opportunity for future LDA researchers to systematically gather interviews from larger groups of students over time in order to ascertain even better understanding of cheating and collusion.

Consequently, our study is subject to the basic caveat of using LDA, namely, topics require interpretation by the researchers. The number of topics is subject to interpretation- it is not a necessary given from the analysis. However, we followed the conventions of prior LDA studies in terms of identifying topics, and used LDAvis to convey results. We also worked closely with the Kingland LDA administrators in deciding on the topic solutions and interpreting results. Therefore, we feel confident our interpretations are reasonable and accurate with regard to our data. So, what have we learned from LDA? We learn that students view classroom cheating from the classroom level. Rather than talk in terms of greater ethical principles or codes, they talk about instrumentalities and temporal immediacy. The nature of the assignment, the team dynamic, and the perceived immediate consequences weigh more heavily in their language than do big picture long term things. Students view the decision to collude as a function of course assignments and perceived workload. Their moral reasoning seems to be based on the here and what near-term consequences might be. The immediate context is more relevant to them than the bigger picture. Given this, our research fits with previous research indicating that both context (e.g. codes, McCabe & Trevino, 2002) and morality (West et al. 2005) matter. Our study found only small differences between how colluders and non-colluders describe a shared experience. Therefore, while not expressly tested, our results appear to be consistent with this general finding.

This is also the first time of which we are aware that unique words have been used to identify and discuss topics. By identifying unique words, we were, in turn, able to more clearly identify topics. LDA is free from a priori assumptions about the nature of concepts or factors. The identification of unique words aids in the exploration of the corpus and naming of topics, in our view. Uniqueness is used in this paper to refine, not define, the topics. It offers a more granular statement about the meaning of the topic and helps clarify the results of our exploration.

A weakness of this study is that the corpus is not large. The number of interviews and amount of text is not particularly great in terms of what most LDA studies examine. However, we do have all the possible or available interviews. Our sample is actually a universe and is, therefore, representative. We have all the possible data from this naturally occurring filed experiment. We believe it very reasonable to assume that our students were telling the truth in the interviews and that the interviews captured the essence of the collusion issue. We also view the accounting course in question as typical of other graduate accounting courses and that it created classroom dynamics similar to those of other business courses taught elsewhere.

However, even with these limitations, this research has practical teaching implications. Our results clearly indicate that the course context is salient in terms of collusion. Future research should delve more deeply into group and team issues, that nature and clarity of the course assignment, and the extent to which students will compare themselves with other in terms of the cheating opportunity.

APPENDIX A – Phone Interview Questions

1. How did the idea of colluding in general first come up? What made you think that this was an option?

2. Do you know who the first group to collude was?
    a. How did you find out about this group?

3. Did knowing that other groups were colluding influence your decision to collude? If so, how?

4. Who first brought up the idea of predetermining sides in your debates?

5. Do you believe that there would be any ramifications to saying no to a classmate who wanted to collude on the debates? If so, please elaborate.

    a. What about if a classmate wants to look over your homework before it is due?

6. Do you believe that students in previous sections of this course predetermined sides in the debates?
    a. - If so, why do you believe this?

    b. If previous sections engaged in the same behavior, do you have any feelings about the fact that you were discovered and they were not? If so, what are those feelings?

7. Has anyone taking the course this semester talked with you about the debate process?

8. Do you believe that your school's emphasis on ethics had an impact on the debate situation?
    a. If so, what? If not, why not?

9. Do you believe that there are repercussions for engaging in unethical behavior such as cheating?

10. What did you think would happen if you were caught predetermining sides in the debate?

11. Is there some difference between the classes that would make one more likely to predetermine debate sides than the other? If so, what?

12. Why do you think that the students in the other section did not collude?

13. Did the fact that the majority of the class was on the tax track and taking all of their classes together have any influence on the decision to collude? If so, can you describe that influence?

14. How do you think that members of the other class would feel or react if they knew that you had colluded on the debates?
    a. Do you know if anyone in the other section knows that you predetermined sides?

15. How stressed were people during the debate process?
    a. How did they deal with the stress?

16. What role do you think the debate stress played in people's decision to collude?
    a. (if significant) What was the difference between the students who were stressed and colluded and those that felt stress and did not collude?

17. How clear was Professor Smith in letting you know that predetermining sides in the debate would be considered cheating?
    a. Did Dr. Smith say anything before the debate about agreements between competing teams?

    b. Did Dr. Smith say anything before the debate about working with people outside your team on the debate?

18. How important was trusting the members of the other team on your decision whether to collude?

19. How prepared would you and your team have been if you had been double-crossed and your competition chose to argue the side that you had prepared?
    a. How confident were you that this was not going to happen? Why?

20. Is there anything about Dr. Smith or this class that would make students more willing to engage in collusion or similar activities when compared with other classes or other professors?
    a. Debate process itself?

21. How is this class viewed by the students?
    a. How does this class fit into the Accounting program?

22. What do you think about how Dr. Smith handled this situation after discovering the collusion? How do you feel about it?
    a. How would you have handled it if you were him? Why?

23. How well known is this response within the program?

24. Do you believe that there will be any repercussions associated with this response?
    a. e.g., on future cheating?

25. Do you believe any of teams shared evidence or sources with other teams during debate preparation?

26. Is there a difference between discussing arguments or sources with another team in the competition and discussing these things with the team you are competing against? If so, what is the difference?

27. Is there a difference between helping your friends / classmates on a homework assignment that is to be graded and colluding in the debates? If so, what is the difference?

28. Do you believe that your professors are okay with sharing homework assignments that are to be handed in for a grade?

    a. if yes, would you tell them you did it or keep it to yourself? Why?
    b. If no, how does sharing homework differ from predetermining sides in the debate?

29. Why do you think that you colluded on the debates?

30. What (if anything) do you believe you have learned or will remember about this debate experience?

31. Is there anything else we should know or you would like to say about the debate situation last fall?

APPENDIX B – Maps of 5 topics – most relevant and unique terms per topic – figures omitted due to space constraints - available upon request

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DECISION SCIENCES INSTITUTE
An Analysis of Parenting from Online Confessions

ABSTRACT

Anonymous networks offer unique environments for emotion-expression. In this work, we study the expression of emotion in the Scary Mommy Confessional, an anonymous message board, where parents (mostly mothers) post anonymous comments about motherhood, and family life in general. This paper explores how the intensity of sentiment in a confession evokes specific reactions from the readers. Results show that three effects are at work: (1) Ancient Mariner effect: tendency to disclose more intimate information to strangers, (2) Dark Side: tendency to disclose information that has more negative sentiment and (3) Emotional contagion: tendency to be influenced by the emotions.

KEYWORDS: Anonymous social networks, Ancient mariner effect, Emotional contagion, and Online Parenting.

INTRODUCTION

Anonymous networks have been prized for the freedom of expression. In anonymous networks, people can express their thoughts without having to consider the norms of social exchange. For example, before posting content on a profile-centric network such as Facebook, users might think about the possible reactions that the post will elicit. These reactions span the gamut of social exchange. On the positive side, the comment might be well-liked as indicated by the Like and Love buttons or it might warrant significant discussion through threads of comments that affirm or encourage the user who posted the content. On the negative side, the user risks not receiving any feedback, receiving hostile comments, or having the comment reported as inappropriate, and in general degrades the online network reputation of the user. In addition to impacting the online network reputation, posted content and the reactions that it elicits also impact the offline reputation of the individual. While the theory of social exchange in (Meeker, 1978) was developed for traditional offline social networks, work done in (Moore & McElroy, 2012; Murimi, 2016; Wasko & Faraj, 2005) shows that people's behavior on social networking websites is an extension of their behavior in offline social networks. One reason attributed for this extension of personality and behavior is that social networking sites (SNSs) may contain identifying information about the user. Content posted on SNSs such as Facebook and Twitter can be linked to an account and its associated profile due to the profile-centric design of the user experience. However, there exist other SNSs where various parts of a user's profile information are optional, thus creating a range of SNSs that lie on the spectrum of anonymity. Multiple other levels of anonymity have resulted in pseudo-anonymous SNSs where users can choose the level of self-disclosure, and hence their adherence to social norms, by using different SNSs for specific applications. In (Leavitt, 2010), the author found that lower perceived anonymity on Reddit was a strong motivation for using "throwaway accounts". In other work on anonymity and self-disclosure, the authors in (Ellison et al, 2016) showed that selective anonymity allowed on Ask.fm was conducive toward critical development goals in adolescents. Research in (Suler, 2004) has coined this effect as the online disinhibition effect, where the anonymous nature of online communications has been shown to allow people to "feel less vulnerable about self-disclosure and acting out".

In this paper, we study the effect of anonymity on the nature of comments posted on the Scary Mommy Confessional, an anonymous message board, where readers post their comments called "confessions" about motherhood and family life in general. Using a dataset of roughly half a million confessions, we studied patterns in the sentiment of comments, distributions of various reactions, and emotional contagion. These patterns point to the tendency to utilize anonymity to "speak one's mind", and our results show that in the Scary Mommy Confessional, confessions are primarily negative in sentiment, more intimate and cause emotional contagion. Our findings about anonymous confessions provide a rich platform for investigation into the online lives of mothers, unfettered by the norms of face-to-face parenting and social exchange, thus creating a cultural snapshot of the life of an online mother in the age of anonymous SNSs.

RELATED WORK

While no work has yet analyzed the Scary Mommy Confessional, substantial research has been conducted into the use of SNSs by pregnant women, new mothers and motherhood in general (Balaam et al, 2013). Some specific expectations of these subgroups of users include gathering information about pregnancy (Hui, Ly & Neustadter, 2012), childbirth (Choudhury, Counts & Horvitz, 2013) and concerns of new mothers (Gibson & Hanson, 2013), keeping in touch with friends and family after the birth of a baby through updates of pictures and baby milestones (Jomhari, Gonzalez, Kurniawan, 2009), parenting advice, tracking milestones in a baby's growth and blogging about parenthood (McDaniel, Coyne & Holmes, 2012; Morris, 2014; Schoenebeck, 2013). The use of SNSs by fathers and their parenting methods – blogging, posting pictures and sharing information about children - was analyzed in (Kumar & Schoenebeck, 2015). In (Correa at al 2015), the authors analyzed the content posted on Whisper, an anonymous network, where users anonymously post content called "whispers". Whispers were compared to the content on Twitter, a non-anonymous site. The authors found that Whispers were more personal, social and informal than tweets, exhibited more negative sentiment and expressed more wants, needs and wishes than tweets. Another study on Whisper was conducted in (Wang et al, 2014) where the authors study interaction and the absence of persistent social links in anonymous networks. Similar to the work in (Correa at al 2015), the authors found that Whisper users posted highly personal content. This theme was further explored in (Andalibi, Ozturk & Forte, 2017), where the authors conducted an online experiment to study the relationship between content intimacy and willingness to self-disclose in social media. They found a negative relationship between these two factors and showed intimacy of content increased with the level of anonymity. They also found that people were more willing to share intimate content with weak ties such as online friends, than with people nearby. This finding points to the increased support that people find on online networks when dealing with intimate content. The authors in (Ma, Hancock & Naaman, 2016) studied image-based sharing to investigate the role of self-disclosure in the expression of depression-related thoughts. Another finding is that positive sentiment is more common than negative sentiment on profile-centric networks, whereas anonymity allows for more comments with negative valence. In (Ma & Kizilcec, 2014), the authors found that when offered a choice of a sharing platform for content sharing, users preferred anonymity for controversial content.

People's willingness to disclose more intimate content with strangers has long been documented and analyzed from the perspective of social sciences. In psychology literature, the tendency to increase self-disclosure with increase in anonymity is also known as the passing stranger effect, or the ancient mariner effect, after the poem The Rime of the Ancient Mariner written by English poet Samuel Taylor Coleridge (Coleridge & Pato, 1863). In this poem, the ancient mariner willingly recounts to a wedding guest repeatedly his horrific tale of a journey gone awry. Implications of the passing stranger effect have been studied in terms of self-disclosure through writing messages in (Rubin, 1975), where the subjects wrote longer messages to strangers. The passing stranger effect was also observed in (Rubin, 1974), where development of intimacy in relationships with passing

strangers was analyzed. Stranger support was also studied in (Cauce, Felner & Primavera, 1982) through the framework of social support to improve personal well-being by seeking intervention from strangers (for example, doctors and therapists). Our work differs from previous explorations of anonymous parenting behavior in that it analyzes anonymous user reactions to the confessions, thus providing an additional layer of interaction in complete anonymity.

METHOD

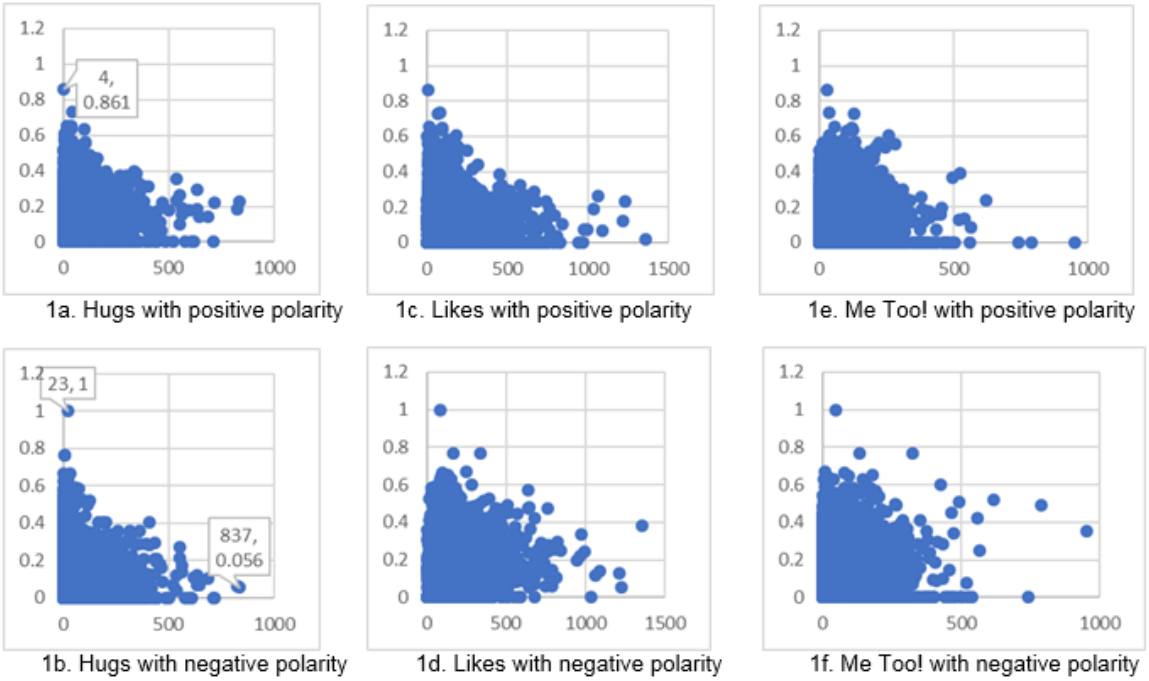
Our work in this paper deals with the Scary Mommy Confessional (Scary Mommy Confessional at http://www.scarymommy.com/confessions/) which is an anonymous message board where visitors to the site may anonymously post a comment called a confession, limited to 255 characters in length. Visitors to the Confessional can view all the confessions and have three ways to interact with the confessions. Similar to a Facebook Like and the broad spectrum of Facebook Reactions, the Scary Mommy Confessional allows a user to click once on one or more of the following options beneath every comment: Hugs, Likes, Me Too!. These one-click tools for interaction, called paralinguistic digital affordances, in (Hayes, Carr and Wohn, 2016) refer to the quick, easy modes of communication on SNSs. On the Scary Mommy Confessional, each click on a Hug, Like or Me Too! increments the current number of Hug, Like or Me Too! and is displayed inside parentheses.

Dataset

All of the confessions posted on the Scary Mommy website were crawled over a six-month period using Python from November 2016 to April 2017. The Scary Mommy Confessional has pages, each containing 10 confessions, and their corresponding numbers of Hugs, Likes and Me Too! reactions. of March 2017, there are little over 49,000 pages of confessions on the Confessional. However, the Scary Mommy Confessional does not have an API, and while it keeps all confessions on the site, it does not keep the number of Hugs, Likes and Me Too! reactions for the older confessions. Thus, older confessions have all zeros for the Hugs, Likes and Me Too! reactions. We found that the site deletes the number of reactions around page 600, and so we only chose the newer confessions on the Confessional. Thus, while our historical data set contains roughly half a million comments, our usable data set consists of confessions from pages from 1 (most recent) to around page 600, after which the site no longer retains the numbers of Hugs, Likes or Me Too! reactions on any confession. The dataset reveals interesting findings about relationships. Mentions of the dear husband (DH) are collectively more (63%) than all other categories, i.e. dear son (DS), dear daughter (DD) and dear child (DC) categories combined. We also found the frequency distribution of ages across gender in the confessions. The most common age of sons is 10 years, and that of daughters is 17 years.

Sentiment Analysis Tools

We used the VADER sentiment analysis tools developed in (Hutto & Gilbert, 2016) to obtain the polarity of each confession. VADER, which stands for Valence Aware Dictionary for sEntiment Reasoning, is a parsimonious rule-based model that assesses the sentiment of content and is well-suited for micro-blog contexts like tweets and short comments. VADER works by extracting the intensity of sentiment through a polarity score that ranges from -1 (most negative) to + 1(most positive). The VADER dictionary of lexical features is particularly well-suited to analyze social media content, such as Scary Mommy confessions, due to its attention to (a) emoticons such as :-) (b) sentiment-related acronyms such as LOL (c) Internet slang such as “nah” and “meh” (d) punctuation marks (multiple exclamation points used to denote intense emotion) and (f)



1a. Hugs with positive polarity | 1c. Likes with positive polarity | 1e. Me Too! with positive polarity

1b. Hugs with negative polarity | 1d. Likes with negative polarity | 1f. Me Too! with negative polarity

Figure 1. Distribution of the Hug, Like, Me Too! reactions as a function of the positive and negative polarity of confessions

capitalization to signal intense emotion. For example, compare, “The food here is great” with “The food here is GREAT!” or “The food here is great!!!”.

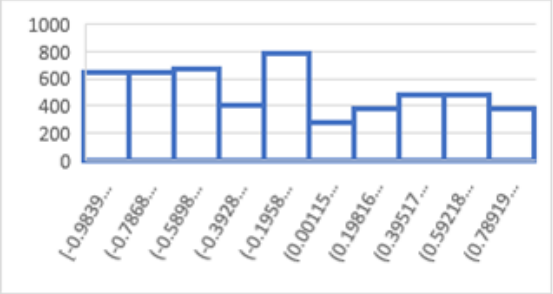
VADER also accounts for modification of inferred sentiment polarity scores found in statements such as “The food here is great, but the service is slow”, where the word “but” reduces the intensity of the overall sentiment. In the next section, we show the distribution of the sentiment intensity in the confessions across the numbers of Hugs, Likes and Me Too! reactions garnered by a confession using VADER.

FINDINGS

Figure 1 shows the distribution of the Hugs and their corresponding positive polarity (Figure 1a) and negative polarity for the confessions (Figure 1b). We see that majority of comments receive less than 450 Hugs, and as the number of Hugs increases, the polarity reduces. The same is true for confessions that receive few Hugs. The highest positive polarity of 0.86 had 4 Hugs. This shows that extreme polarity of sentiment (positive or negative) in the confession was not well-received and did not garner many Hugs. At the same time, confessions that were less positive in sentiment (< 0.5 polarity) elicited maximum Hug response from the confessional readers. A similar effect was observed for the distribution of Hugs with the negative polarity of confessions. The highest polarity of negative sentiment received 23 Hugs, and the confessions receiving the most Hugs (837) had a polarity of 0.05. The maximum Hug response was received for confessions whose polarity was less than 0.4.

We also compare the distribution of Likes, Hugs and Me Too! reactions with the positive and negative polarity of confessions. We see that Likes (Figure 1c, 1d) are the most common reaction, followed by Hugs (Figure 1a, 1b) and Me Too! (Figure 1e, 1f). It should be noted that

Figure 2: Distribution of confession polarity



the Scary Mommy Confessional does not use icons to offer the three reactions and relies on buttons labeled with reaction names. In (Levordashka, Utz and Ambros, 2016), the authors analyzed the motivations of users who clicked the Like button on Facebook and grouped these motivations into categories based on content of the post, acknowledgement, social support and utilitarian responses. Other factors were to acknowledge the source of the post and maintain/strengthen the relationship with the poster. However, unlike (Levordashka, Utz and Ambros, 2016), due to the anonymous environment of the confessions, these other factors have no impact on the motivations of the readers, and hence content of the confession is the primary motivator of the types of reactions it garners. Me Too!, however, is more specific, and conjures images of the reader being in the exact same situation, and hence is not as popular as the Like or the Hug on the Confessional.

Patterns in Anonymous Confessions

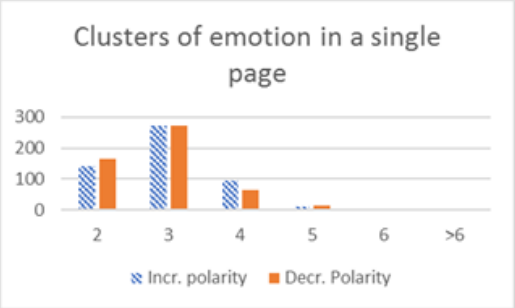
Figure 2 shows the distribution of the compound polarity score of a comment. The compound score is a function of the positive, neutral and negative polarity and lies within the range of -1 to +1. We see that, in general, the confessions tend to be more negative than positive and the highest number of confessions bear polarities that lie in the range of -0.24 to 0.001. Table 1 shows salient statistics of our data set.

Emotional Contagion

Our results in the previous section point to the tendency toward generally negative polarity confessions on Scary Mommy. In this section, we study whether the polarity of confessions on a page affects the polarity of new confessions. For example, if the most recent confession contains mostly negative sentiment, does that influence the intensity of sentiment of an upcoming confession? The phenomenon is widely known as “emotional contagion” (Hatfield, Cacioppo & Rapson, 1962; Schoenewolf, 1984) and has been analyzed for its impact on work dynamics (Barsade, 2002), social networks (Kramer, Guillory & Hancock, 2014), and encounter satisfaction (Pugh, 2001). In (Pugh, 2001), the authors found that emotional contagion can be affected by without direct interaction and occurs even in the absence of verbal cues. This study which was performed on Facebook, by exposing users to the emotions of their friends in their News Feed, found that emotions expressed in online social networks impacted one’s own posts. Our analysis of the Scary Mommy confessions found a similar pattern. We found that emotional contagion existed in clusters. That is, sentiment of the previous confessions had the greatest impact on the sentiment of a new confession. Thus, if the previous two confessions were increasingly negative

Table 1: Key Statistics of Scary Mommy Confessions	
Feature	**Average**
Hugs	53
Likes	125
Me Too!	53
Compound Score	-0.08
Confession length	28 words

Figure 3: Distribution of confession polarity in clusters



or increasingly positive, the upcoming confession had an increasingly positive or negative polarity as well.

Figure 3 shows the clusters of emotion encountered in the Scary Mommy confessions. We see that the largest cluster of emotion occurs for clusters of size 3, followed by clusters of size 4. Thus, confession-posters are heavily influenced by the emotion (positive or negative) expressed in the previous two (cluster of size 3) or previous three (cluster of size 4). Thus, looking at a cluster of size 3, if the previous two confessions had polarities of 0.2 and 0.4 respectively, the next confession had a higher probability of having a polarity that was > 0.4. Our study affirms the emotion contagion theory for the case of anonymous SNSs.

DISCUSSION

This paper provides an overview of interaction mechanisms and their implications on the Scary Mommy Confessional, an anonymous message board that caters to parents, mostly mothers. The study shows how the content of the comment evokes specific reactions from the site's affordances for interaction with the confessions. Our study found that the confessions had a mostly negative sentiment, inspired emotional contagion and were intimate disclosures about parenting, motherhood and family life, in general. We also found that of the three affordances – Hug, Like and Me Too! – the Like was the most commonly used affordance. The Hug and Me Too! affordances are unique to the Scary Mommy Confessional and offer an exclusive one-click tool to model empathy and compassion in a digital framework. The anonymity of the Scary Mommy Confessional ensures that the empathy, compassion and enthusiasm for a confession is motivated solely by the content, since there is no subliminal motivator such as the maintenance of social ties, a concept seen frequently in profile-centric SNSs such as Facebook, Twitter or LinkedIn (Hayes, Carr and Wohn, 2016). However, further research is needed to understand the implications of affordances on SNSs that are used to convey human emotion. Does a Hug on the

Confessional trigger the same benefits as a hug in offline social networks? SNSs offer the benefit of receiving empathy, compassion and enthusiasm, and other emotions that lie on the spectrum of positive and negative psychology, from both strangers and friends. In an anonymous setting such as the Scary Mommy Confessional, a click on any of the three affordances in response to a confession is an endorsement of the confession from a stranger. Does it imply, then, that we are open to receiving empathy, compassion and enthusiasm from complete strangers even in offline social networks? Online disinhibition (Suler, 2004) is a significant factor in this disparate behavior online and offline, and further work needs to be done to determine why we welcome attention from strangers in certain SNSs and are averse to friend requests and profile views from strangers in other SNSs.

Scary Mommy caters to an exclusive demographic: pregnant women, new mothers and mothers of young children. The content of a confession does not require the writer to provide gender information, yet it is generally assumed that most confessions were written by female users. In certain instances, the confession is written with clear phrasing indicating that the writer is a male. The content on sites such as Scary Mommy and our perception of the confessions reveals that our own assumptions about gender roles may have significant implications on our online behavior. For example, the name “Scary Mommy” implies the existence of a forum for mothers, but would fathers be comfortable using the Confessional to seek support and validation about their parenting challenges in an anonymous forum? Research addressing questions such as these will help us understand the gender disparity in the use of technology for niche applications.

CONCLUSIONS

This paper offered an analysis of reactions to anonymous confessions about motherhood, and family life in general on the Scary Mommy Confessional, an anonymous message board. The Confessional offers three ways for readers to interact with a confession, by clicking on buttons labeled Like, Hug or Me Too!. We found that Likes were the most popular reaction, and overall the confessions veered more toward negative sentiment. Extreme intensity of sentiment (highly positive or negative polarity) were eschewed in favor of moderate sentiment value. We also found that the content of the confessions frequently contained intimate content, displaying the Ancient Mariner (passing stranger) effect, where people willingly disclose intimate content to strangers. Emotional contagion was also observed, where the intensity of sentiment affected the sentiment of new confessions and created clusters of emotion with similar sentiment. Among future directions, we hope to understand expression of various emotions in both non-anonymous and anonymous social networks for various niche demographics to better understand user behavior online. Our findings shed further light on anonymity-induced online behaviors of mothers and have potential implications in the design of anonymous networks featuring user interactions for various network demographics.

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An Analytical Methodology to the Optimal Fortification of a Rail Intermodal Terminal Network

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"ABSTRACT"

We propose an analytical methodology to solve a tri-level mathematical model developed to protect a given number of rail intermodal terminals such that the effect of disruptions is minimized. More specifically, a tabu-search algorithm is combined with a decomposition-based technique to solve the tri-level model. The proposed methodology is used to solve and analyze problem instances generated using the realistic infrastructure of a railroad operator. We also highlight the computational efficiency of the proposed methodology, and compare it to the existing techniques.

KEYWORDS: Intermodal transportation, Mixed-integer program, Fortification, Metaheuristic, Decomposition

INTRODUCTION

Intermodal transportation, which exploits the synergy of at least two transport modes, has experienced phenomenal growth over the last two decades. This has been attributed to competitive pressures on global supply chains, and the increasing demand for new service patterns driven by ocean carriers as well as the globalization of industry. Rail-truck intermodal transportation, which combines the accessibility advantage of road networks with scale economies associated with railroads, is attractive to shippers for two reasons: *first*, the significant reduction in both delivery and lead-time uncertainty because of the schedule-based operation of intermodal trains; and *second*, a more efficient and cost-effective overall movement ensured by combining the best attributes of the two modes.

Intermodal transportation plays a vital role in the economic growth of North America, and hence the associated infrastructure could be deemed critical, i.e., systems and assets whose destruction (disruption) would have a crippling effect on security, economy, public health, and safety (DHS, 2018). Disruptions could be induced by nature such as Katrina and Rita in 2005 that could crippled the nation's oil refining capacity (Mouawad, 2005), or man-made threats such as the 9/11 terrorist attacks in the United States (Scaparra and Church, 2012). One of the ways to mitigate the impact of disruption is to design supply chain configuration, so that it operates efficiently (i.e., at low cost) both normally and when a disruption occurs (Snyder et al., 2006). Alternatively, one could attempt to improve the reliability of existing infrastructures by using fortification models to identify optimal strategies for allocating limited resources. This

study makes use of the latter technique to preserve the functionality of the rail-truck intermodal transportation system. More specifically, we consider disruption only at intermodal terminals and formulate it as a tri-level problem, in which the defender (i.e., network owner) has a limited number budget to protect or harden some of the terminals, an attacker has enough resources to interdict some of the un-protected terminals, and finally the defender (i.e., network operator) attempts to meet demand on a reduced intermodal network.

The rest of the paper is organized as follows. The relevant literature is reviewed in the next section, followed by the problem description and assumptions. We then outline the tri-level mathematical model, and the solution methodology. Finally, the analyses of the realistic problem instances before the conclusion.

LITERATURE REVIEW

Given the focus of this study on fortification and interdiction of rail-truck intermodal terminals, the relevant papers can be organized under four streams: protection and fortification; disruption of networked system; metaheuristic applications in interdiction-fortification; and, rail-truck intermodal transportation systems.

Literature Review on Protection and Fortification

Planning and is an enormous exercise especially given the complexity of a typical intermodal infrastructure, the interdependencies among various components (Liberatore et al., 2012), and the prohibitive cost. A majority of the works has approached the fortification problem, within the facility location domain, as a leader-follower game (Stackelberg, 1952), in which the defender is the leader and the interdictor the follower, and modeled as bi-level programming problems (Dempe, 2002). Furthermore, it is assumed that the attacker is going to make the most disruptive decision, and hence worst-case scenarios are modeled (Scaparra and Church, 2008). To ease the complexity of the bi-level programming problems, Church and Scaparra (2007) and Scaparra and Church (2008) proposed single-level formulations, and an explicit enumeration technique for solving the problems. Uncertainty associated with the attacks has been incorporated by attaching a probability of successful attacks on facilities, and by making use of a probability distribution for estimating the number of facilities that could be attacked (Liberatore et al., 2011). While the concept of investing protection measures to reduce the recovery time of the system has been investigated in Losada et al. (2012), fortification within a system of capacitated facilities has been recently investigated by Scaparra and Church (2008).

Literature Review on Disruption of Networked System

Peer-reviewed works on the disruption of a networked system, on the other hand, have primarily focused on the analysis of risk (i.e., identifying the most critical components of a system) through the development of interdiction models. The effect of interdiction on the maximum flow through a network is studied by Wood (1993), while Lim and Smith (2007) made use of a variant of multicommodity shortest path problem to investigate the impact on revenue from arc interdictions. The concept of fortification against worst-case losses for network models has been discussed in Brown et al. (2006), wherein a tri-level optimization model to represent fortification, interdiction, and network flow decisions (i.e., defender-attacker-defender) was developed. Finally, a number of applications making use of this framework appeared in the literature such as power grid (2014), and water supply (2007). It is important to note that

intermodal transportation is a relatively nascent area, and there is no peer-reviewed work relevant to intentional disruption.

Literature Review on Metaheuristic Applications in Interdiction-Fortification

Though metaheuristic solution techniques have been around for over four decades, we are aware of only three peer-reviewed efforts within an interdiction-fortification setting. Aksen et al. (2013) studied the p-median problem for the planning and protection of critical facilities, and suggested three solution methods including a two-phase tabu search algorithm to solve the resulting bi-level program. Kecici et al. (2012) applied a tabu search-based solution methodology to analyze the design of a public service facility network in the presence of possible terrorist attacks. Finally, Cheng et al. (2016) examined applications of three metaheuristic techniques (i.e., tabu search, genetic algorithm, and simulated annealing) to the interdiction-fortification problems and showed the efficiency of hybrid techniques.

Literature Review on Rail-Truck Intermodal Transportation System

Although rail-truck intermodal transportation has been an active research area over the last two decades (Macharis and Bontekoning, 2004), the discussion about disruption is still in its infancy. We are aware of only two peer-reviewed works. In Sarhadi et al. (2015), an arc-based formulation with no capacity constraints at intermodal terminals was proposed, and it was demonstrated that smaller problem instances could be solved easily using commercial solvers. However, larger problem instances involving path-based capacitated formulations challenged the capability of the existing optimization packages, and thus necessitated the development of a decomposition-based solution technique (Sarhadi et al., 2017).

PROBLEM DESCRIPTION

The protection planning of rail-truck intermodal transportation problem entails interaction amongst three players, i.e., network owner, the interdictor, and the network operator –wherein each is in a different hierarchy (Figure 1). At the highest level, the network owner tries to minimize the cost of using the system by fortifying a limited number of intermodal terminals. Note that this is possible only if the owner knows the cost of the worst-case attack by the interdictor, and hence the latter's problem is a part of the former's. Next, the interdictor wants to maximize the cost of using the system by attacking a limited number of (unprotected) terminals, which is achieved through complete information about the network operator's problem. Finally, following interdiction, the network operator has to meet customer demand using the available intermodal terminals and (reduced) train services.

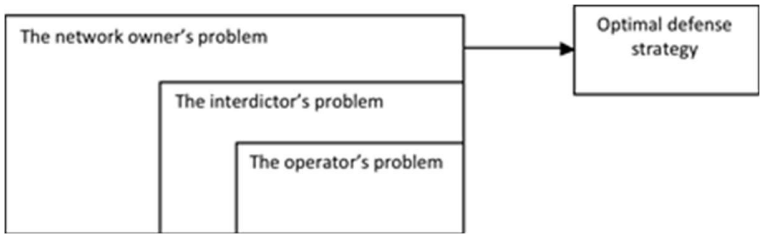


Figure 1: Hierarchical structure for the protection planning

For expositional reasons, we note that a rail-truck intermodal transportation system comprises three processes: (i) inbound drayage, (ii) rail-haul, and (iii) outbound drayage. Thus, the

network operator endeavors to find the minimum-cost way to satisfy customer demand, given the connections between the available intermodal terminals and shippers/receivers, and the pre-defined intermodal trains. In an effort to ensure feasible solutions (i.e., demand is satisfied), direct trucking is permitted between each shipper-receiver. Note that the central question about allocating limited resources such that post-disruption functionality of the intermodal infrastructure is preserved is fairly complex, in large part due to the interaction amongst the three players.

MATHEMATICAL MODEL

In this section, we present the mathematical model of the optimal fortification problem.

Sets

I Set of shippers, indexed by *i*
J Set of receivers, indexed by *j*
P_{ij} Set of intermodal paths between shipper *i* and receiver *j*, indexed by *p*
K Set of intermodal terminals in the network, indexed by *k*
P_{ij}^{k} Set of intermodal paths between shipper *i* and receiver *j* which uses intermodal terminal *k*
V Set of intermodal train services defined on the network, indexed by *v*
L^{v} Set of service legs for train service *v*, indexed by *l*
$S^{l,v}$ Set of intermodal paths using service leg *l* of train service *v*

Variables

X_{ij}^{p} Number of containers using intermodal path *p* between shipper *i* and receiver *j*
XT_{ij} Number of containers using direct trucking service between shipper *i* and receiver *j*
N^{v} Frequency (or the number) of trains of type *v*
$z_k = \begin{cases} 1, & \text{if terminal } k \text{ is protected} \\ 0, & \text{otherwise} \end{cases}$
$y_k = \begin{cases} 1, & \text{if terminal } k \text{ is interdicted} \\ 0, & \text{otherwise} \end{cases}$

Parameters

W Maximum number of terminals that the network operator can protect
R Maximum number of terminals that the interdictor can disrupt
C_{ij}^{p} Cost of transporting one container from shipper *i* to receiver *j* on intermodal path *p*
CT_{ij} Cost of sending a container using truck on the shortest path from shipper *i* to receiver *j*
T_{ij}^{p} Expected travel time from shipper *i* to receiver *j* on intermodal path *p*
T_{ij} Delivery time using truck on the shortest path from shipper *i* to receiver *j*
$\bar{T}_{ij}$ Delivery due date promised by shipper *i* to receiver *j*
D_{ij} Number of containers demanded by receiver *j* from shipper *i*
PC_{ij} Penalty cost per container per unit time between shipper *i* and receiver *j*
α^{v} Capacity of train service *v*
FC^{v} Fixed cost of operating train service *v*
U_k Capacity of intermodal terminal *k*

(P)

$$Min_z C(z) \quad (1)$$

subject to:

$$\sum_{k \in K} z_k \leq W \quad (2)$$

$$z_k \in \{0,1\} \qquad \forall k \in K \quad (3)$$

where,

$$C(z) = Max_y C(y) \quad (4)$$

subject to:

$$\sum_{k\in K} y_k \leq R \quad (5)$$

$$y_k \in \{0,1\} \qquad \forall k \in K \quad (6)$$

$$y_k + z_k \leq 1 \qquad \forall k \in K \quad (7)$$

where,

$$C(y) = Min \left[\sum_{i\in I}\sum_{j\in J}\sum_{p\in P_{ij}} C_{ij}^p X_{ij}^p + \sum_{i\in I}\sum_{j\in J} CT_{ij} XT_{ij} + \sum_{i\in I}\sum_{j\in J}\sum_{\substack{p\in P_{ij} \\ T_{ij}^p > \bar{T}_{ij}}} \left(T_{ij}^p - \bar{T}_{ij}\right) PC_{ij} X_{ij}^p + \sum_{i\in I}\sum_{\substack{j\in J \\ T_{ij} > \bar{T}_{ij}}} \left(T_{ij} - \bar{T}_{ij}\right) PC_{ij} XT_{ij} + \sum_{v\in V} FC^v N^v \right] \quad (8)$$

subject to:

$$\sum_{p\in P_{ij}} X_{ij}^p + XT_{ij} \geq D_{ij} \qquad \forall i \in I, \forall j \in J \quad (9)$$

$$\sum_{i\in I}\sum_{j\in J}\sum_{p\in P_{ij}^k} X_{ij}^p \leq U_k(1 - y_k) \qquad \forall k \in K \quad (10)$$

$$\sum_{i\in I}\sum_{j\in J}\sum_{p\in P_{ij}\cap S^{l,v}} X_{ij}^p \leq \alpha^v N^v \qquad \forall v \in V, l \in L^v \quad (11)$$

$$N^v \geq 0, integer \qquad \forall v \in V \quad (12)$$

$$X_{ij}^p \geq 0, integer \qquad \forall i \in I, \forall j \in J, \forall p \in P_{ij} \quad (13)$$

$$\boldsymbol{XT_{ij} \geq 0, integer} \qquad \boldsymbol{\forall i \in I, \forall j \in J} \quad (14)$$

(P) depict the tri-level optimization model that could be used to make protection planning decision. The *outer* level problem belongs to the network owner whose objective is to minimize total cost by fortifying a given number of intermodal terminals. Constraints sets (3) enforce the binary nature of the terminal fortification decision. The *middle* level problem belongs to the interdictor who intends to maximize the total cost of using the system. Constraints sets (5) depict the finite resources available for interdiction or disruption of intermodal terminals, whereas (6) represents the binary nature of the interdiction decisions. Constraints sets (7) combine the decisions of the network owner and the interdictor by prohibiting the disruption of fortified terminals. Finally, the *inner* level problem belongs to the network operator who intends to minimize the total cost of using the system. Note that this is a variant of the multi-commodity flow problem with capacity, delivery time, and penalty cost considerations. The objective function, i.e., (8), will capture the overall cost of moving shipments using the rail-truck intermodal option, any direct trucking service if applicable, the penalty costs for late deliveries, and the fixed costs of running different intermodal trains in the network. Constraints sets (9) ensure the demand is satisfied either using the intermodal option or through direct truck service. Constraints sets (10) enforce the capacity at various terminals in the network, and states that the interdicted terminals cannot be a part of different paths to meet demand. Constraints sets (11) determine the number of intermodal trains of a specific type needed in the network. Finally, the sign restrictions are imposed through constraints sets (12) to (14).

SOLUTION METHODOLOGY

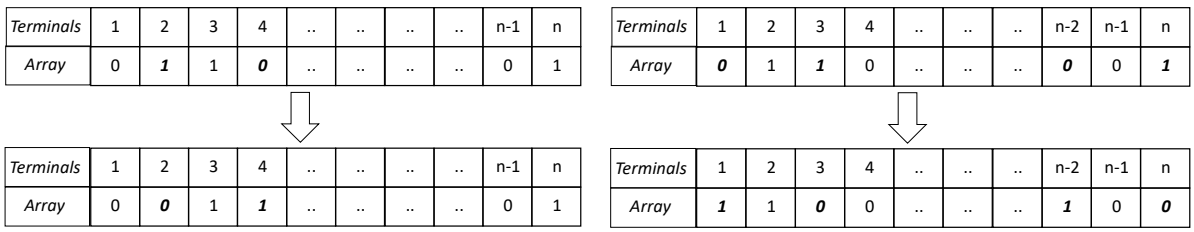
The solution methodology for **(P)** entails a metaheuristic-based technique to solve the outer level problem (i.e., the network operator), and a decomposition-based approach developed earlier in the literature (Sarhadi et al., 2017) to solve the attacker-defender sub-problem (i.e., the interdictor and the intermodal operator).

Tabu Search for the network operator's problem

We chose tabu search (Glover, 1989) over other local searches (such as simulated annealing, variable neighbourhood search) due to its demonstrated success on problems involving dispatching n objects into k sets within a constrained setting, and some recent applications in interdiction-fortification. We invite the reader to refer to Galinier and Hertz (2006), Cordeau and Laporte (2005), Zufferey et al. (2008), and Aksen et al. (2013) for successful applications. We briefly outline the different steps of tabu search adapted for **(P)**, and then explain the execution of the metaheuristic-decomposition algorithm.

a) Encoding: Each feasible solution for the defender's problem is represented by a binary vector of length n, where n refers to the total number of terminals in the network. If a given cell has value of 1, then the corresponding terminal is completely fortified. If the network operator can defend a maximum of W terminals (i.e., receive a value of 1), then the remaining (n-W) positions in the vector will receive a value of 0.

b) Neighbourhood: In order to generate a neighbouring solution of the current solution, we propose two distinct schemes: 1-swap; and, 2-swap. Figure 2a depicts the 1-swap transformation of the current solution, which for a maximum of W fortifications amongst n terminals will require evaluating $\binom{\mathbf{W}}{\mathbf{1}}\binom{\mathbf{n-W}}{\mathbf{1}}$ transformations. Figure 3b shows the equivalent representation of 2-swap transformation, and would entail evaluating a total of $\binom{\mathbf{W}}{\mathbf{2}}\binom{\mathbf{n-W}}{\mathbf{2}}$ transformations.



(a) 1-swap transformation (b) 2-swap transformation

Figure 2: Neighbourhood generation

c) Tabu tenure: The complete exploration of the neighbourhood of the current solution constitutes an iteration. The iteration at which a move is made is noted, and a condition is added to forbid the reverse move for four iterations of the algorithm. It should be clear that when a swap is happening, the most recent swap displaces the oldest swap on the tabu tenure list, and that the latter becomes available for possible transformation. Hence, one could think of the proposed tabu tenure technique as a first-in-first-out queue with a capacity to hold four recent moves.

d) Stopping condition: The algorithm stops either when the number of iterations reaches 10, or if there is no improvement in the solution in 4 consecutive iterations.

Decomposition procedure for the attacker-defender sub-problem

For a given solution generated through tabu-search, all the neighbors are examined by solving the resulting attacker-defender sub-problems. We briefly outline the solution technique for each sub-problem, and invite the reader to consult Sarhadi et al. (2017) for complete technical

details. In the first step, the network operator's problem is solved to determine the routing plan and the optimum number of intermodal train services, wherein the latter are integer valued. The output of sub-problem (SP) becomes the parameters used to build the master-problem (MP), which is a single level interdictor's problem.

SP and MP would be solved iteratively to find the optimum interdiction at each node of the search tree. More specifically, the SP and the MP are determining the upper bound and lower bound of the algorithm, respectively. At the beginning, the upper bound is set to positive infinity and the lower bound is set to negative infinity. Then, the SP is solved and it updates the upper bound and also provides the train flow information to the MP. Subsequently, the MP will be formed and solved thereby updating the lower bound. This process constitutes one-iteration of the algorithm. The algorithm continues until the lower bound and the upper bound become close enough or the maximum number of iterations is reached. However, to make this more explicit, we next outline the general steps involved in building the MP.

Step 1: Define three sets of dual variables corresponding to constraint sets (9) to (11) in **(P)**.

- ω_{ij}, β_k, and θ_l, respectively.

Step 2: Attach the dual of the network operator's problem to the interdictor's problem, and generate the following objective function:

- $Max_{y_k}\left(Max_{\omega,\beta,\theta}\left(\sum_{i\in I}\sum_{j\in J} d_{ij} * \omega_{ij} + \sum_{k\in K} u_k * \beta_k * (1-y_k)\right)\right)$

Step 3: Linearize each non-linear term in the objective function.

Each non-linear term of $\sum_{k\in K} u_k * \beta_k * (1-y_k)$ can take two values depending on the value of the binary variable y_k. It can be $u_k * \beta_k$ if $y_k = 0$, and it is zero if $y_k = 1$. Now, replace each $\beta_k * (1-y_k)$ by a new variable φ_k, and constraints sets (15) to (17) would ensure that φ_k would assume the desired values. Note that M is a large positive number.

$$\varphi_k \leq \beta_k + M * y_k \quad (15)$$
$$\varphi_k \geq -M * (1-y_k) \quad (16)$$
$$\varphi_k \leq 0 \quad (17)$$

CASE STUDY

In this part, we apply the proposed framework to a case study from the existing literature. Figure 3 depicts the intermodal transportation network of a Class I railroad operator in North America, and is borrowed from existing literature (Verma et al., 2012). We first provide the relevant details on the parameters used to solve the problem instance, and then analyze the results using four variants of the proposed tabu-search algorithm. Finally, we provide some managerial insights.

Estimation of parameters

The parameters used in the mathematical model were originally introduced in the literature (Verma et al., 2012; Sarhadi et al., 2015), and were estimated using publicly available information.

Cost: In the United States, trucks can travel at a maximum speed of 50 miles/hour, but due to lights and traffic an average speed of 40 miles/hour is assumed (Verma and Verter, 2010). Normally the drayage is charged in terms of the amount of time the crew (driver-truck) is engaged, and an estimate of $300/hour including the estimated hourly fuel cost is used. A

penalty cost of $40 per hour per container was used. As indicated there are two types of intermodal train services, namely, regular and express. Average intermodal train speed was calculated using the Railroad Performance Measure website (RPM, 2014), and was estimated to be 27.7 miles/ hour for regular, and 36.8 miles/hour for express service. Consistent with the published works, we estimated a rate of $0.875/mile for regular and $1.164/mile for express service. The hourly fixed cost of running a regular intermodal train is $500 per hour, which takes into consideration the hourly rates for a driver, an engineer, a brakeman, and an engine, which are $100, $100, $100, and $200, respectively. The express service is 50% more expensive at $750 per hour (Verma, 2012).

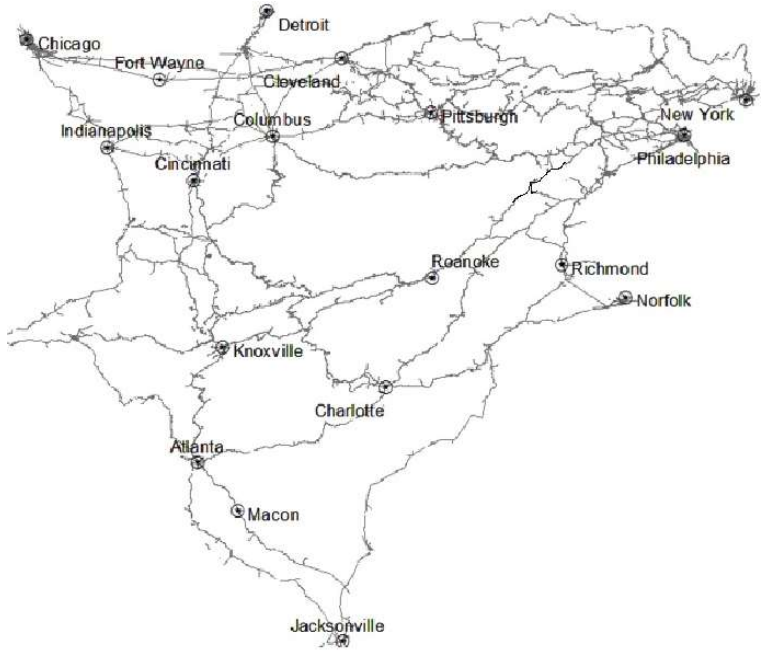


Figure 3: Rail-truck intermodal infrastructure

Due Dates: The distance (d in miles) between each shipper and each receiver was estimated in ArcView GIS (ESRI, 2008). Next, the travel time (in hours) was computed as d/40, where the denominator indicates the average speed of trucks. Finally, a constant of 15 was added to the travel time to obtain the delivery due date for each shipper-receiver pair.

Demand Level and Terminal Capacity: The innermost problem belonging to the intermodal operator was solved in CPLEX 12.6.0 (IBM, 2014) on the dataset used in Verma et al. (2012), and the solution was decoded to estimate the traffic volume through each intermodal terminal. It was assumed that the terminal utilization was 80%, and hence the terminal capacity is 1.25 times (i.e., 1 divided by 0.8) the traffic volume through each terminal. The demand level was set according to the dataset used in Verma et al. (2012). Finally, we set the optimality gap $\boldsymbol{\varepsilon}$ in the decomposition algorithm to 1%, and the maximum number of iterations to 10.

Analysis of the results

In an effort to find the best setting of the tabu search algorithm, we experimented with four variants of the algorithm. Each was coded in C# using CPLEX 12.6.0 concert technology on a PC with Core 2 Quad, 2.4 GHz processor with 4GB of RAM. The four variants are as follows:

- *Variant 1:* The tabu search algorithm starts with the output of the AD problem, i.e., the worst-case attack by the interdictor is the starting point. Under this setting, a 1-swap transformation is used to generate the neighbouring solutions.
- *Variant 2:* The tabu search algorithm starts from a randomly generated solution, followed by a 1-swap transformation to generate the neighbouring solutions.
- *Variant 3:* The tabu search algorithm starts with the output of the AD problem, followed by a 2-swap transformation to generate the neighbouring solutions.
- *Variant 4:* The tabu search algorithm starts from a randomly generated solution, followed by a 2-swap transformation to generate the neighbouring solutions.

To compare the performances of the proposed variants, forty-nine instances of the tri-level problems were solved, and the resulting solutions were analyzed for computational times and objective function values. It is important that, for variants 2 and 4, each problem instance was solved ten times to account for the random starting solutions, and the average results are reported. Thus, a total of 980 problem instances were solved using these two variants, and 98 for the other two variants.

Number of terminals							
Fortified	**Interdicted**						
	3	***4***	***5***	***6***	***7***	***8***	***9***
3	12.75	13.03	13.30	13.58	13.86	14.04	14.35
4	12.45	12.72	12.99	13.28	13.55	13.77	13.91
5	12.22	12.49	12.78	12.98	13.15	13.29	13.32
6	11.88	12.16	12.35	12.57	12.66	12.72	12.86
7	11.58	11.77	11.95	12.09	12.24	12.31	12.38
8	11.26	11.42	11.58	11.72	11.80	11.88	11.91
9	11.18	11.30	11.41	11.50	11.58	11.59	11.60

Table 1: Optimal objective function values ($ millions) using the four variants of tabu search

Table 1 shows the objective function values for the forty-nine problem instances (i.e., different combinations of terminals attacked/ defended) using the four variants of the proposed tabu search algorithm. It is important that each variant is able to find the optimum solutions for all problem instances, and thus any is effective. More importantly, each of the four could find the optimum solution for larger problem instances (i.e., the last two columns), which was not possible using the implicit enumeration technique prevalent in the literature (Sarhadi et al., 2016) where the computational time was capped at thirteen hours, and none of the larger problem instances could be solved optimally. We comment more on this when discussing Table 2.

It is interesting to note that for a given row, i.e., a fixed level of fortification, the cost imposed on the transportation infrastructure increases with higher levels of interdiction. On the other hand, for a fixed level of interdiction, the cost decreases as one goes down a column. The latter could be attributed to the effectiveness of the fortification measures because a higher level of fortification forces the interdictor to disrupt less important terminals wherein the cost of

disruption is not as severe. Table 2 depicts the computational times for the forty-nine problem instances for the four variants, and the exact solution technique.

For brevity, and also for expositional reasons, we report only the computational time to find the best solution for the four variants, and note that the total time until algorithm termination ranged between 700 seconds and 20,860 seconds.

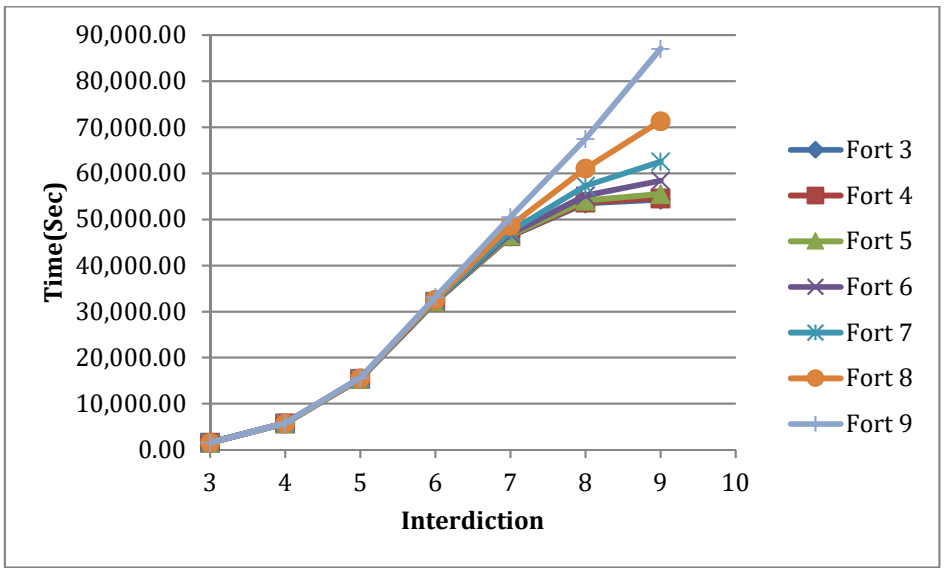


Figure 4: Computational time for Exact solution technique at different Fortification levels

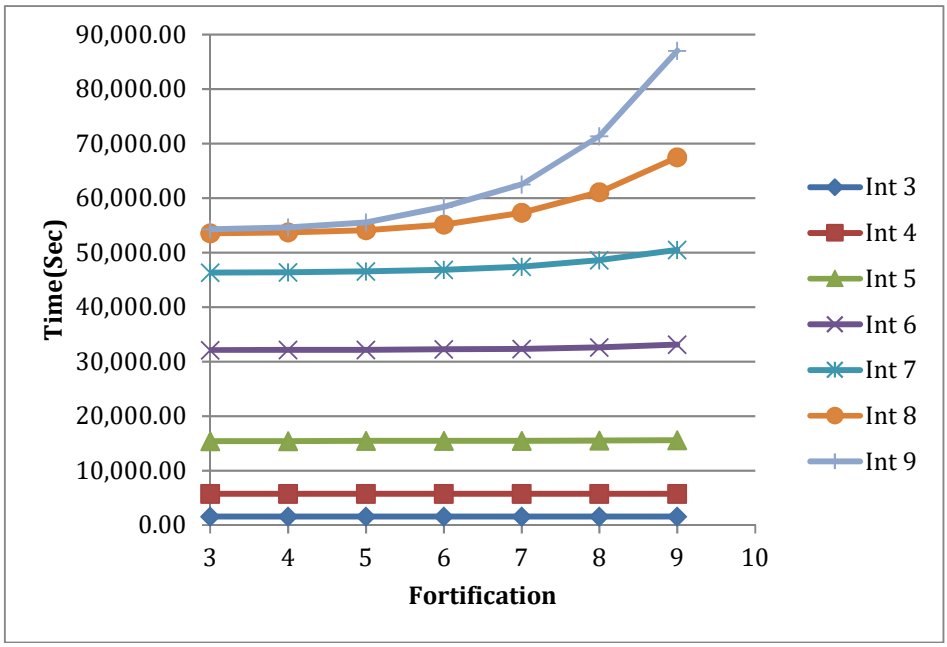


Figure 5: Computational time for Exact solution technique at different Interdiction levels

Number of terminals							
Fortified/ Interdicted	***Exact Solution Technique***						
	3	***4***	***5***	***6***	***7***	***8***	***9***
3	1.570	5.746	15.436	32.127	46.342	53.530	54.287
4	1.570	5.747	15.442	32.146	46.401	53.699	54.606
5	1.570	5.749	15.449	32.188	46.544	54.129	55.540
6	1.571	5.750	15.467	32.271	46.857	55.155	58.411
7	1.571	5.753	15.495	32.337	47.394	57.314	62.532
8	1.571	5.758	15.539	32.605	48.647	61.086	71.375
9	1.571	5.764	15.602	33.119	50.489	67.489	87.047
	Variant 1						
3	0.210	0.249	0.210	0.217	0.189	0.183	0.157
4	0.671	0.720	0.504	0.500	0.489	0.257	0.587
5	0.800	0.404	0.342	0.326	0.284	0.297	0.275
6	0.449	0.452	0.420	0.420	0.377	0.373	0.347
7	1.056	0.990	1.001	0.966	0.930	0.837	0.807
8	1.405	1.375	1.466	1.359	1.152	0.960	0.964
9	2.095	2.130	2.148	1.984	1.783	1.593	1.671
	Variant 2						
3	0.496	0.466	0.316	0.336	0.397	0.425	0.433
4	0.855	0.999	0.785	0.599	0.588	0.612	0.765
5	1.125	1.418	0.919	1.030	0.907	1.171	1.102
6	1.903	1.967	1.660	1.244	1.253	1.323	1.175
7	2.077	2.273	1.601	1.540	1.686	1.816	1.777
8	2.009	2.404	2.030	2.270	2.189	2.043	2.062
9	2.907	2.667	2.714	3.045	2.364	2.127	2.178
	Variant 3						
3	1.316	1.411	0.773	0.900	2.660	3.253	2.110
4	2.650	3.345	1.265	2.020	2.022	1.970	1.846
5	3.451	4.368	5.220	4.021	5.600	6.081	9.860
6	7.145	7.820	4.560	3.345	4.558	4.263	8.240
7	6.648	7.170	6.604	5.720	6.623	5.593	5.401
8	9.552	6.620	6.030	8.820	8.366	7.640	7.114
9	11.825	8.640	9.400	14.458	8.640	9.189	6.690
	Variant 4						
3	1.816	1.811	0.973	1.220	3.421	4.251	2.310
4	4.850	4.345	1.965	2.130	2.220	2.053	2.246
5	5.451	4.768	5.720	5.631	6.730	7.327	10.941
6	8.445	8.820	5.760	3.045	6.681	4.931	8.698
7	7.948	9.170	6.904	5.720	7.631	7.236	6.412
8	8.352	8.260	6.855	8.313	10.366	8.012	9.412
9	12.825	11.640	14.246	14.258	13.640	13.219	12.215

Table 2: Computational time (x 10^3 seconds) for tabu search variants and exact solution technique

In an effort to underline the efficiency of the proposed metaheuristic-decomposition-based methodology to solve the tri-level problem, we note that the combination of the implicit enumeration and the exact solution could not solve larger problem instances in thirteen hours, i.e., 46,800 seconds (Sarhadi et al., 2017). This is also reflected in the Exact Solution Technique block in Table 2, where eighteen problem instances required more than thirteen hours to find the optimum solution. Under this technique the computational time increases both across a row and down a column. More specifically, for a given fortification level, the computational time increases rapidly with the increase in the interdiction budget because a larger number of patterns need to be enumerated thereby requiring more time (Figure 4). On the other hand, for a fixed level of interdiction, the computational time increases more rapidly for larger problem instances because of the explosion in the size of the tree to be searched (Figure 5).

It is encouraging to see that according to Figure 6, without loss of generality, for Variant 1 the computational time is fairly stable for a given fortification level, and exhibits low fluctuations. However, at a given interdiction level, computational time shows an increasing trend with regard to fortification resources (Figure 7), which is due to the fact that with an increase in the fortification budget the size of the network operator's feasible region increases. Consequently, by combining Figures 6 and 7, it is safe to say that the metaheuristic-based methodology is effective in reducing the computational burden of the problem compared to the combination of the implicit enumeration and the exact solution technique since with a fixed fortification budget, a non-increasing trend in the computational time is happening. Furthermore, according to Table 2, each variant beats the exact solution technique easily, and is a definitive improvement over the prevalent techniques to solve tri-level problems. It is clear that Variant 1 outperforms Variant 2 though both are based on 1-swap transformation, which also underlines the significance of the initial solution. The former variant exploited the results yielded by the attacker-defender sub-problem to start the search, whereas the latter made use of random starting points, which often resulted in reaching the best solution very close to the time when the algorithm terminated.

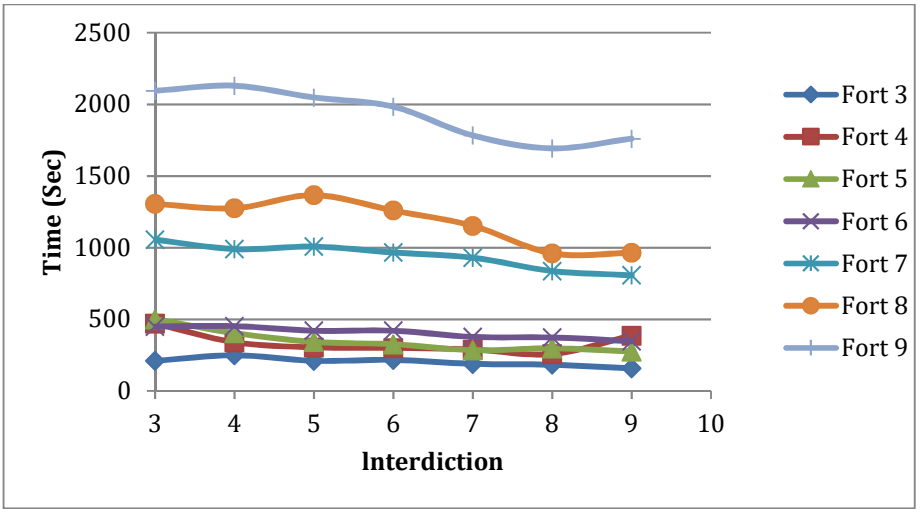


Figure 6: Computational time for Variant 1 at different Fortification levels

This is important, because as mentioned in the fortification-interdiction literature, although the solution to the attacker-defender sub-problem (i.e., critical terminals) may not be the optimal solution to the tri-level problem, we have shown that using the attacker-defender solution to initialize the tabu search algorithm will result in reaching the optimal solution much more quickly

than initializing with a random solution. This phenomenon also explains why Variant 3 outperforms Variant 4, both of which are using 2-swap transformation. Finally, comparing Variant 1 and Variant 3, both of which make use of the same initial solution throws light on the role of the neighbourhood structure on the computational performance. It is evident that 1-swap transformation is outperforming the 2-swap transformation, because the latter forces radical changes in the search process thereby delaying the convergence process. To sum, Variant 1 is the most efficient, and should be used for all computational experiments.

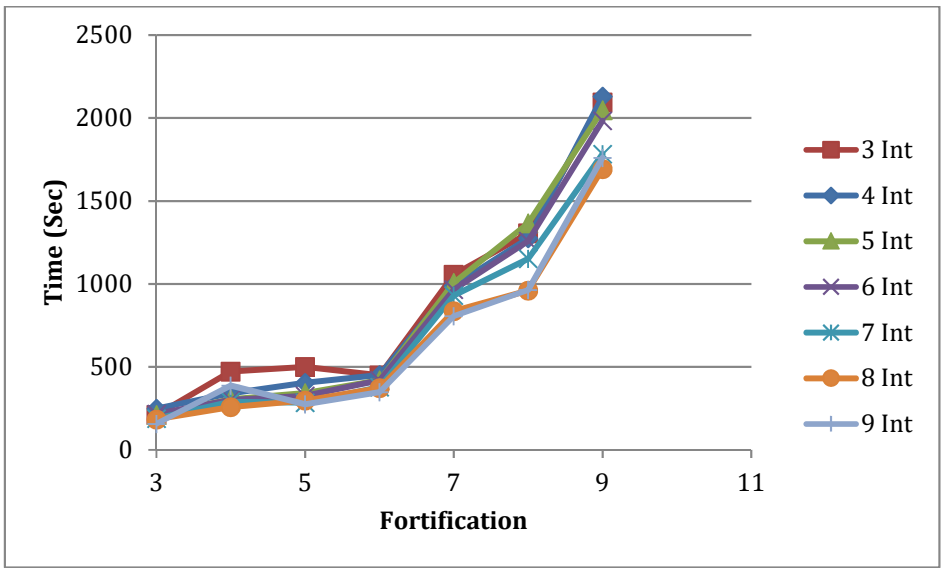


Figure 7: Computational time for Variant 1 at different Interdiction levels

Managerial Insights

Finally, we demonstrate the importance of having a sound fortification plan in place, and highlight the role such a plan plays in the smooth operation of a rail-truck intermodal transportation system. Table 4 depicts the average capacity utilization, the number of terminals at different levels of capacity utilization, and the percentage of demand that lost its connection to the intermodal network. As evident, when there is no attack or defense, i.e., the Base-Case, the average capacity utilization is 80% and all the demands are connected to the network.

For expositional purposes, we report results under two approaches: the optimal fortification (OP) using the proposed metaheuristic-decomposition-based methodology; and, fortification of critical terminals (CP) as identified by solving the AD sub-problems. It is clear that for every fortify/interdict combination, OP would yield a higher average capacity utilization and a lower demand with lost connectivity compared to CP. The results provide additional credence to the notion that the solution to the AD sub-problems will not provide the best protection plan. Note that as the number of terminals fortified/ interdicted increases, both the average capacity utilization and percent of demand that lost access to the network deteriorates under CP, but improves under OP. It is a clear indication that for larger networks, and higher values of fortified/ interdicted terminals, OP will yield significantly better solutions and thus should be the preferred approach for fortification decisions. Also, the percentage of the demand that lost its connection to the intermodal network is always lower in OP compared to CP. For both approaches, with the increase in the number of terminals fortified/ interdicted, the percentage of the demand that

loses the access to the network decreases and especially for the OP the most of the demand could have access to the intermodal network.

Number Fortified	Number Interdicted	Cases	Avg. Cap. Utz. (%)	Number of terminals (utilization)						% loss
				<25	<50	<65	<80	<90	<100	
0	0	*Base-Case*	80.0	0	0	0	10	7	1	0.0
3	3	*CP*	61.0	4	4	2	4	1	3	37.0
		OP	68.0	3	3	1	7	3	1	24.7
4	4	*CP*	60.3	5	3	5	3	1	1	35.0
		OP	68.0	4	1	4	5	1	3	20.0
5	5	*CP*	60.0	6	3	4	3	1	1	36.0
		OP	65.0	6	2	2	4	2	2	15.0
6	6	*CP*	59.0	7	3	3	3	1	1	34.0
		OP	70.1	6	0	1	6	3	2	9.0
7	7	*CP*	58.0	9	1	3	2	0	3	31.4
		OP	68.0	10	0	2	2	2	2	1.8
8	8	*CP*	24.0	16	0	0	1	0	1	30.0
		OP	71.0	9	0	0	3	3	3	1.4
9	9	*CP*	14.0	16	1	0	0	0	1	28.0
		OP	77.0	9	0	0	2	5	2	1.0

Table 4: Average capacity utilization & percent of demand lost

CONCLUSION

In this paper, we propose a methodology to solve a tri-level mathematical model developed to protect a given number of rail intermodal terminals such that the effect of disruptions is minimized. More specifically, we propose a tabu search algorithm to more efficiently solve the outer level problem that belongs to the network operator and was until now being solved using the implicit enumeration scheme of Scaparra and Church (2008). We then outline a solution methodology that combines the tabu search process with the decomposition technique developed in the literature (Sarhadi et al., 2017) to more efficiently solve the tri-level model. The proposed methodology was used to solve and analyze problem instances based on the realistic infrastructure of a class I railroad operator. In addition, the computational efficiency of the proposed methodology was highlighted in relation to the existing techniques in the literature.

Through numerical analysis, we can conclude three things. First, it is important to spend the finite resources judiciously to fortify a given number of intermodal terminals, since doing so would improve the post-interdiction performance of the remaining intermodal transportation system dramatically. Second, the proposed metaheuristic-decomposition-based methodology returns optimal solutions much faster than the exact techniques. This is a significant improvement over the existing techniques, including the implicit enumeration strategy proposed in Scaparra and Church (2008). Third, the 1-swap transformation that makes use of the output of the attacker-defender sub-problem yields optimum solutions in the quickest time, and thus should be the preferred variant of the tabu search process. In addition, the identification of the reduction rule facilitates further improvements to the computational performance of the algorithm.

There are a number of future research directions. First, the terminal capacities could be integrated to the model such that the remaining network would have enough capacity to meet the demand. Second, the design of intermodal train services could be explored such that loss in the connectivity, following interdictions, would not be dramatic. Finally, the current model can be augmented by adding uncertainty in the decision making process. For instance, in the absence of perfect information, the attacker may disrupt terminals other than the most important ones. Alternatively, the defender may not know the exact number of disruptions in advance, and may have to fortify the network against the expected number of disruptions.

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An Anomaly in Yates' Correction for Continuity in the
2x2 Cross-Tabulation Chi-Square Test of Independence

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ABSTRACT

Cross-tabulation and its accompanying chi-square statistical hypothesis test is among the most commonly applied types of analysis. Though not without subtle aspects, the basic analysis is straightforward. A chi-square test statistic is calculated and on the basis of the accompanying p-value the null hypothesis of independence is either rejected or not rejected. For 2x2 cross-tabulations it is commonly held that the original calculation of the chi-square statistic should employ Yates'(1934, 1984) correction for continuity. The present research highlights an anomaly that can occur with that correction.

KEYWORDS: Cross-tabulation, Chi-square, Yates' correction for continuity

Full text and references available upon request.

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An empirical study of adoption and diffusion of electronic commerce in large enterprises in the Mexico City region

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ABSTRACT

Electronic commerce represents a very attractive business opportunity for enterprises because of its characteristics and potential advantages. This paper aims to analyze the diffusion of e-commerce in a group of large enterprises in the municipality of Iztapalapa, Mexico. A quantitative and content analysis of the web pages of the enterprises was conducted to establish the adoption and use of e-commerce.
This technological application is a convenient strategy for manufacturing and commercial enterprises. Likewise, the implementation of such a strategy implies an important investment for enterprises. It was found that the use of e-commerce has not been generalized in large enterprises in Iztapalapa.

KEYWORDS: Information technology, on line shopping, Information systems, electronic commerce, large enterprises

INTRODUCTION

Information technology is still in an evolving phase for many reasons, such as the grow of Internet users and broadband subscriptions; the increasing use of mobile technology to access the Internet; the diffusion of Social Networks sites; the need for government to provide services through e-government allowing online transactions; and the spread of cloud computing services (Fredriksson, 2013).
The development of digital economy around the world has been different in speed and level. On the one hand, the economical activities, digitalization and transactions can help to avoid barriers that allow a more inclusive development. On the other hand, it also means a division between well prepared countries to commitment and benefit of the digital economy, facing its risks and causing a digital gap with unprepared countries (UNCTAD, 2017).
In the same sense, enterprises digitalization shows the level of adoption and use of Information Technology (IT). The adoption of IT can be measure through standard indicators such as computer availability, access to Internet and others IT. While more activities within enterprises become digital, the firms will need to be on line and be visible for other consumer enterprises (UNCTAD, 2017).
In particular, Internet has created a new universal technological platform, which has flood the market with multiple applications for domestic and organizational use. Improving the enterprise possibilities to implement technological innovations in different levels and for diverse functions. Concerning electronic commerce (e-commerce), enterprises used patented systems to integrate data from their internal systems to communicate with their customers and commercial partners. Those systems were expensive and based on standard technologies, which only few

enterprises can reach (O'Brien & Marakas, 2007; Stair & Reynolds, 2006). However, this situation has been modified due to IT developments, the creation of web technology in 1992 and the introduction in 1996 of the security encoded SSL 3.0 (Secure Sockets Layer) (Fernandez-Portillo, et al., 2015). Currently e-commerce has been spread because Internet has become as a universal technology used for interchanging products and services, as it is a natural platform choice to develop e-commerce. It also represents an easy way at low cost for connection, business, and users.

E-commerce has evolved from a passive and static activity used by enterprises to show products and services catalogs, to a strategic tool with capacities to develop new businesses, to expand firms and to maintain close relationships with their customers and suppliers.

Because of e-commerce characteristics and the growing number of electronic devices used to search and buy products and services, enterprises have to adopt and implement this technology. The electronic commerce phenomenon continues to generate great interest among researchers. However, the development of e-commerce is uneven and unequal around the world, in particular Mexican organizations present a low level of growth. Attempting to gain an understanding of the adoption of e-commerce, this paper aims, in this first stage, to present the results of the descriptive and explorative research of how enterprise are starting to adopt and use e-commerce in large enterprises in Mexico City.

The paper is divided in various sections. First we present a theoretical framework that includes a definition of e-commerce, its advantages and disadvantages; as well as research topics about e-commerce adoption and multistage model for e-commerce implementation. Next an analysis of the actual situation of e-commerce diffusion in Mexican enterprises is reported, following by the methodology used to develop the research. The following section presents the findings obtained from data collection and an analysis is also included. Finally we present the conclusion of the research.

LITERATURE REVIEW

Electronic commerce

Following UNCTAD (2017:3), e-commerce "refers to purchases and sales conducted over computer networks, using multiple formats and devices, including the web and electronic data interchange and the use of personal computers, laptops, tablets and mobile phones of varying levels of sophistication". E-commerce implies the entire online process of developing, marketing, selling, delivering, servicing and paying for products and services commercialized on Internet (Fredriksson, 2013). E-commerce can include for example interactive marketing, ordering, payment, and customer support process through catalogs and auction sites (Guerrero Cuellar & Rivas Tovar, 2017).

There are different categories of e-commerce (O'Brien & Marakas, 2007; Stair & Reynolds, 2006):

- Business to Business (B2B) in which the participants are organizations.
- Business to consumers (B2C) where business develop electronic marketplaces to sell products and services to consumers.
- Consumer to Consumer (C2C) which involves consumers selling directly to other consumers.
- Business to Government (B2G) where the transactions are between business and government.
- Consumer to Government (C2G), which involves government offering services to consumers.

The advantages of using this technological platform include its universal use and the easy way to employ it, because electronic commerce is based on standards that all enterprises with different characteristics can use it (Fernandez, Hurtado & Peral, 2005). It can be used in any context where documents between organizations are interchanged. The web sites are available 24 hours a day, 365 days per year; products such as software, music, videos, books, for example can be distributed through Internet. Organizations can also use net to distribute information on products or services, for example: price, general characteristics, options, availability or delivering time.

Based on its own characteristics, e-commerce has also had an effect on other areas, such as, developing new channels for sells and marketing; interactive access to electronic catalogs of products and services; price lists; specific characteristics and publicity; uninterrupted technical support; customer support and after-sales services (Rios Ruiz, 2014).

There are multiple advantages for enterprises to use Internet for the buy and sell process; they can reduce transaction costs and delivering time for products, in particular the digital ones, for example, software, text products, images or videos. They can also speed up the flow and information of products, to improve customer support and to coordinate producers, suppliers and customers. Enterprises can also have a global presence, unlimited availability working hours, competitive increase, personalized products and services, remove of intermediaries, to offer products with digital format, new business opportunities, new products and services opportunities, new publicity forms, and a better customers' knowledge and inventory reduction (Guerrero Cuellar & Rivas Tovar, 2017; Fernandez-Portillo, et al., 2017; Rios Ruiz, 2014; Sojo Obando 2001).

Customers can also benefit from e-commerce, for example its more confortable to shop on line, they economize time and resources, there is a broader selection of products and prices; customers also might have enough information about merchandise and easy access to consumer reviews; stores are available 365 days per year; they can have personalize service based on previous purchases and geographical independence; and convenient home delivery (Chang, Kao & Jain, 2014; Sojo Obando, 2001).

However, the adoption of e-commerce can also imply many difficulties for enterprises. It represents a considerable investment in hardware and software; it needs special personal to attend orders; enterprises have to organize special logistic for delivering products; a financial sells cost; management of all site's visits and cost for publicity (Fernandez, Hurtado & Peral, 2005; Sojo Obando, 2001).

When enterprises decide to innovate, for example to adopt e-commerce, they have to realize that market must be ready for such technology; suppliers and customers should get familiar with these tools (McKeen & Smith, 2015). Technological infrastructure and complementary products and services must be available as well, for example, an effective and efficient communication network and associated software to take advantages of this technology. It is important to mention that many innovations fail because an organization's culture cannot sustain or take advantage of them (McKeen & Smith, 2015).

Therefore, before deciding to implement e-commerce, organizations must analyze diverse factors such as the possible benefits; the economical, technical, knowledge and personal requirements for the adoption. Organizations have to consider also, the characteristics of an innovation that influence adoption: relative advantage, complexity and compatibility (Rogers, 2003). Finally, they must to analyze if the decision to adopt a new innovation relates to the business objective, strategies and evaluate the impact that their use will have in the whole organization.

Adoption refers to the decision of individuals or organizations to make use of an innovation, different approaches to IT adoption can be found in the literature. One approach examines the relation between IT acceptance and its impact on the individual user, e.g. the decision made by an individual within an organization (Jeyaraj, Rottman & Lacity, 2006; Rogers, 2003; Venkatesh

et al., 2003). Another approach explains the overall impact of IT adoption within the organization itself (Frambach & Schillewaert, 2002; Jeyaraj, Rottman & Lacity, 2006).

On the stream of research which deals with technology adoption from the users' point of view, we can find a group of diverse factors associated with users' decision to adopt a technology, such as personal's attitude –based o values and beliefs-; personal norms–motivation- (Ajzen, 1991); usefulness and user friendliness (Davis et al., 1989); perceived usefulness (Venkatesh et al., 2003). The analysis of these kind of determinants has been also translated into the studies on individual level adoption of e-commerce, for example: customer perceived value, customer loyalty, perceived risk, perceived benefits, information security, satisfaction purchase intention, perceived usefulness, perceived easy of use (Chang, Kao & Jain, 2014; Jun & Yang, 2013; Lim, Lim & Heinrichs, 2014; Lu et al., 2013; Sharma et al., 2017).

Other studies focus on e-commerce from an organizational perspective. Studies analyze factors related to the adoption of e-commerce such as: organizational, innovation, technical, environment, country level, and knowledge (Kuan, & Chau, 2001; Fernandez-Portillo, Antonio, et al., 2015; Frasquet Deltoro, Molla Descals & Ruiz Molina, 2012; Merhi, & Ahluwalia, 2014; Panda & Das, 2016; Rodriguez-Ardura, Meseguer Artola & Vilaseca i Requena, 2008; Sepulveda Robles, et al., 2016; Thong, 1999; Wymer, & Regan, 2005). Various researchers conclude that some factors related with a successful e-commerce adoption are: firm's size, firm's age, products' characteristics, degree of innovation, degree of internationalization, internet marketing levels, regional economic-cultural differences, communication, industry, financial cost, technical competence.

Another research stream describes the history of e-commerce development (Fernandez Nodarse, 2013; Guerreo Cuellar & Rivas Tovar, 2006). Authors describe the first e-commerce models as the ones to use Internet as a virtual shop window to present their products, the main objective was to assure its presence in Internet. Later on e-commerce evolve to web 2.0 models where the main actor was the customer, in those sites it was possible to do sell and buy transactions through digital media. In a third stage, the e-business is developed; it includes applications and process that allow firms to do the whole commercial process by Internet. Finally some authors posit the idea of a new model, web 3.0, based on web site that uses 3D interfaces and artificial intelligence (Fernandez Nodarse, 2013).

It is possible to find some research focusing on the creation of models explaining the stages through which organizations have to move in order to adopt and implement e-commerce as part of its diffusion (Daniel, Wilson & Myers 2002; Guerrero Cuellar & Rivas Tovar, 2005; Montijano Guardia, et. al., 2002; Veciana Verges & Serrasols Torres, 2001). In that sense Guerrero Cuellar & Rivas Tovar (2005, cited by Andrews 2002) describe three stages as part of the selling process based on telecommunication: the first is the pre-sell stage where customer have access to firm's site and visualize their purchase history and status; the second one is defined as surfing and buying, where users can access the firm's site to search products in catalogs, to find products information, to select products or services and to purchase their merchandise; finally the integrative stage where the firm offers customers the possibility of integrating their buying- selling processes through the use of a complimentary software given by the seller.

Daniel, Wilson and Myers (2002) point stages to adopt e-commerce by SMEs, as they gather experience. In each stage firms develop applications and activities involved with this technology that works as a foundation for the next stage. In the first stage organizations start developing the first e-commerce services, activities related to e-mail communications with customers and suppliers, creating products and services databases to be published in the web site. In the second stage the web site functions with information created in the previous stage, there is electronic interchange of documents within and outside the firm. In the next stage an application has been developed to create and receive on line orders, e.g. the possibility to make digital transactions. In the last stage firms implement the whole e-commerce process allowing to buy products and services electronically, and to provide after-sales services.

Veciana Verges and Serrasols Torres (2001) and Montijano Guardia, et al., (2002) suggest also that firms start adopting Internet technology, including e-commerce by stages. According to Veciana Verges and Serrasols Torres (2001), the first stage includes information in the web site aiming to have presence in Internet; in the second stage firms translate some process to the web site, for example products' catalogs, to recruit personal and for customer service. In the last stage enterprises have the possibility to do transactions on line in their web sites.
In the same sense Montijano Guardia, et al., (2002) establish that enterprise's web presence can be classified in three stages: information web where organizations use Internet to diffuse information of themselves; transactional web, where firms incorporate diverse activities by using e-mail and questionnaires to query customers and to offer their products through this media. Operational web, where firms establish an interconnection with suppliers and customers in order to do electronic data interchange, as well as commercialize their products by Internet.

Multistage model for e-commerce

An e-commerce system requires that firms implement on line all the stages that customers usually experience in the sale cycle of life. That is why firms need to provide the tools for helping users to search and find the products they are looking for, to select the ones they are interested on, to negotiate the price, to choose the type and terms of payment, and to be aware of the delivering date. Once a customer has done the previous stages, firms proceed to complete the purchase order of the products and to make the payment; finally, the buyers receive the product and after-sales services (O'Brien & Marakas, 2007; Stair & Reynolds, 2006). Multistage model for purchasing on Internet includes search and identification, selection and negotiation, purchasing products and services delivery, and after-sales support. According to O'Brien and Marakas (2007) and Stair and Reynolds (2006), firms will be successful only if they include at least next elements in their e-commerce process:

- Access control and security in order to establish mutual trust and secure to make the electronic commerce transaction. Firms should incorporate authenticating users, authorizing access, and enforcing security features in their web site.
- Profiling and personalizing, once customers have gained access to the web site, profiling process can occur obtaining data on customers and their surfing, behavior and choices while on the website; these profiles are used to recognize each customer as an individual user and to offer a personalized point of view of the website, as well as for recommending products or services.
- Search management to help customers finding a specific product or service they want to evaluate or buy.
- Content and catalog management to develop, generate, deliver, update and save files with data and multimedia information of the web sites.
- Payment, usually by using a shopping cart where customers can add their products. Afterwards customers select a payment method and complete the purchasing.
- Workflow management to guarantee that firms' workflow operates properly in order to make the correct transactions, decisions and activities, with the correct data and to deliver the documents to the right employees, customers, suppliers and other business partners.
- Event notification, to respond the diverse activities in the e-commerce process, e.g. new customer's first website access, to payment and delivery processes, customer relationships and supply chain management activities.
- Collaboration and trading are support activities for vital collaboration agreements and trading services needed by customers, suppliers and other partners to accomplish e-commerce transactions.

Electronic commerce context

As we previously mentioned, the development and diffusion of IT have increased the number of Internet users as well as the way business has implemented electronic commerce. According to official UNCTAD statistics (2017) the international level o e-commerce includes business to business (B2B) and business to consumers (B2C) categories, the global electronic commerce in 2015 reach the $25,293 billions. The amount of B2C sells represented $2,904 billons, about ten percent of the global overall estimated. On the contrary B2B sells reached $22,389 billion (UNCTAD, 2017). China still represents the mayor B2C market of e-commerce ($617 billion), closely followed by the United States of America ($612 billions) (UNCTAD, 2017). However, the United States reported the mayor B2B market with $6,443 billions, followed by Japan ($2,382 billions) (UNCTAD, 2017). The ten biggest e-commerce markets reported include: United States, Japan, China, Republic of Korea, Germany, United Kingdom, Northern Ireland, France, Canada, Spain and Australia. No developing country was featured among the top ten lists.
For 2014 the Asia-Pacific market estimated a growth of 23%, been China (65%) and Indonesia (71%) the main sector' actors (Rios Ruiz, 2014). North America and East Europe would growth at 12% (Rios Ruiz, 2014).
In the case of Mexico, according to official data (INEGI, 2016), IT diffusion has had a constant growth, the number of computers users increased from 16.74% in 2001 to 51.25% in 2015; the number of Internet users grew from 7.95% in 2001 to 57.43% in 2015; and the number of mobile phone users were increased from 43.91% in 2009 to 71.46% in 2015.
According to Rios Ruiz (2014), enterprises started to connect to Internet in 1994 in Mexico and the number that has implemented e-commerce has increased constantly; the country is the second in Latin America after Brazil. Data from the Internet Mexican Association shows that the economic flow produced by e-commerce has multiplied by five since 2009 (24,500 million of Mexican pesos) to 2013 (121,500 millions of Mexican pesos) (AMIPCI, 2013). Data also shows that e-commerce has had a positive evolution in recent years (See Table 1), for 2014 the growth passed from 34% to 59% in 2015.

Table 1. Mexican e-commerce evolution (thousand of millions Mexican pesos)

	2009	2010	2011	2012	2013	2014	2015
Estimated value of the e-commerce market	24.5	36.5	54.50	85.70	121.60	162.10	257.09
Source: AMIPCI (2016).							

The AMIPCI (2016) study on e-commerce reports that shoppers from an international retailer have grown from 57% in 2015 to 60% in 2016, the United State was the main source country of enterprises where users buy the most (61%). The same research shows that three mayor categories of products purchased online are cloth and accessories (53% in 2015 an 2016), digital download (49% in 2015 and 46% in 2016), and event tickets (35% in 2015 and 37% in 2016) (AMIPCI, 2016). PayPal (62%), debit cards (51%); and personal credit cards (56%) were the preferred payment methods for online purchases.
Based on the previous data, we can observe that the use of e-commerce in Mexico is becoming more and more popular; nevertheless except for multinational firms or specific sectors few enterprises have taken advantage of this technology. Seeking to understand how enterprises are adopting e-commerce and how is its diffusion in developing countries, this research aims to analyze how firms are adopting e-commerce focusing on the analysis of the web sites and e-commerce sites in large enterprises in Iztapalapa, Mexico City.

METHODS

The research question for this research was ¿how e-commerce is diffused in Mexico through its adoption by large enterprises in Iztapalapa, México City? To answer the research question a descriptive study was conducted in order to determine the properties, characteristic and profile of a set of enterprises located in the region.

According to INEGI (2013), Mexico City is the most important city and the main economic region in the country. It represents the first state in the country contributing the most of the enterprises (8.15%) and the highest contribution to national GDP with 16.7%. Based on the economic census in 2014 (INEGI) the Iztapalapa municipality is the one with more firms established there (73,321), the one with the greater number of employees working there 320,196 and the most important contribution to Mexico City GDP with 4.9%.

The unit of analysis for this research is a group of 273 large enterprises established in the municipality of Iztapalapa, which already has a technological infrastructure that allows them to implement e-commerce. As a general data source for contact firms with 100 or more employees, a database of INEGI (2017) national statistics directory of economic units was used. A content and qualitative analysis of the web pages and e-commerce sites of the enterprises' sample was conducted from May to September 2017. The analysis includes surfing the enterprises' web pages and their e-commerce application already implemented. A static analysis content of both sites was also conducted, in order to review the general characteristics of e-commerce.

The first goal of the content analysis was to determine the level of Internet implementation as foundation of e-commerce adoption. Based on Veciana Verges and Serrasols Torres (2001) stage model to develop e-commerce, we created dichotomous variables to determine the specific stage where large enterprises of Iztapalapa web site are. For the content of analysis the presence or absent of several characteristics of the sites were identified and counted to establish each level o stage.

The first stage corresponds to the Internet presence or absence in the enterprises web sites. Associated with this level we included dichotomous variables related to the firm's inclusion in different electronics directories: corporates, sectorial, and job placement. Variables that show enterprises' general information such as: e-mail address, physical address, phone, age, enterprises' origin, name of the conglomerate, global site, language, kind of enterprise, contact, if the firm is social responsible, if it has any kind of certification, standards or normalization were also defined.

To determine the second stage of web site development we included the following dichotomous variables: general information of products or services, products or services catalogs, specific information about customers, products or services' searching, customer's link, suppliers' link, downloaded information, customer services' link, job placement link and a link for organization recruitment.

The last stage belongs to the possibility to make online transactions in the web page. In the study there are enterprises that have already implemented applications such as intranet, extranet and e-commerce. Thus, we included the following variables: online transactions, intranet, extranet, e-commerce, and category of e-commerce. In this stage enterprises allow users to make online commerce so we reviewed if the web pages include all elements of the multistage model of e-commerce such as search and identification, selection and negotiation, purchasing products and services, delivery and after-sales services. At this level we reviewed variables including: quote or budget solicitude, quote or budget online solicitude, online store access, data and register user, management content, profiling and products personalization, update shopping list, purchase order, payment, delivery method, refund policies and after-sales services.

Data collected from the web and e-commerce sites were coded before the statistical analysis. This analysis was made using JMP software. In order to present the results of this first stage of the research an exploratory statistics based on frequency distributions were used to obtain the characteristics of each variable included in the analysis.

RESULTS AND DISCUSSION

According to the national statistics directory of economic units there are 273 large enterprises registered in Iztapalapa (INEGI, 2015). The majority of the companies were in the manufacturing sector (57%), 27% were in the commerce sector and the remaining 16% in the services sector. In this municipality there were enterprises with more than 100 years old (9), others were established between 1931 and 1950 (25); it was found that the majority of firms were created between 1951 and 1980 (63); 44 firms were established between 1981 and 1997, and only 10 companies were created since 2001. The majority of the companies are Mexican (90%) and more than a half were part of a conglomerate (51%). The majority of them were wholesale firms (86%) and 14% were retailer companies.
It was possible to establish the telecommunication technology foundation related to web site adoption in large enterprises in Iztapalapa, by the number of enterprises with Internet presence in different stages. In relation to the first level of informative web adoption according to Veciana Verges and Serrasols Torres (2001), enterprises adopt this technology aiming to obtain presence in Internet and then include only general information (See Table 2).

Table 2 First stage of electronic commerce adoption: Information Web

Variable	Number of enterprises with	Number of enterprises without	Percentage of enterprises with	Percentage of enterprises without
Web page	227	46	83.15%	16.85%
E-mail	239	34	87.54%	12.45%
Corporate directory	265	8	97.97%	2.93%
Sectorial directory	252	21	93.30%	7.69%
Job placement directory	250	23	91.57%	8.42%
Visitors' register	75	198	27.47%	72.52%
Global site	61	212	22.34%	77.65%
Language	65	208	23.81%	76.19%
Event publicity	112	161	41.02%	58.97%
Contact	243	30	89.01%	10.98%
Certification/Normalization/Standards	160	113	58.60%	41.39%

Source: Own elaboration.

Some characteristics that can be observed in web sites reported that 88% of the firms had an e-mail compared to 83% enterprises that already have their own web site. This shows that organizations start using the Internet adopting an e-mail. Enterprises are interested in having presence in Internet by the development of their own web site or by been part of others' directory that are in Internet, such as corporate (97%), sectorial (92%), or as a job-placement reference (92%).
The majority of web site firms' did not registered visitors, only 27% did, losing the opportunity to have information of organizations or users than can return to the site and would be interested in

obtaining much more information about products or services. Only 22% of the web sites is global, that is they show the branch conglomerate, there are multinational enterprises which their sites show the same information nevertheless the country or region were the visitors are. No matter the origin of the firms the 76% of the sites can display the information in English, probably because is a key element to start internationalizing or reinforcing their presence at a global level.
Firms in their web pages present general information, for example: event publicity (59%), contact information (89%), e-mail' contact information (77%). They also indicated if they have any kind of special certificate, or accomplish some norms (59%). Web sites analysis indicates that more than a half of the firms are socially responsible (53%).
The second stage of the e-commerce adoption process is relates to a procedure web that allow firms to include some elements or processes than can be done in the enterprises' web sites (See Table 3).

Table 3 Second stage of e-commerce adoption: Procedure Web

Variable	Number of enterprises with	Number of enterprises without	Percentage of enterprises with	Percentage of enterprises without
Products or service's description	232	40	85.29%	14.70%
Catalog	192	81	70.33%	29.67%
Search	153	120	56.04%	43.95%
Customer link	144	129	52.74%	47.25%
Supplier link	79	194	28.93%	71.06%
Public link	85	188	31.13%	68.86%
Applications	79	194	28.93%	71.06%
Customer service link	150	123	54.94%	45.05%
Job placement	42	231	15.38%	84.61%
Recruitment solicitude	40	233	14.65%	85.34%

Source: Own elaboration.

The majority of the sites has already included products and services description (85%), as well as an electronic catalog of their merchandise (70%). It is also possible for visitors to search specific products (56%), to show specific communication address to customers (69%), as well as direct link to customers (53%), suppliers (29%), or general public (31%). In the same sense, but with minor percentages of firms, the user can download applications, technical manuals or complement documents of products or services (29%). The sites also have a special link for customer service (55%). Another process that companies are including in the web site is publicity of their job placement (15%), and in some cases a questionnaire for on line recruitment (15%).
In this stage it was visible that firms start establishing some tools to have bidirectional communication with the visitors, in order to have a channel to obtain in particular feedback of their actual customers or potential customers. Also, that allows to make easier some product's searching or selection for traditional commerce or at least to request an online quote or budget.
The third web site stage is related to transactional characteristics, e.g. in this level firms already incorporated process in order to have electronic transactions in the web site (See Table 4).

Table 4 Third stage of e-commerce adoption: Transactional Web

Variable	Number of	Number of	Percentage	Percentage of

	enterprises with	enterprises without	of enterprises with	enterprises without
Transactions	56	217	20.51%	79.48%
Intranet	93	180	34.06%	65.93%
Extranet	69	204	25.27%	74.72%
E-commerce	53	220	19.41%	80.58%
Source: Own elaboration.				

In the third stage of e-commerce adoption, 21% of the sites included the option to make diverse electronic transactions; in some cases they include applications, which imply another level of function such as intranet (34%) and extranet (25%) implementation.

At this level we found 53 enterprises that have already adopted e-commerce, which represents 19% of the sample. The majority makes business-to-business e-commerce (84%) and 26% business to consumers (O'Brien & Marakas, 2007; Stair & Reynolds, 2006).

From this set of enterprises, 51% were in the manufacturing sector, 41% in the commercial sector and the rest 8% in services. Regarding to the age of firms, 7 organizations have more than 100 years operating, and they have already implemented e-commerce. In the web sites that include their foundation year, it was found that 2 enterprises established before 1950, and 17 created between 1981 and 1997 have already adopted e-commerce. It is remarkable that none of the youngest organizations founded after 2001 (10) have adopted e-commerce yet. Analyzing the firms' age, results show that enterprises with more experience, established and with a branch presence will be able to offer their products and services on line, compared with young enterprises.

The majority of this group of enterprises was Mexican (92%) and 19% operate in a global site. Nearly half of the firms were part of a group of enterprises (47), assuring that online selling operations were uniform for all the subsidiaries.

As Sojo Obando (2001) indicates, e-commerce adoption requires an important investment in hardware and software; therefore it could be easier for those firms that have a technological foundation as well as technological innovation expertise the possibility to adopt e-commerce. Research results show that the set of organizations that have adopted e-commerce, they have already adopted other technologies such as intranet (80%) and extranet (74). The previous applications required complements for e-commerce use as the multistage model indicates about the importance of interconnection and communication between different areas of the enterprise involved in the purchase and sale process (O'Brien & Marakas, 2007; Stair & Reynolds, 2006). In the same sense, it will be easier for those enterprises, which are part of a group of companies to share and adopt new technologies.

An electronic commerce system requires that organizations also have an Internet platform to implement a multi stage model, in order to make possible for users to carry out the sale cycle process online secure and efficient. The first element of this model is to have an e-commerce secure site with control access (O'Brien & Marakas, 2007; Stair & Reynolds, 2006). Research results show that 83% of the enterprises require users to register to get access the e-commerce site, and 79% requires visitors to fill a questionnaire. Based on that information, organizations will built the customer profile, and personalize the site for each one of them. This first step implies an important task in order to collect customer data, analyze their behavior and to make recommendations for future visits based on their profile and likes (Rios Ruiz, 2017; Sojo Obando 2001). It is important to have this data, it result a great omission for those firms that do not collect them. Only 8% of enterprises did not have basic tools to make online shopping correctly, for example, they did not have a link to start the buying process or they did not have

the option for register visitors (17%), or neither they ask user's information (21%). These failures generate concerns on potential customers (Fernandez, Hurtado & Peral 2005).
The web site for e-commerce has to include a tool to manage the content of products and services, to allow buyers finding and selecting products and services, as well as to establish the price of the purchase, to look the general characteristics, and eventually update their order. The majority of enterprises (91%) has a management content and a catalog to allow visitors to make the purchase; 58% of the sites allow buyers to personalize products, taking advantage of the e-commerce benefits (Fernandez Portillo, et at., 2017; Sojo Obando, 2001). Once users have selected a product they can add it in the shopping cart (96%). In the same sense in the 91% of the web sites, visitors can modify and update their purchase before they pay it (O'Brien & Marakas, 2007; Stair & Reynolds, 2006).
After that, the system needs to include everything about the payment, e.g. when the customer is ready to carry out the purchase, the 96% of the web sites produce a purchase order and show the payment options, to finish the purchase. In the majority of the web sites the payment is online (97%), with credit or debit card (42%) or by PayPal (55%). The whole process was supervised through the different areas and employees of the company (O'Brien & Marakas, 2007; Stair & Reynolds, 2006). The use of secure payment methods such as, credit or debit card, or pay pal allows customers to purchase having a support of a financial institution and if necessary, to make complaints (Montijano Guardia, et al., 2002; Rios Ruiz, 2017).
An advantage of e-commerce is to avoid the need for customer to buy somewhere else (Fernandez Portillo, et al., 2017; Rios Ruiz, 2017; Sojo Obando, 2001), so one element of the multistage model determines the option for delivery the product; 74% of the enterprises send the order by traditional messenger company and 26% deliver it directly in the enterprise. Results show that 94% of the enterprises only have domestic transactions, wasting one of the e-commerce advantages that allow firms to have a global presence (Rios Ruiz, 2017; Sojo Obando 2001). Maybe because the delivery cost is high, or because of the characteristics of the products or services firms probably consider not financially convenient their internationalization. Another aspect to consider are international regulations, not all products or services are able to be traded internationally some require particular permissions or simply are for internal consumption.
In the e-commerce transactions the possibility to return a product is very important, the 62% of the firms have refund policies, but the rest 38% do not have that option which discourages the use of this application (Fernandez Portillo, et al., 2017; Rios Ruiz, 2017).
The last stage in this process is the after-sales services, which allows enterprises to interact with their customer, establishing a new communication channel (Fernandez Portillo, et al., 2017; Rios Ruiz, 2017; Sojo Obando 2001). This stage represents a key element compared to traditional commerce; 62% of the firms have this option in their web sites. Finally a relevant particularity in the development of this technology is security of the commercial transaction, while the majority of the firms (80%) has a secure web site, 20% did not. This element probably limits the e-commerce because customers more often are paying attention in the secure elements of online transactions (Fernandez, Hurtado & Peral, 2005).
Research results indicate that although adoption and diffusion of e-commerce are constantly growing in developed countries, in countries like Mexico its implementation is still low only 19% of the large enterprises of Iztapalapa are using this technology.
As O'Brien and Marakas (2007) and Stair and Reynolds (2006) posit, e-commerce is general and standard technology that any kind of organization can adopt; we found firms that have adopted e-commerce in the three sectors, practically half of the manufacturing firms have implemented it, a bit less than half of the commercial enterprises (42%) and few services firms (8%). For firms in commerce sector the use of this application could be a natural step to translate their operations to e-commerce.

CONCLUSION

Despite receiving much attention, e-commerce adoption at the global level remains quite low (Merhi & Ahluwalia, 2014). The results allowed us to determine the level of development in the case of web sites of a set of large enterprises in Iztapalapa from e-commerce adoption point of view in this region of Mexico City. Even though the 83% of firms have already an Internet information web site, firms need to continue developing it in order to pass to the next stage of procedure web and transactional web. Firms have to keep working in their web site development in order to include new information and more procedures to achieve the final adoption of e-commerce.

Based on the research results, we obtained a whole outlook of IT diffusion in a group of enterprises, in particular about e-commerce adoption; even though adopting is still low because firms have not yet taken advantages of its multiple benefits. Although e-commerce diffusion in Mexico has grown in the last years according to statistics (AMIPCI, 2013, 2016), its diffusion is still low as the 19% of large enterprises in Iztapalapa have adopted e-commerce. Inclusive in some cases this application has not included the adequate security features, causing that potential customers do not establish commercial relations with enterprises.

For those firms using e-commerce, they are taking advantages obtained benefits such as, the creation of new marketing and sales channels; the opportunity to access new interactive catalogs, price lists, and the alternative to personalize products base on each customers' needs; and have an after-sales services (Rios Ruiz, 2014; Sojo Obando 2001). Benefits that make organizations different from those not using this tools.

Additionally, e-commerce represents for enterprises an always-open window with unlimited timetable available to anyone, because of its permanent presence in Internet; therefore they would be more competitive, eliminate intermediaries and an increase customers' knowledge (Rios Ruiz, 2014).

It is important that before firms make the decision of adopting e-commerce, they have to consider the following key aspects: which one is the strategic objective that leads enterprises to adopt e-commerce; it is important to determine their price policies; enterprises have to reinforce all security features such as, payment, delivery and product characteristics; to know the customer profile; to establish a communication strategy (to have presence in Internet searching and key websites, links and banners, newspaper adds, specialized magazines, radio, television, personalized marketing and public advertising); to develop their web site (reinforce the electronic-commerce strategy with their own personnel, outsourcing others for design and implementation), delivery (sell products by Internet through intermediaries, invest in future) (Sojo Obando, 2001).

The research reported in this paper has allowed achieving its objective obtaining a general outlook of e-commerce adoption and diffusion in large enterprises in Iztapalapa as a first stage of this study; there is also a knowledge base for continuing in depth into the study of these technologies. In the second stage of the research a survey will be conducted to enterprises with e-commerce, aiming to study what are the organizational, technological and environmental factors associated with the adoption of these technologies, and to analyze the organizational experience of e-commerce usage, the benefits and risks obtained for it.

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An empirical study of the application of Lean tools in U.S. industry

ABSTRACT"

Lean manufacturing involves implementing a variety of tools and practices for the 6 purpose of reducing waste and increasing an organization's overall productivity. This paper examines the application of lean tools in various U.S. industries to further clarify the impact lean processes may have on an American business's production and efficiency. The analysis of the information collected from the survey demonstrates how lean tools have influenced American industries and allows us to see which Lean practices contribute the greatest to overall company performance, as well as observe patterns in how company characteristics may affect the successful implementation of Lean processes**.**

KEYWORDS: Lean Process, Quality Management, Empirical study, US Industry, Continuous Improvement

INTRODUCTION

Lean Manufacturing

In today's world, high levels of quality and efficiency are essential to maintain a competitive position in both the domestic and global markets. In the mid-twentieth century, Toyota Motor Company developed lean manufacturing techniques to address their specific manufacturing shortcomings during an economic crisis, thus enabling them to remain competitive in the national and international markets (Sharma, Sachdeva and Gupta, 2017). Toyota's successful processes, now referred to as the Toyota Production System (TPM), were direct predecessors to what is now widely known as "Lean." Although Toyota's systems had proven especially successful for the company's individual goals, competitors did not exhibit particular interest in Toyota's processes until the oil crises of the 1970s, during which Toyota managed to remain competitive due to their world-class operating system (Holweg 2006). While many U.S. companies have successfully implemented Lean practices and experienced notable improvement in their processes and significant decreases in waste, many have still not reaped the full benefits of Lean tools.

Research Goal

Our intention with this research is to discover how many organizations are implementing lean practices and to what extent in order to observe the impact these practices are having on organizational performance.

Importance of Study

Considering that business success stories have repeatedly shown that Lean has significant positive impacts on the bottom line (Abdulmalek & Rajgopal, 2006). Lean thinking has proven its status as a significant stepping stone in achieving greater profits and enhancing competitive advantage. Adopting Lean is a culture change for any organization that previously utilized none of the Lean tools; therefore, it represents a greater movement towards a new and continually improving means of carrying out business activities.

The following section summarizes the relevant findings of our thorough literature review, identifying key variables and factors to consider in the questionnaire creation and analysis. Following the literature review, the research questions are posed and supported with evidence

from the preceding literature analysis. Thereafter, the methodology used is explained in detail, to be followed up by our analysis and results. The paper concludes with a short summary and discussion of the implications and limitations of our research.

LITERATURE REVIEW

Lean Manufacturing Variables

During an intensive examination of literature regarding lean manufacturing, we discovered a multitude of variables that earlier research either stressed as a contributor to successful lean implementation or claimed had no notable correlation to such practices. Shah & Ward (2007) identified 48 items, or identifiers, to use when measuring the crucial components of lean production. They produced a set of 10 scales to use for conducting empirical research that will help in the process of analyzing successful lean implementation in a wide array of companies and industries. More importantly, Shah & Ward (2003) identified key variables to take into consideration for lean implementation, including plant age, plant size, and level of unionization. We have incorporated these factors into our questionnaire to further explore the correlation between the variables and group the data according to the strongest correlations. In addition to these easily measurable variables, previous literature also stresses the importance of considering employee involvement, communication, understanding of the tools used, culture change, and education training (Alhuraish, Robledo and Kobi 2017; Marin-Garcia and Bonavia 2014; Prasad, Khanduja, Sharma 2016; Di Pietro, Mugion, Renzi 2013; Fullerton, Kennedy & Widener 2013; J. R. Alves and J. M. Alves 2015). However, the scales and identifiers provide no assistance without a thorough understanding of the concept of lean practices from the start, an issue that arose during the infant stage of lean's existence. Having awareness of the history of lean and its emergence from the Toyota Production System (TPS) gives today's manufacturers insight into the initial intentions for lean and a solid example of lean tools' ability to improve an organization's efficiency (Holweg 2006).

Selecting appropriate lean tools A key issue companies face when deciding to begin lean manufacturing processes is selecting the correct lean tools for their specific problem. Too often organizations choose inappropriate tools for the problem at hand, thus missing their chance to achieve maximum efficiency. Prior research has provided us with various selection processes and criteria to consider when collecting our data to determine whether or not companies have failed to successfully implement lean techniques due to an uninformed selection of tools. A huge component of lean manufacturing research consists of attempts to create a decision framework or formula that increases the likelihood of selecting the most appropriate lean tools for the production problem at hand (Amin & Karim 2013; Ramesh & Kodali 2011; Hines & Rich 1997; Mejabi 2003; Hodge, Ross, Joines & Thoney 2011; Alhuraish, Robledo & Kobi 2017).

Lean Manufacturing and Company Culture Effective lean systems require company-wide implementation in order to produce positive results, in other words, applying lean practices where they did not exist before means a change in a company's culture must take place (Prasad, Khanduja & Sharma 2016; Di Pietro, Mugion & Renzi 2013; Fullerton, Kennedy & Widener 2013; J.R.X. Alves & J.M. Alves 2015). For instance, lean practices often incorporate green ways of thinking to promote waste reduction. A company that previously did not operate

sustainably or “think green” may experience a major 26 culture shift within the organization as a direct consequence of adopting lean principles (Alves & Alves 2015; Prasad, Khanduja & Sharma 2016; Miller, Pawloski & Standridge 2010).
THEORETICAL DEVELOPMENT/MODEL

RESEARCH QUESTIONS

The research questions assessed through our survey are derived from the findings of the literature review. A recurring theme in the collected literature identifies the selection of specific lean tools and techniques as a major obstacle in achieving substantial results from Lean practices; therefore, we deem it necessary to assess the various Lean methods on an individual basis.
Process Improvement Practices

RQ1. Do process improvement practices positively affect organizational performance through elimination of waste?

Manufacturing Planning and Control Practices

RQ2. Do manufacturing planning and control practices positively affect organizational performance through aligning production and demand, eliminating waste and involving the workforce?

Human Resource Practices

RQ3: Do human resource practices positively affect organizational performance through involvement of the workforce and elimination of waste?

Supplier Relationship Practices

RQ4. Do supplier relationship practices positively affect organizational performance through integration of suppliers and elimination of waste?

Customer Relationship Practices

RQ5. Do customer relationship practices positively affect organizational performance through elimination of waste and alignment of production and demand?

METHODOLOGY

Developing the Questionnaire
In order to effectively analyze the implementation of Lean tools within U.S. industries across the nation, we developed a questionnaire intended to evaluate the level of implementation of individual tools and practices grouped together into five meaningful categories.
(1) Pilot Survey: we created and distributed a pilot survey as a means to test the effectiveness and relevance of the research variables we chose to consider, summarized in the five categories of the questionnaire mentioned above.
(2) Random Survey: Similar to the pilot survey, we distributed the final questionnaire to a broad range of organizations working in a wide variety of industries. Out of the 500 responses received, we ruled 236 as invalid due to incomplete responses or notably short completion times, leaving us with 264 valid completed surveys from which to draw our data.

Company Demographics
Collecting specific details of each company is crucial to our research, as it allows us to group the responses according to industry, company age, etc. Our company detail survey questions address

the following aspects of the surveyed organizations: (1) Area of work at the organization; (2) general industry of the company (service or manufacturing); (3) company's annual revenue (USD); (4) company size by number of employees; (5) specific industry of business (i.e. automotive, food, etc.); and (6) the ownership of the company (joint venture, state-owned, etc.) The results from these questions will enable us to analyze the collected data in categories to determine whether any of these characteristics demonstrate an influence over the success of Lean implementation.

Levels of Lean Implementation

To measure the extent of implementation of Lean in each organization, we assessed the 5 categories of Lean practices (PIP, MPC, HRP, SRP, CRP) in individual questions to receive the most specific responses. Each question gauges the level of implementation by employing a Likert scale from 1 to 5, in which 1= "Complete Implementation"; 2 = "Extensive Implementation"; 3 = "Some Implementation"; 4 = "Little Implementation"; 5 = "No Implementation." The following paragraphs detail the tools and practices assessed in each Lean category.

The first category focuses on tools that affect Process Improvement Practices (PIP). This includes 10 different tools and techniques that are intended to streamline and remove waste from any kind of business process. These include: Kaizen/Continuous Improvement, 5S, Setup time reduction, Cellular Manufacturing, Continuous Flow, Equipment Layout, Product Design Simplicity, Error Proofing Equipment (poka-yoke), Total Preventive Maintenance (TPM), and Analysis tools (5Whys, Pareto charts, etc.) The second category of Lean covers Manufacturing Planning and Control practices (MPCP) which includes 10 practices that relate to this area of business operation. These methods include: Levelled production, kanban/pull production, daily schedule adherence, small lot size, visual management, value stream mapping, takt time, statistical process control (SPC), standardized work/qualification, and plant layout reconfiguration.

While the first two categories of practices relate primarily to the efficiency of business processes, the last three categories focus heavily on the human components of any business operation, including internal human resources, suppliers and customers. The third category on the survey corresponds to human resources (HRP), listing five Lean human resource practices for survey respondents to rank. These 5 are: group problem solving, cross training/flexible workforce, cross functional teams, employee involvement/empowerment, and workforce commitment. The fourth category addresses four components of supplier relationship practices (SRP) including: JIT delivery, supplier quality level, supplier involvement in quality improvement program, supplier involvement in product design and development. The last of the five categories considers Customer Relationship Practices (CRP), and is divided into 5 different common practices that promote Lean business operation. These practices include: customers provide feedback on quality and delivery performance, customers are actively involved in current and future product offerings, customer frequently share current and future demand information with marketing department, we (the surveyed company) deliver products to our customers JIT, customers are involved in quality programs in our plant.

Each survey respondent is asked to rank the implementation of each tool/practice of each of the five categories in order to assess the relationships between the tools and methodologies in question and a business's overall performance. As a means to insure that the survey reaches the personnel with adequate skill sets to understand the terminology within the questionnaire, we

require that every recipient first answer a basic question regarding their current position within the organization. Based on their response to this question, they may or may not continue onto the rest of the survey. This question helps guarantee that those in the organization with the greatest knowledge of the company's current processes, as well as the language that accompanies Lean thinking, are the ones to fill out the survey, thus providing the greatest accuracy in response.

Green Supply Chain Management Practices

In addition to the Lean portion of the questionnaire, we included a second major section concerning the stage of implementation of Green Supply Chain practices, in an effort to collect data to both encourage and provide for future research in the field of Green Supply Chain Management. Since Lean is generally considered a "Green" method of conducting business, including this section in the survey may also provide evidence for a relationship between Lean and Green business practices (Prasad, Khanduja & Sharma 2017; Chiarini 2014).

This format of the section mirrors that of the Lean section, in that it is divided into 5 meaningful categories, those being: Internal Environmental Management practices (EMP), Green Purchasing practices (GPP), Green Customer Cooperation practices (GCCP), Investment Recovery Green practices (IRGP), and Eco-Design Green practices (EDGP). Each category lists the most common green practices, of which each survey recipient must rank their stage of implementation on a Likert Scale of 1 to 5, with 1 representing implementing successfully already and 5 representing not considering to implement. While the data collected from this portion of the survey are not considered the foci of our research questions, including these sections in the questionnaire may provide insight into relationships between Lean and Green practices and/or provide a foundation for future research.

ANALYSIS OF RESULTS

Description of the Sample

Survey Respondents: Position & Area of Work

The 264 completed surveys we received cover a wide range of organizations of various industries, ages, sizes, and areas of business. Although our research seeks to assess successful Lean implementation in U.S. industry in general, it is crucial to consider where our results are coming from and how that may shape and/or limit our overall results. Firstly, of the 264 survey respondents, 63% hold managerial positions in their company, 25% are directors, 8% are vice-presidents and 4% hold C-suite positions. These percentages are favorable, as managers and directors are most likely to have the most holistic understanding of the business processes with which they are involved, as well as how those processes fit into the greater context of their organization. Had the bulk of responses come from C-suite positions, their knowledge would mostly relate to the organization's overall strategic position, rather than the day-to-day processes that would have the most direct contact with the Lean practices under study.

In regard to area of work, 45% work in the engineering department, 32% in the quality management department, 15% in the logistics and/or distribution department, and 8% in the supply chain management department.

Organization Specifics

In regard to the demographic details of the organization's surveyed, we asked the size of their company in number of employees, specific industry type (i.e. automotive, food, etc.),

ownership type, and annual revenue to categorize the surveyed organizations and examine each categories relationship to organizational performance. Figure 3 displays the results from the question regarding size of company based on number of employees, showing that the largest portion of surveyed organizations have less than 500 employees, making up 34% of the sample. The next most common size is having greater than 10,000 employees, making up 29% of surveyed organizations.

The results of the question concerning the different specific industry types of each organization, which consisted of a wide variety of answers as the distribution of our survey did not discriminate against industry type.

About the ownership type, the results show that a notable majority of collected surveys come from private ownerships, making up 69% of the responses. This is important to note, as any results and conclusions drawn from the analysis will primarily be representative of organizations of this nature.

The percent distribution of the surveyed organization's annual revenue. The results here are in line with those of the size of industry, in that both ends of the spectrum are covered very well in the sample.

Descriptive Statistics & Measurement Model Testing

For the purpose of assessing the statistical make-up and reliability of our survey and collected responses, we constructed tables of each category of variables that displays the mean and standard deviation of the Likert scale results of each tool under study, the factor loading analysis results, Cronbach's alpha, alpha if item deleted, and the overall mean and standard deviation of all of the tools within that category.

Overall, the factor loading analysis of each tool and practice in all 5 categories indicated a factor loading (extraction) value greater than 0.5, indicating that the factors assessed in the survey have substantial influence over the variables under question. Furthermore, the Cronbach's alpha value for each category of tool is greater than 0.890, indicating that our survey model is reliable in that the factors addressed in each category adequately correspond to the category as a whole. From this, we can conclude that our survey categorizations are sound; therefore, any analysis based on these survey results may be considered reliable.

Regression and Correlation Results

A correlation analysis is used to determine relationships between variables under study to assess any potential multicollinearity issues and eliminate any variables accordingly

The correlation analysis measuring the relationship between LM and GSCM indicated a strong relationship ($r=0.75$) between the methodologies, supporting the notion that the two practices often occur in conjunction with one another. Due to this relationship, the GSCM practices are not part of the following analysis, as their strong correlation presents a multicollinearity problem in regard to impact on performance; therefore, the application of GSCM practices will be the focus of future research. Upon removing GSCM from the variables

under consideration, another correlation analysis examines the relationships between the five categories of Lean tools and PERF.
After removing multi-collinearity issues from the final analysis, we run a regression analysis on the remaining variables to further determine their fitness for the final model and their effect on performance. Upon first glance, the F-value is 0, indicating a 0% likelihood that the regression output is due to chance, thus allowing us to move forward in the analysis.

ANOVA Results

To analyze the relationships between each set of Lean tools (MPC, HR and CRP) or PERF and the demographic makeup of all survey respondents, we conducted ANOVA to evaluate any statistically significant differences (α=5) among the various tools and categories of organizations we surveyed. A Tukey post hoc test revealed even further the unique relationship between each sub-category of the company characteristics under study (i.e. general industry, size, specific industry, ownership, revenue) and the three categories of Lean tools participating in the final analysis.
The ANOVA results regarding ownership type (i.e. state-owned, joint venture, etc.) show that statistically significant differences occur within the categories MPC ($F(3,260) = 5.489$, $p = .001$) and PERF ($F(3,260) = 1.563$, $p = .199$) at α=5, thus indicated that a further look need be taken in regard to these variables through a Tukey post hoc analysis. The Tukey analysis reveals that within the MPC category, statistically significant differences exist between state-owned and joint venture ($p = .020$), state-owned and FDI ($p = .001$), and state-owned and private ($p = .010$). Within the PERF category, differences exist among state-owned and joint venture ($p = .033$) as well as state-owned and private ($p = .032$). It should be noted that two of the significant differences occur among the same relationships in CRP and PERF; therefore, those should receive particular attention in a future study.
The ANOVA results concerning annual revenue of the surveyed companies indicates that statistically significant differences occur in the categories MPC (*$F(5,258) = 5.095$, $p = .000$*), CRP (*$F(5,258) = 3.382$, $p = .006$*), and PERF (*$F(5,258) = 5.429$, $p = .000$*); therefore, the HR category is the only group which may be disregarded in the Tukey post hoc analysis. From the Tukey results, we see that statistically significant difference do occur between groups within MPC, CRP and PERF. Within MPC, these differences occur between $50 million and $51-250 million (*$p = .019$*), $50 million and $251-500 million (*$p = .021$*), $50 million and $501-750 million (*$p = .043$*), and $50 million and >$1 billion (*$p = .000$*). Within CRP, differences occur between $50 million and >$1 billion (*$p = .003$*). Lastly, within PERF, differences occur between $50 million and $51-250 million (*$p = .023$*) and $50 million and >$1 billion (*$p = .000$*). From these observations, it is recommended that further analysis into the relationships of these subgroups take place in a future study.
Notice that the 3rd-level section heading (below the 2nd-level section) is not boldfaced and simply underlined, with only the first letter capitalized.

DISCUSSION

Overall, we may conclude that both human resource practices and manufacturing planning & control practices based on the Lean methodology have a positive impact on organizational

performance, thus providing affirmative answers to RQ2 and RQ3. Although the categories of tools assessed RQ1 and RQ5 had to be removed due to multicollinearity issues, the practices and tools of those categories may be closely tied to those of the MPC category; therefore, a positive impact on organizational performance from those categories may be deduced from MPC's apparent positive relationship. At this time, no final conclusion may be made regarding customer relationship practices on performance, due to the negative slope observed at the 1% confidence level for this variable.

In relation to green supply chain management, an apparent correlation between Lean and Green practices exists, suggesting that the two often operate together; however, future studies need to assess this further. In regard to the ANOVA and Tukey results, the statistically significant relationships among the demographic differences of the companies in relation to the categories of Lean practices under study need be further assessed to determine where and how these differences arise.

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An Experimental Study of Croston's Forecasting Method under Cross Correlation Conditions

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ABSTRACT

Croston's method (1972) and variations have shown promise in forecasting average demand per period for items with intermittent demand. This paper examines how Croston's method and Croston's method corrected for bias performs when demand is correlated with the time between demands. In addition, we assess the performance under two distributions for time between demands. Results reveal the distribution for the time between demands may have a stronger effect on the performance of these methods.

KEYWORDS: Croston's Method, Forecasting, Intermittent Demand, Cross Correlation

INTRODUCTION

Forecasting techniques for intermittent demand or slow-moving products have been explored extensively. Examples of this research are numerous, but most center around applications of Croston's method (1972). This paper assess Croston's method under two conditions that are not assumed in its proposed form. The distribution of the time between demands is allowed to be U-shaped and demand and the time between demands are allowed to be cross correlated. Altay, Litteral, and Rudisill (2011) examined the effect of cross correlation on Croston's method. Our study differs in that the time between demands has either the geometric or a U-shaped distribution.

Improved forecasting methodologies (A. A., 2007; Altay, Rudisill, and Litteral, 2008; Levén and Segerstedt, 2004, 2002; Syntetos, A. A., & Boylan, J. E., 2001, 2005, 2006; Willemain, T. R., Smart, C. N., & Schwarz, H. F., 2004), inventory systems (Chung, K.-J., & Hou, K.-L., 2003), method comparisons (Ghobbar, A. A., 2004) and case studies (Hua, Z. S., Zhang, B., Yang, J., & Tan, D. S., 2007) are many of the areas that have been studied related to slow-moving inventory. However, many of the characteristics of forecasting times series with regular demand have not been thoroughly investigated for items with intermittent or slow-moving demand. Altay, Litteral, and Rudisill (2008) demonstrated that a modification of Holt's method can be used to satisfactorily forecasts when trends are present. Lindsey and Pavur (2008) studied the effect of trends and Altay, Litteral, and Rudisill (2011) examined the effects of correlation when demand is intermittent. Despite studies that highlight its shortcomings, Croston's method (1972) has found widespread use and has been the theoretical and practical benchmark for inventory models and forecasts (Syntetos and Boylan, 2005, 2006; Altay, Rudisill and Litteral, 2008; Teunter, Syntetos & Babai, 2010; Xu, Wang, & Shi, 2012; Ramaekers & Janssens, 2014). Levin and Segerstedt (2004) proposed a technique that handles forecasting items with regular demand and slow moving items.

Leven and Segredst (2004) proposed a procedure with a new estimator for mean demand and for the variance of the forecasted demand rate when the demand rate is modelled as an Erlang distribution. Despite its shortcomings, this approach could provide an opportunity to overcome forecasting issues related to cross correlated data. Furthermore, an item would have a positive cross-correlation when a long demand interval is followed by a high demand size or a short interval is followed by a low demand size. They claim the estimator is unbiased, however, Syntetos and Boylan (2006) shows it is not and the bias is greater than the original procedure and SES. The argument for increased bias in the modified procedure assumes independence and a constant probability of demand. However, we will investigate the application of the modified procedure when cross-correlation is present. The modified procedure may offer advantages over the original method when many of the assumptions are violated.

LITERATURE REVIEW

Croston's method (1972) is one of the most popular techniques when demand is intermittent and is the practical standard for inventory models (Teunter, Syntetos and Babai, 2010; Xu, Wang, & Shi, 2012; Ramaekers and Janssens, 2014). Croston's method has documented benefits by Willemain, Smart, Shockor, and DeSautels (1994), Johnston and Boylan (1996) and others. The procedure generates one forecast for the demand quantity and one for the time between demands and combines them into one forecast. Syntetos and Boylan (2001) provided a modification to correct an identified bias in Croston's method. Studies have compared the bias corrected method with the original without identifying a superior method (Eaves & Kingsman, 2004; Syntetos & Boylan, 2005; Teunter & Sani, 2009; and Teunter & Duncan, 2009).

Croston's Method

See Willemain, et al. (1994) for a succinct review of the methodology. Croston (1972) recommends small alpha values between 0.1 and 0.2. Croston's method is based on assumptions of stationary, identically, independently distribution of demand sizes and intervals, geometrically distributed inter demand intervals and independence of demand sizes and intervals.

Syntetos and Boylan's Bias Corrected Modification for Croston's Procedure

Syntetos and Boylan (2001) identified a bias in Croston's (1972) method. The bias increases as the smoothing constant increases. It can be minimized by using a small alpha. See Boylan and Syntetos (2005) for the formulation. Teunter and Sani (2009) advocate that in cases when limited periods have no demand, Croston's method excels and when most periods have no demand Syntetos and Boylan's correction is better.

Leven and Segerstedt Method

The modified Croston procedure from Leven and Segerstedt (2004) presents two new estimators. The new estimator for mean demand is:

$$\hat{d}_n^{MC} = \hat{d}_{n-1}^{MC} + \alpha\left(\frac{X_n}{T_n - T_{n-1}} - \hat{d}_{n-1}^{MC}\right) \quad (1)$$

The new estimator for variance of the forecasted demand rate is:

$$\hat{d}VAR_n^{MC} = \hat{d}VAR_{n-1}^{MC} + \beta\left(\left(\frac{X_n}{T_n - T_{n-1}} - \hat{d}_{n-1}^{MC}\right)^2 - \hat{d}VAR_{n-1}^{MC}\right) \quad (2)$$

Although this estimator is criticized by Syntetos and Boylan, it should be explored when there is a violation of the standard assumptions used in assessing Croston's method.

EXPERIMENTAL SIMULATION STUDY

Data are generated for demand using a normal distribution with a mean of 200 and a standard deviation of 10. The time between demands is generated under either the Geometric distribution or a U-shaped beta distribution such that the expected time between demands is 5 periods. A normal-to-anything transformation, as described in Altay et al. (2011), is used to incorporate a cross correlation between the demands and the time to demand of either zero, -0.8, or 0.8. 1000 simulations were conducted for each condition. The Geometric distribution has an expected time between demands of 5 for a "p" parameter equal to 0.2. The U-shaped distribution had two high probabilities for the values of 1 and 10 for the time between demands and small probabilities, for the values between 1 and 10. This study uses a normal distribution for product demand.

RESULTS

In Table 1, Croston's performance does not vary much under the three cross correlation conditions. There appears to be a slight uptick in the RMSE for the negative correlation when the smoothing constant is 0.05 and a slight uptick the RMSE for the positive correlation when the smoothing constant is 0.2. A column labeled "Croston Bias Corrected with True Parameter" is included to use as bench mark. This study uses the RMSE to examine the accuracy of Croston's smoothed demand divided by the smoothed time between demands as an estimator of the population ratio of total demand divided by the time investigated.

Table 1. Performance of Croston's Method under Cross-Correlation using a Geometric Distribution for Time between Demands.

Smoothing Constant = 0.05	**SES**	**Croston**	**Croston Bias Corrected**	**Croston Bias Corrected with True Parameter**	**Reduction byCroston PerCent**	**Reduction by Croston BIAS_C PerCent**
Positive Correlation 0.8	12.25	5.32	5.19	5.14	56.58	57.62
Zero Correlation	12.63	5.48	5.35	5.30	56.63	57.66
Negative Correlation 0.8	13.00	5.63	5.50	5.45	56.69	57.68
Smoothing Constant = 0.2						
Positive Correlation 0.8	27.10	13.64	12.47	11.86	49.66	53.99
Zero Correlation	26.56	13.11	11.99	11.46	50.64	54.87
Negative Correlation 0.8	26.01	12.56	11.49	11.05	51.72	55.83

Table 2 serves to contrast the performance of Croston's Method when a U-Shaped distribution is used for the time between demands. The performance is better when a Geometric distribution is assumed. The percent reduction by Croston over the exponential smoothing method is less compared to Table 1.

Table 2. Performance of Croston's Method under Cross-Correlation using a U-Shaped Distribution for Time between Demands.

Smoothing Constant = 0.05	SES	Croston	Croston Bias Corrected	Croston Bias Corrected with True Parameter	Reduction byCroston PerCent	Reduction by Croston BIAS_C %
Positive Correlation 0.8	13.26	5.89	5.70	5.57	55.61	57.06
Zero Correlation	13.20	5.76	5.61	5.53	56.34	57.48
Negative Correlation 0.8	13.27	5.79	5.68	5.63	56.34	57.20
Smoothing Constant = 0.2						
Positive Correlation 0.8	31.03	16.67	15.42	14.35	46.28	50.32
Zero Correlation	31.01	16.59	15.37	14.33	46.52	50.44
Negative Correlation 0.8	31.06	16.63	15.43	14.41	46.47	50.32

DISCUSSION AND CONCLUSIONS

Many studies have investigated the performance of Croston's method and concluded that it is a robust methodology. Altay, Litteral and Rudisill (2011) appears to be the major study that has investigated Croston's method under cross-correlation. Their study did not show a substantial change over the values of the correlation selected. In that regard, their study and this study show agreement. However, this study also considers the effect of the distribution of the time between demands along with the cross correlations. A conclusion is that the distribution of the time between demands appears to have a greater effect of the performance of Croston's method than cross-correlations. The bias correction for Croston's method is clearly more important for larger smoothing constants. Altay, Litteral and Rudisill (2011) explain why it is necessary to used theoretically generated data versus real world data in examining the performance of Croston's method. It is difficult to know the true population distribution of either the demand or the time between demands in real data. The experiment designed here controls for correlations and distributions and make conclusions as to their effects.

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An Information Signaling Model of Supply Chain Management Capability

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ABSTRACT

Exceling in supply chain management (SCM) is a challenge. Businesses struggling with SCM can try to emulate the practices of firms exceling in SCM if they know who these firms are. Information signaling theory asserts that a credential can be a signal of possessing an underlying capability. Gartner annually publishes a list of who they believe are the top 25 companies worldwide in SCM. Being on this list can be viewed as a credential. However, credentials must be examined for their value. We develop a modified form of the event study methodology to see if the Gartner credential has value-relevance.

KEYWORDS: *Supply Chain Management, Information Signaling, Event Study, Value Relevance*

INTRODUCTION

Excellence in supply chain management (SCM) is crucial for firms since it manifests itself in enhanced financial performance (D'Avenzo, Lewinksi, & Wassenhove, 2003; Presutti & Mawhinney, 2007). However, exceling in managing a firm's supply chain is a complex challenge involving different dimensions including strategy, business process, and technology. The role of industry exemplars who have superior SCM capability becomes key as other firms try to emulate the processes, practices, and technologies employed by these leaders. But how do business managers at large find out who these exemplars are? If they incorrectly identify these exemplars, then it could become a case of the blind leading the blind. Information signaling theory states that the possession of an underlying capability by someone can be signaled to the world by the possession of a credential (Spence, 1973, 2002). Information signaling has been used in a variety of contexts such as the job market where a candidate's inner capabilities and competence are manifested by the degree they possess (Spence, 1973, 2002). Of course, the quality of all credentials may not be the same. A degree from a top-tier university is not the same as that from a local college. Hence, before simply taking a credential at face value and acting upon it, the quality or value of the credential must be examined.

In the SCM area, Gartner, an analyst firm, annually publishes a list of 25 firms that it believes are the best firms worldwide in managing their supply chains. We will refer to this list as the SCT25. From an information signaling standpoint, we treat being listed on the SCT25 as the acquisition of a credential that is supposed to reflect superior SCM capability. Whether it truly does that or not is the question that this study addresses. Whether the credential of being listed

in the SCT25 truly correlates with superior SCM capability of course depends on the methodology that Gartner is using in identifying the top firms in SCM. Not much is publicly known about Gartner's methodology because the SCT25 report identifying these top 25 firms is not a document in the public domain as it is available only to its subscribers. Of course, information about the list itself propagates quickly as it generates commentary by other analysts who may have their own views on the best firms in SCM, which could be different from Gartner's. It is to be noted that industry analysts are selling an intellectual product in competition with each other and so there is no reason at all to expect that all these analysts will line up in perfect unison about who the best SCM companies are.

In this article, we develop in this paper a modified event study methodology that has been customized to examine the value-relevance of the SCT25 information. If Gartner is indeed correctly identifying the top players in SCM, which other firms can emulate, then it is providing valuable information which can be expected to have an impact on the capital markets. The standard event study methodology with its short two-day window is however not appropriate for this study. This is because the information that is being disclosed is not factual information, such as an announcement of earnings or a new product release or a corporate acquisition. The SCT25 information is Gartner's opinion about who the best firms in SCM are. Other analysts may well have other opinions that surface in the discussion that occurs in the industry after the publication of Gartner's SCT25 report. We refer to information that is opinion rather than factual as *controvertible* information. When controvertible information is disclosed, the rational investor would naturally want to hear all sides before making a stock market move. Equivalent to waiting, if an investor did make a decision to take a long position on a stock immediately upon the disclosure that it featured high in the SCT25 list, that investor may choose to close or partially close that position upon hearing other analysts challenging Gartner's opinion. As the discussion in the industry takes place in the few days immediately upon the publication of Gartner's SCT25 report, we used a [-1, +7] window in our study. In other words, we accumulate the stock market returns from the previous calendar up to seven calendar days after the day of the announcement. This allows sufficient time for other analysts to weigh in on Gartner's opinion. The accumulation of returns over this long event window allows for the effect of Gartner's opinion together with countervailing views to be captured by our model in terms of the net stock market impact.

Using our modified event study methodology, we find that the SCT25 information indeed has value-relevance. However, a disturbing result that emerges from our study is that if you break up the 2004-2014 period of our study into intervals, or epochs, then the SCT25 information is found to have value-relevance in the earlier epochs, such as 2007-2011, but not in the latter epochs such 2012-2014. This could mean that the methodology that Gartner had successfully applied for many years to identify the best firms in SCM needs to be updated. Clearly, this finding has major implications for both Gartner and the businesses at large that rely on Gartner to identify the best firms in SCM, which they could then emulate.

LITERATURE REVIEW

To excel in managing the supply chain is easier said than done. It is a multi-facetted challenge that embraces strategy, business process, and technology. At the level of strategy, Christopher and Ryals (1999) underline the importance of having a corporate-wide strategy for the supply chain that embraces all the business units. At the business process level, new processes and practices such as collaborative planning, forecasting, and replenishment, or CPFR, must be implemented to ensure that the entire supply chain works in unison (Seifert 2003; Russell and

Taylor 2009). These business practices also include innovations such as vendor managed inventory (VMI) (Nagarajan & Rajagopalan, 2008; Niranjan, Wagner, & Nguyen, 2012), which mitigates the so-called “bull whip” effect (Warburton, 2004; Kok et al., 2005; Panda & Mohanty, 2011) where inventory tends to pile up the further away we move from customers and towards the supplier end of the chain. Excess inventory is of course only one form of inefficiency. Firms must also broadly apply the principles of lean production and management (Womack & Jones, 1996; Holweg, 2007) in all its business processes throughout the supply chain to eliminate all forms of inefficiency and waste. The impact on the environment must also be considered in the operation of the supply chain (Pil & Rothenberg, 2003). Information systems such as supply chain management systems must be used at the operational level to facilitate the execution of strategy and the implementation of best practices (Gunasekaran & Ngai, 2004).

To add to the challenges in strategy, process, and execution, firms must also master a range of complex information technologies (IT) to facilitate the integration of information systems of various organizations in the supply chain. This complex IT includes XML and Web Services (Krafzig, Banke, & Slama, 2005) for integrating software applications such as enterprise resource planning (ERP) and materials requirements planning (MRP) across the various business entities in the supply chain. Firms setting out to improve their supply chains are clearly facing a complex multi-facetted challenge with ramifications for strategy, process, and technology.

Although Gartner’s methodology for identifying the best firms has not been publicly debated, it is possible to make some educated guesses about their methodology. Often in developing these rankings, a panel of experts is constituted who independently rank the firms. The final ranking could be obtained through an arithmetic summarization of the individual rankings by the experts. Other methodologies could be more quantitative in nature where a range of predictor variables, or key performance indicators (KPI) of SCM performance, is used in some sort of a regression model to predict overall SCM performance. It is also possible to develop a methodology of ranking firms using a combination of both subjective and objective elements. Whether a subjective or objective approach, or some combination of the two, is used by Gartner in developing the SCT25 ranking, it is important to recognize is that any methodology does not remain robust indefinitely.

If a panel of experts is being used, and they are very good, what happens when some of those experts leave the panel? If their replacements are not equally proficient in identifying the best firms in SCM, the SCT25 list may not be as spot-on in identifying the best firms as it once was. Even if some objective quantitative model was built to predict the best firms in SCM, the model itself may need to be updated with a newer set of variables to reflect changed business conditions. It should be noted that the SCT25 list was first published in 2004. Since then, there was the financial crisis of 2007 to 2009, a global event leading to a financial meltdown which many people did not see coming. It is arguable that many business models, albeit built for different purposes, may have needed some updating after the financial crisis of 2007 to 2009, which forced a reexamination of basic business assumptions. The financial crisis, even though it originated in the housing and the financial services industry, had lessons for all managers about how to think about risk and how to best manage risk.

As we stated earlier, the value of the SCT25 credential is only as good as the methodology used by Gartner in identifying the firms best in SCM and the same methodology cannot be assumed to be robust indefinitely. This paper addresses the issue of the change in the value of SCT25 credential over time in the 2004 to 2014 time frame of the study. To examine the time-

varying nature of the value of the SCT25 signal, we developed a modified form of the event study methodology. Our modified event study methodology examines the stock market return accruing to the firms that appear on the SCT25 list in a window around the publication date of the SCT25 report in any given year. Like the standard event methodology, we also assume that the strong form of efficiency is a good approximation of capital market reaction to new information disclosures. In other words, all information, public or private, is quickly discounted by the stock market. This fundamental assumption is the basis of using a short event window in the traditional event study methodology of two days, denoted as [-1, 0], where day 0 is the day that the information appears in the mass media and day -1 is the previous day. The previous day is also included because there is generally some leakage of information that occurs prior to the news appearing in the mass media.

Another significant difference between the event study methodology we developed for our study and the traditional event study methodology is that we explicitly account for the occurrence of confounding events. McWilliams and Siegel (1997) lament that many event studies simply fail to account for the fact that there are other value-relevant events happening in the window of the event under study. They report that the results from several event studies would actually *change* if confounding events had been taken into consideration. It can be argued that if you have a short event window of two days, the probability that a major confounding event occurring in the short window that reverses the direction of impact of the event under study is low. While this argument may have some validity for short event window studies, clearly in case of a long event window study such as ours where the window is about a week long, confounding events can certainly occur in a window that long. Hence, we depart from the standard event methodology both in terms of having a long [-1, +7] window and also in terms of explicitly removing the effect of confounding events in that long window.

It should be noted that there was a study done by McCarthy and Nayar (2010) on examining the stock market impact of the SCT25 information disclosure. Our study differs from that of McCarthy and Nayar (2010) in several key respects. First of all, the main goal of our study and theirs is different. Their study was geared towards establishing that there is value-relevance of the SCT25 information, or that the disclosure of the SCT25 information has market-moving impact. They found this result in the 2004 through 2008 time frame of their study. We do not question the basic result of their study. In fact, their result that SCT25 information has value is the basis of our study, which covers the longer 2004 through 2014 time frame, and focuses on whether the market-moving impact of the SCT25 information could in fact be diminishing with time. In other words, is the credential of being listed in the SCT25 still a valid information signal of underlying superior capability in SCM.

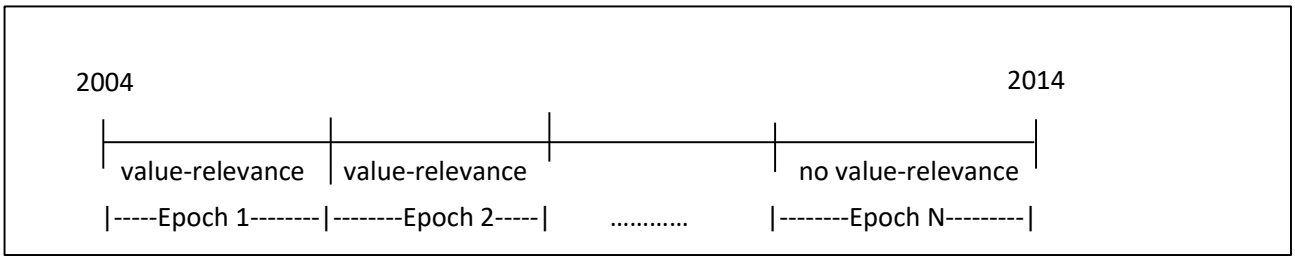
McCarthy and Nayar's (2010) study also had some methodological weaknesses in that they used the standard two-day [-1, -0] short window. Hence, they did not address the controvertible nature of the SCT25 information where other analysts may offer dissenting views and they should be heard as well. To include the impact of dissenting views, we have to lengthen the event window so that they can be heard. McCarthy and Nayar (2010) also did not attempt to make any correction for confounding events. We have developed a more robust and accurate methodology to gauge the value-relevance of the SCT25 information that does not suffer from these shortcomings.

RESEARCH FRAMEWORK AND METHODOLOGY

Hypotheses

The primary research question of this longitudinal study is to examine not only whether the SCT25 information has value-relevance but also if the SCT25, even if it had value-relevance in the past, continues to have value-relevance in more recent years. In other words, we are also searching for chronological patterns of value-relevance. If we break up the 2004 through 2014 period of the study into sub-intervals, or epochs, and we find a pattern as shown in Figure 1 where there was value-relevance of the SCT25 information in the initial epochs but not in the latter epochs, then a significant result would have been obtained. This result would essentially indicate that the methodology that Gartner had successfully used in identifying the best firms in SCM when it first devised this methodology and started publishing the SCT25 list may have become outdated. The methodology may no longer be finding the best firms in SCM in the changed business environment of today. Clearly, such a result would have important implications for Gartner and its subscribers. It would essentially indicate that the methodology needs to be updated to reflect the business conditions of more recent years.

Figure 1: Pattern of Changing Value-Relevance of SCT25 Information



Hence the null hypothesis we are testing is:

> **Hypothesis 1**: Regardless of how the time frame 2004 through 2914 is divided into epochs corresponding to a sub-interval in that time frame, the SCT25 information disclosure remains value-relevant in each epoch.

If this hypothesis is rejected, then there is some basis for a closer examination of Gartner's methodology of identifying the best SCM firms and looking into areas where the methodology can be improved. Hypothesis 1 is actually a family of hypotheses as it depends on how the 2004 through 2014 period is divided.

Addressing Confounding Events

To address confounding events, we first identify the days in the [-1, +7] window when other important information about a firm in the SCT25 list was disclosed, such as earnings, new product launches, mergers and acquisitions, divestments, litigation, key executive changes, competitor actions, and market changes. We used the LexisNexis database to find the major confounding events that occurred in the [-1,+7] event window. To illustrate the procedure, to find key events pertaining to Dell in the time interval 11/14/2004 to 11/22/2004, which is the [-1, +7] interval relative to the publication date of the 2004 SCT25 report of 11/15/2004, the search filter is set as:

LOAD-DATE AFT(11/13/2004) AND LOAD-DATE BEF(11/23/2004) AND HEADLINE(Dell) AND ORGANIZATION(Dell)

The name of the firm is used in both the HEADLINE and the ORGANIZATION search keys to ensure that the news item is principally about the firm in question. The LOAD-DATE AFT and LOAD-DATE BEF search keys are used to define the timeframe of the search. After the dates for the confounding events have been found in the event window, each confounding event is itself assigned the standard [-1, 0] window as its market-move days. The standard [-1, 0] window is chosen because confounding disclosures, such as about earnings, acquisitions, divestments, and product launches, are not controvertible opinion like the SCT25 information. Once the market-move days for the major confounding events have been found, these days are removed from the long [-1, +7] window of the SCT25 information disclosure.

Test Statistic for Longitudinal Value-Relevance of SCT25 Information Signal

We develop a statistic for testing the value-relevance of the SCT25 information over epochs defined in the 2004 to 2014 time frame of the study with a longer than standard event window and correcting for confounding information disclosures in this window. Since the test statistic for the standard event study using a two-day window with no correction for confounding events is clearly not applicable in our study, we develop our test statistic from first principles using Lindeberg's Central Limit Theorem (Feller, 1966). Lindeberg's Central Limit Theorem states that:

$$\lim_{n\to\infty}\left(\frac{X_1 + X_2 + \cdots X_n}{s_n}\right) = Z \quad \text{where } s_n = \sqrt{\sigma_1^2 + \sigma_2^2 + \cdots \sigma_n^2} \tag{1}$$

where the X_i's are zero-centered and independent random variables that are not necessarily identically distributed. The test statistic $\left(\frac{X_1+X_2+\cdots X_n}{s_n}\right)$ converges to a standard normal distribution for sufficiently large *n* provided that the following condition known as Lindeberg's condition is satisfied:

$$\text{For any } \epsilon > 0, \lim_{n\to\infty}\frac{1}{s_n^2}\sum_{j=1}^{n} E\left(X_j^2\, I\{|X_j| > \epsilon\, s_n\}\right) = 0 \tag{2}$$

where $I\{.\}$ is the indicator function or $I\{|X_j| > \epsilon s_n\} = 1$ when $|X_j| > \epsilon s_n$ and 0 otherwise.

To apply Lindeberg's Central Limit Theorem (Feller, 1966) in our context, we define the following variables:

- y = a year in which the SCT25 is published
- y_1 = first year of publication of the SCT25 in this study, which is 2004.
- y_2 = last year of publication of the SCT25 in this study, which is 2014.
- M_y = number of stocks in the SCT25 in year y that are traded on the NYSE or NSADAQ. M_y is not necessarily 25 as some of the firms in the SCT25 in a given year are not traded on the NYSE or NASDAQ. As an example, foreign stocks that don't have an ADR traded on the NYSE or NASDAQ are excluded from the study.
- N_y = M_y plus the stocks which were in the SCT25 list the previous year but were dropped in the current year y. If the SCT25 is correctly identifying the firms that excel in SCM, then we would expect a negative abnormal return for those stocks dropped in year y. Hence, the negative of the abnormal return

for these stocks upon the disclosure of the SCT25 information is included in the accumulation of the abnormal returns that form the test statistic.

D_y = the set of market open days in year y in the event window $[\tau_1, \tau_2]$, which is [-1, +7] for this study. It should be noted that the stock market is not open on all days in the event window.

L_y = cardinality of the set D_y

D_{iy} = the set of market-open days in D_y during which confounding information disclosures for firm i in year y are discounted by the market

K_{iy} = cardinality of the set D_{iy}

AR_{ity} = abnormal return in the event window for firm i on day t and year y, where t is a market-open day in the event window. With regard to the stocks that were in the SCT25 in the previous year but were dropped in the current year y, the negative of the abnormal return is used in the accumulation of the abnormal returns for forming the test statistic

R_{mty} return from the market on day t and year y

T_1 = start of the estimation period

T_2 = end of the estimation period

T = length of the estimation period, $T = T_2 - T_1 + 1$

$\bar{R}_{my}$ = average market return over the estimation period in year y

s_{iy} = residual standard deviation obtained from the estimation of the market model for firm i in year y

C_{ty} = correction factor reflecting increase in variance because of prediction outside the estimation period. The standard deviation of the abnormal return AR_{ity} is $\sqrt{C_{ty}}s_{iy}$. The correction factor is given by $1 + \frac{1}{T} + \frac{(R_{mty}-\bar{R}_{my})^2}{\sum_{t=T_1}^{T_2}(R_{mty}-\bar{R}_{my})^2}$

For large T, the correction factor can be ignored as $C_{ty} \approx 1$.

SAR_{ity} = The standardized abnormal return or $AR_{ity}/(\sqrt{C_{ty}}s_{iy})$

The subscripted X variables in Equations (1) and (2) correspond in our model to the SAR_{ity} terms. Each SAR_{ity} is a Student t distribution with T – 2 degrees of freedom. The total number of SAR's accumulated in the numerator, or the value of n in Equation (1), is given by:

$$n = \sum_{y=y_1}^{y_2} \left(N_y L_y - \sum_{i=1}^{N_y} K_{iy} \right) \tag{3}$$

As indicated in the definition of the AR terms, the number of firms included in a given year y includes the firms in the SCT25 in that year and also any firms that appeared in the previous year but were dropped in the given year. For the firms that were dropped, the sign of the SAR term is reversed when their SAR's are added to the numerator in Equation (1). Also, for any firm to be included in the study, it must be traded on the NYSE or NASDAQ. With regard to foreign stocks in the SCT25, only those that have an ADR that is traded in the US markets are included in the study. The number of firms in our study in any year that the SCT25 is published is not necessarily 25 because some firms in the list are not traded on the NYSE or the NASDAQ. If we denote as L_y the number of stock market open days in the [-1, +7] window in year y, then there would be $N_y L_y$ days in year y for which there would be SAR's in the numerator of Equation (1) before considering the issue of confounding information. Since we exclude the market-move days of confounding information, then with K_{iy} representing the number of market-move days

when confounding information is moving the markets for stock *i* in year *y* in the [-1, +7] window, Equation (3) gives the total number of SAR's in the numerator of Equation (1).
Since each *SAR* is a Student t distribution with T-2 degrees of freedom, the test statistic $\frac{X_1+X_2+\cdots X_n}{s_n}$ is given by:

$$\frac{1}{\sqrt{\left(\frac{T-2}{T-4}\right)\left(\sum_{y=y_1}^{y_2}\left(N_y L_y - \sum_{i=1}^{N_y} K_{iy}\right)\right)}} \sum_{y=y_1}^{y_2} \sum_{i=1}^{N_y} \sum_{t\epsilon\{D_y - D_{yi}\}} SAR_{ity} \tag{4}$$

If the Lindeberg condition is satisfied then the test statistic converges to the standard normal distribution or:

$$\frac{1}{\sqrt{\left(\frac{T-2}{T-4}\right)\left(\sum_{y=y_1}^{y_2}\left(N_y L_y - \sum_{i=1}^{N_y} K_{iy}\right)\right)}} \sum_{y=y_1}^{y_2} \sum_{i=1}^{N_y} \sum_{t\epsilon\{D_y - D_{yi}\}} SAR_{ity} \to Z \tag{5}$$

Since the X_j variables in Equation (2) correspond to the SAR's and each SAR has the same Student t distribution with T-2 degrees of freedom, the expression in the condition can be simplified as follows:

$$\frac{1}{s_n^2}\sum_{j=1}^{n} E(X_j^2\, I\{|X_j| > \epsilon s_n\}) = \frac{nE(X_1^2 I\{|X_1| > \epsilon s_n\})}{n\sigma_1^2} = \frac{E(X_1^2 I\{|X_1| > \epsilon s_n\})}{\sigma_1^2} \tag{6}$$

where X_1 is any SAR in the series of SAR's summed to form the test statistic. Since each SAR has a Student t distribution with T-2 degrees of freedom, we can substitute for s_n in Equation (6) to express the Lindeberg condition as:

$$\text{For any } \epsilon > 0, \lim_{n\to\infty} \frac{E\left(X_1^2 I\left\{|X_1| > \epsilon\sqrt{n\left(\frac{T-2}{T-4}\right)}\right\}\right)}{\sigma_1^2} = 0 \tag{7}$$

Finally, since X_1 is any SAR and thus has a Student t with T-2 degrees of freedom, the condition reduces to:

$$\text{For any } \epsilon > 0, \lim_{n\to\infty} E\left(t^2 I\left\{|t| > \epsilon\sqrt{n\left(\frac{T-2}{T-4}\right)}\right\}\right) = 0 \tag{8}$$

For any fixed ϵ, the limit in Equation (8) is of the form:

$$\lim_{n\to\infty} E\left(t^2 I\left\{|t| > c\sqrt{n}\right\}\right) = 0 \tag{9}$$

where *c* is a constant. Note that the lowercase *c* here is not the same as the uppercase C_{ty} term indicated in the definition of the variables in the model. If we let t_n be the random variable $t^2 I\left\{|t| > c\sqrt{n}\right\}$, then:

$$t_n = t^2 \text{ when } |t| > c\sqrt{n} \text{ and}$$
$$t_n = 0 \text{ otherwise} \quad (10)$$

Equation (10) asserts that t_n is non-zero only when the event $|t| > c\sqrt{n}$ occurs. However, as $n \to \infty$, the probability of the event $|t| > c\sqrt{n}$ occurring tends to 0. Hence, as $n \to \infty$, $t_n \to 0$. This establishes Equation (9) and shows that the Lindberg condition holds and that the test statistic given by Equation (1) has a standard normal distribution for large *n*.

The remaining question is how large *n* should be for the Lindeberg Central Limit Theorem to hold and the test statistic given by Equation (1) to be deemed an approximately standard normal distribution. With regard to the standard form of the Central Limit Theorem (CLT), it is sufficient for *n* > 30 for the standard form of the CLT to hold (Anderson, Sweeney, & Williams, 2010). In our study, when the full timeframe of 2004 to 2014 is considered, the number of *SAR*'s accumulated or the value of *n* is 1340. Even when an epoch is collapsed and reduced to a single year, as was done to explore the time-dependent nature of the value-relevance of the SCT25 information at a granular yearly level, the value of *n* is above 100. When multi-year epochs are concerned the value of *n* is much larger. Hence, there is no issue about the size of *n* when applying the Lindeberg Central Limit Theorem in our context.

Data Set

The list of the Top 25 supply chain companies from 2004 through 2014 produced by Gartner was obtained from McCarthy and Nayar (2010) and also from various vendor web sites. Table A.1 in Appendix A gives the consolidated rankings of the firms in the SCT25 over the 2004 to 2014 time frame. Table A.2 in Appendix A indicates the market-move dates of confounding information about various firms in a given year's SCT25 list in the [-1, +15] window around the nominal publication date of the SCT25 report. We collected data for confounding events for an even larger window than [-1, +7] to test for the robustness of the results if the window was shortened or lengthened from the [-1, +7] window size. These confounding event dates were obtained by searching the LexisNexis database using the procedure described in Section 2.2. The standard two-day [-1, 0] window was allocated for the discounting by the capital markets of the confounding information.

RESULTS

To obtain a hint on how to break up the 2004 through 2014 time frame into meaningful epochs, we examined how the value-relevance of the SCT25 information would change if each individual year is treated as its own epoch. Figure 2 shows the value of the test statistic with each year treated as its own epoch. It is seen from Figure 2 that the value of the test statistic is quite low in the initial years of 2004 and 2005, is high in some of the years in the middle portion of the 2004 to 2014 time frame of the study, and then it goes into a steady decline even reaching negative values towards the tail-end of the time frame from 2012 through 2014.

This suggested a way of segmenting the 2004 through 2014 time frame into the following epochs: Epoch I (2004-2005), Epoch II (2007-2011), and Epoch III (2012-2014). We then tested for value-relevance in each of these epochs and the p-values of the hypothesis of no value-relevance by epoch is shown in Table 1. As Table 1 shows, we did not find any value-relevance of the SCT25 information in either the front end (2004 to 2005) or the tail-end (2012 to 2014)

time frame of the study. But it was strongly value-relevant in the middle portion comprising the years 2007 through 2011.

Figure 2: Epochs of Value-Relevance of SCT25 Information

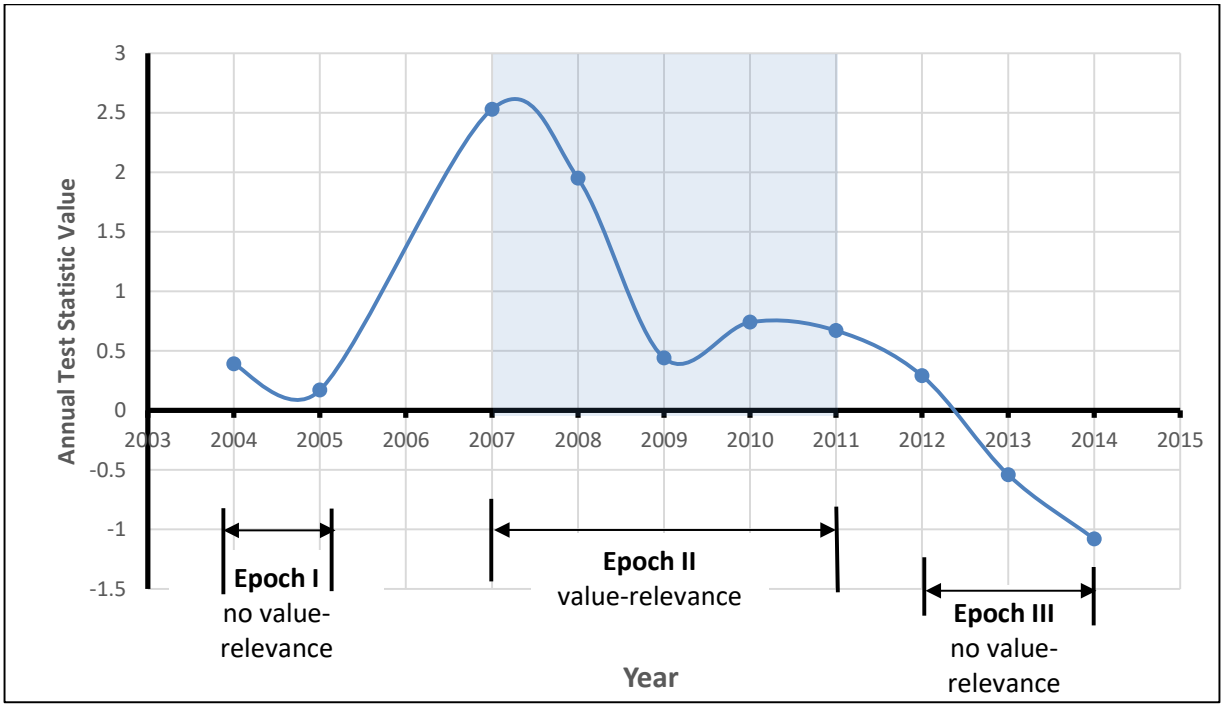


Table 1: Epoch-based P-values

Epoch	P-value
I (2004 to 2005)	0.3504
II (2007 to 2011)	0.0023**
III (2012 to 2014)	0.7808

DISCUSSION OF RESULTS

The conclusion of no value-relevance of the SCT25 information towards the tail-end of the 2004 through 2014 time frame, corresponding to the 2012 through 2014 epoch, implies that perhaps the methodology that Gartner is using to identify the best firms in SCM may need some updating. It is also interesting to observe that there was no value-relevance of the SCT25 information at the front-end of the time frame, or the 2004 to 2005 epoch. This could be explained by the fact that because the SCT25 information is opinion, there must first be credibility built for this type of opinion before rational investors will believe it and act upon it.

The SCT25 report was actually first published by AMR Research, a relatively small research firm, that Gartner acquired in 2009. Gartner is a large well-established analyst firm with $3.3 billion in 2017 revenues and 15,000 employees. In contrast, at the time of the acquisition by Gartner in 2009, AMR Research had a revenue of $40 million and less than 100 employees. The Gartner acquisition gave AMR Research a tremendous amount of visibility and credibility.

But in the early years when AMR Research was on its own and was producing the SCT25 report, the authors would have had to establish credibility for themselves and their methodology before the market would give credence to their opinion.

The lack of value-relevance in the 2012 through 2014 epoch likely implies that the methodology that Gartner has been using for identifying the best companies in SCM may be in need of some updating. In the aftermath of the financial crisis of 2007 through 2009, many business assumptions across-the-board have had to be reassessed. At the heart of the financial crisis was a highly incorrect assessment of the risk of certain financial instruments. The notion of risk and how to best manage it is not limited to the financial services industry. Risk management is an issue in every industry and the fundamental notion of risk pervades many types of business models. Also, many experts did not see this crisis coming at all and were caught on the wrong foot. Regardless of whether Gartner is using a panel of experts or some objective quantitative model or a combination of both, the aftermath of the financial crisis behooves an across-the-board rethinking about risk and the best ways to manage risk.

IMPLICATIONS

Implications for Theory

This article makes two important theoretical contributions. The first is methodological. We have developed a model for assessing the value-relevance of controvertible information. The existing event study methodology is useful mainly for factual information. Facts are not disputable. A report on last quarter's earnings or a corporate acquisition are facts. Controvertible information, such as an analyst pronouncing an opinion on who is best in something such as SCM capability, can be challenged. Other analysts may produce a dissenting opinion. Hence, to find the value-relevance, or market-moving impact, of controvertible information, it is necessary to first have a longer event window to allow for dissenting opinion to be voiced. It is the net market-moving effect of both the original opinion and the dissenting voices that is key in assessing the value-relevance of the original opinion. Hence, a longer window becomes necessary and, given a longer window, the issue of confounding events can no longer be ignored and must be explicitly addressed. This article develops a general methodology for assessing the value-relevance of controvertible information with longer windows and with an explicit correction for confounding information. There are many examples of subjective rankings produced by industry analysts and other gurus in many different walks of life such as yearly rankings of automobile manufacturers or airlines. Our general methodology for examining the value-relevance of controvertible information can be applied by researchers to all these other contexts.

The other important theoretical contribution of this article is that focuses attention on the construct of *credibility* as an important aspect of information, particularly that of controvertible information, as a determinant of value-relevance. If the information is from a source that is not regarded as credible, then it will not move markets. We saw in this study that the AMR Research authors who produced the SCT25 report originally had to first build credibility for themselves and their methodology before investors would believe them and make market moves based on their opinion. That very likely is the reason behind the SCT25 information disclosure not having market-moving impact in the early years of 2004 to 2005, with 2004 being the first year of the publication of the report. We know from past research (Malatesta & Thompson, 1985) that information that is novel has more market impact compared to information that is partially anticipated. This research shows that both novelty and credibility of information play a key role in moving markets. The notion of credibility of information has not been the subject of much research and therefore there is a great deal of room to further explore

the construct of credibility along with that of novelty in future research on value-relevance of information.

Implications for Practice

The main implication here is that Gartner should take a closer look at its methodology of identifying the best companies in SCM and explore areas of improvement. Regardless of whether the identification of the best companies in SCM is done subjectively using a panel of experts or objectively using some kind of quantitative model or a combination of both, a reexamination of the composition of the panel or the predictor variables in a quantitative model is warranted. As stated earlier, in the aftermath of the financial crisis of 2007 to 2009, fundamental notions of risk and how best to manage it are being rethought across the board and not just in the financial services industry. It should also be noted that experts and industry pundits uniformly failed to see this crisis coming. Managers who rely on Gartner's opinion on exemplars in SCM as they make decisions about their own supply chains should ask for more transparency about Gartner's methodology of identifying the exemplars. They should also ask what Gartner has done to update this methodology in the aftermath of the financial crisis which has led to a rethinking about the notion of risk. If the experts in the financial services who deal with managing risk of investments every day could be so wrong about risk, so could managers in other industries.

CONCLUSION

Our article makes a number of notable contributions. We first develop an event study methodology that is appropriate for disclosure of controvertible information or opinion. The staple event study methodology that exists is really appropriate only for the disclosure of factual information. Our new methodology makes feasible the study of the value-relevance of opinion disclosures in many different contexts. We then apply the methodology we have developed to the case of Gartner's opinion about the top 25 companies who excel in managing their supply chains. We validate that Gartner did indeed develop a good methodology for identifying the top companies in SCM. Their disclosure of the top 25 companies in SCM was value-relevant and highly significant when we look at the 2007 through 2011 epoch. However, a concern is that in more recent years, the disclosure of the SCT25 information has not made a statistically significant impact on the market. This may indicate that Gartner's methodology for identifying the best companies in SCM may need to be updated. Particularly, in the aftermath of the 2007 to 2009 financial crisis, the fundamental notion of risk itself is being reassessed by managers in many industries. Risk is a fundamental notion that permeates many business models.

APPENDIX A

Table A.1: Yearly Rank of Firm in Gartner's Supply Chain Top 25 (SCT25)

Company	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014
3M	14	26	26	26	26	26	24	21	19	18
Amazon.com	26	26	26	26	26	10	5	2	3	3
Apple	26	26	2	1	1	1	1	1	1	1
AstraZeneca	26	26	25	26	26	26	26	26	26	26
Best Buy	18	17	9	14	21	24	26	26	26	26
Canon	24	26	26	26	26	26	26	26	26	26
Caterpillar	26	26	26	26	26	26	26	20	18	23
Cisco	26	18	11	8	5	3	6	8	7	7
Coca Cola	17	25	13	13	13	13	11	6	9	10
Colgate Palmolive	26	26	26	26	20	17	13	11	10	9
Cummins	26	26	26	26	26	26	26	23	23	24
Dell	1	1	26	3	2	5	2	4	11	26
Ford Motor	26	26	26	26	26	26	26	26	22	26
GlaxoSmithKline	15	26	20	26	26	26	26	26	26	26
Hewlett Packard	13	26	21	18	17	15	17	24	26	26
Home Depot	21	26	26	26	26	26	26	26	26	26
IBM	4	3	4	5	4	8	14	26	26	26
Intel	19	11	26	26	25	18	16	7	5	8
Johnson Controls	8	10	16	23	26	26	26	26	26	26
Johnson & Johnson	7	6	14	19	12	14	21	22	25	22
Kimberly-Clark	26	26	26	26	26	26	26	25	26	21
Lockheed Martin	26	26	22	22	19	22	26	26	26	26
Lowe's	22	20	19	26	26	26	26	26	26	26
McDonald's	26	26	26	26	26	11	8	3	2	2
Microsoft	26	26	26	26	26	12	12	26	26	26

TABLE A.1: Yearly Rank of Firm in Gartner's Supply Chain Top 25 (SCT25) (continued)

Company	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014
Motorola	26	15	12	26	26	26	26	26	26	26
Nike	26	21	18	15	14	16	20	14	14	12
Nokia	2	4	1	2	6	19	26	26	26	26
Paccar	26	26	24	26	26	26	26	26	26	26
PepsiCo	10	16	15	11	9	6	9	12	16	15
Posco	16	26	26	26	26	26	26	26	26	26
Proctor & Gamble	3	2	3	4	3	2	3	5	6	5
Schlumberger	26	26	26	20	11	25	26	26	26	26
Qualcomm	26	26	26	26	26	26	26	26	24	19
Starbucks	26	26	26	26	26	26	22	16	15	17
Research in Motion	26	26	26	26	26	9	4	19	26	26
Seagate	26	26	26	26	26	26	26	26	26	20
Sysco	26	24	26	26	26	26	26	26	26	26
Tesco	9	9	8	12	15	20	23	26	26	26
Texas Instruments	26	19	17	21	18	26	26	26	26	26
Toyota	6	5	5	7	10	26	26	26	26	26
Unilever	26	26	26	26	22	21	15	10	4	4
Walmart	5	8	6	6	7	4	7	9	13	14
Walt Disney	26	26	26	17	16	26	26	26	26	26

Notes:

a) Only companies whose stocks are traded on either the NYSE or NASDAQ exchanges are included. Foreign companies included in the study are those that have an ADR traded on either the NYSE or the NASDAQ.
b) The highest rank is 1 and 25 is the lowest rank in the Supply Chain Management Top 25 list.
c) The rank of 26 indicates that the firm was not in the SCT25 list in that year.

TABLE A.2: Two-Day Market Move Dates of Confounding Events

2004		2005		2007	
Company	**Market Move Dates**	**Company**	**Market Move Dates**	**Company**	**Market Move Dates**
Dell	11/12, 11/22, 11/23	Dell	11/7, 11/10, 11/11	Nokia	6/4
Nokia	12/1, 12/2	IBM	11/14, 11/16, 11/17	Apple	5/31, 6/1, 6/4, 6/5, 6/11, 6/12, 6/13, 6/14, 6/15, 6/18, 6/19
IBM	11/23, 11/24, 12/3, 12/6, 12/7	Nokia	11/16, 11/17, 11/25, 11/28	IBM	5/30, 6/1, 6/4, 6/5, 6/6, 6/7, 6/11, 6/12
Toyota Motor	11/17, 11/18, 11/24, 12/1, 12/2	Toyota Motor	11/7, 11/9, 11/10, 11/11, 11/14, 11/18, 11/21, 11/23, 11/25, 11/28	Toyota Motor	5/30, 6/1, 6/4
Johnson and Johnson	12/1, 12/2/2, 12/6, 12/7	Johnson and Johnson	11/7, 11/8	Best Buy	6/4, 6/5
Tesco	11/12	Tesco	11/7, 11/8, 11/25, 11/28	Cisco	6/1, 6/4
Hewlett Packard	11/23, 11/24, 12/1, 12/2	Intel	11/7, 11/8, 11/10, 11/11, 11/21, 11/22, 11/29, 11/30	Motorola	5/30, 5/31
Coca Cola	11/15, 11/18, 11/19, 11/23, 11/24	Motorola	11/16, 11/17, 11/29, 11/30	Coca Cola	5/31, 6/1, 6/4, 6/5, 6/6, 6/7
Best Buy	11/16, 11/17	PepsiCo	11/9, 11/10, 11/29, 11/30	Lowe's LOW	6/5, 6/6
Intel	11/12, 11/19, 11/22, 11/23, 11/24, 11/29, 12/2, 12/3, 12/6	Cisco	11/7, 11/8, 11/9, 11/10, 11/17, 11/18, 11/21	Hewlett Packard	6/18, 6/19
Home Depot	11/16, 11/17, 12/1, 12/2	Lowe's	11/14, 11/15		
Lowe's LOW	11/15, 11/16	Nike NKE	11/10, 11/11, 11/21, 11/22, 11/23		

TABLE A.2: Two-Day Market Move Dates of Confounding Events (continued)

2008		2009		2010	
Company	**Market Move Dates**	**Company**	**Market Move Dates**	**Company**	**Market Move Dates**
Apple	6/3, 6/4, 6/5, 6/6, 6/9, 6/10	Apple	6/3, 6/4, 6/5, 6/8, 6/9, 6/10, 6/11	Apple	6/1, 6/7, 6/8, 6/9, 6/10, 6/11, 6/14, 6/15, 6/16, 6/17
Nokia	6/9, 6/10, 6/11	Dell	5/27, 5/28, 5/29, 6/10, 6/11	Cisco	6/3, 6/4
Dell	5/28, 5/29, 5/30, 6/2, 6/3	Cisco	6/1, 6/2	Dell	6/3, 6/4, 6/10, 6/11, 6/13, 6/14
Toyota Motor	5/30, 6/2, 6/6, 6/9, 6/11, 6/12	Nokia	5/27, 6/15, 6/16	McDonald's	6/4, 6/7
PepsiCo	6/11, 6/12	Toyota Motor	5/27, 5/28, 6/10, 6/11	Microsoft	6/1, 6/2, 6/3, 6/4, 6/8, 6/9, 6/10, 6/14, 6/15
Tesco	6/10, 6/11	Tesco	6/16, 6/17	Intel	6/1, 6/14
Coca Cola	5/28, 5/29	Texas Instruments	6/8, 6/9	Nokia	6/16, 6/17
Best Buy	6/2, 6/16, 6/17	Lockheed Martin	5/27, 6/15	Tesco	6/8, 6/9
		Best Buy	5/27, 6/16, 6/17	Lockheed Martin	6/1, 6/2, 6/3, 6/7, 6/8, 6/9, 6/16, 6/17, 6/18
		Unilever	5/28, 5/29	Best Buy	6/14, 6/15, 6/16
		Intel	5/27, 6/4, 6/5, 6/9, 6/10		

TABLE A.2: Two-Day Market Move Dates of Confounding Events (continued)

2011		2012		2013	
Company	**Market Move Dates**	**Company**	**Market Move Dates**	**Company**	**Market Move Dates**
Apple	5/31, 6/1, 6/2, 6/3, 6/6, 6/7, 6/8, 6/9, 6/10, 6/13, 6/14, 6/15, 6/16, 6/17	Apple	5/18, 5/21, 5/29, 5/30, 5/31, 6/4, 6/5, 6/7, 6/8, 6/11	Apple	05/21, 05/22, 05/23, 05/24, 05/28, 06/03, 06/04, 06/05, 06/06, 06/10, 06/11
Research in Motion	6/13	Amazon.com	5/30, 5/31	McDonald's	05/23, 05/24, 05/28, 05/29
Amazon.com	6/13	McDonald's	5/24, 5/25, 5/29, 5/30	Amazon.com	05/22, 05/23, 06/10
McDonald's	6/8, 6/9, 6/10	Dell	5/21, 5/22, 5/23, 6/1, 6/4	Intel	06/04, 06/05
Microsoft	6/1, 6/2, 6/3, 6/6, 6/7, 6/9, 6/10	Nike	5/31, 6/1	Proctor & Gamble	05/24, 05/28
IBM	6/13, 6/15, 6/16	Starbucks	6/5, 6/6	Cisco	06/07, 06/10
Intel	6/6, 6/7, 6/21, 6/22	Research in Motion	5/24, 5/25	Dell	05/22, 05/23, 05/28, 05/29, 05/31, 06/03, 06/05, 06/06
Starbucks	6/2, 6/3	Caterpillar	5/18, 5/29, 5/30, 5/31, 6/5, 6/6	Nike	05/28, 05/29
Tesco	5/31, 6/1, 6/14, 6/15	Johnson and Johnson	5/29, 5/30, 6/4	Caterpillar	06/04, 06/05
		Hewlett Packard	5/21	Ford Motor	05/21, 05/22, 05/23, 05/24, 05/29, 05/30, 05/31, 06/03

TABLE A.2: Two-Day Market Move Dates of Confounding Events (continued)

2014	
Company	**Market Move Dates**
Apple	05/28, 05/29, 05/30, 06/01, 06/02, 06/03, 06/04, 06/05, 06/06, 06/09
McDonald's	05/28, 05/29, 06/09, 06/10
Amazon.com	06/26, 06/27, 05/19, 05/23, 05/27, 05/28, 05/29, 06/01, 06/02, 06/03, 06/04, 06/05, 06/09
Unilever	05/22, 05/23
Cisco	05/20, 06/03, 06/04
Intel	05/27, 05/28
Nike	05/28, 05/29
Caterpillar	06/10, 06/11

Notes:

a) Firms are listed in the order of their rank in the SCT25 in a given year.
b) The Lexis Nexis database was used to find the dates of other announcements in the SCT25 event window.
c) The media publication date about some major other news about the company is day 0. The market move dates for this confounding news is [-1, 0] provided that both day 0 and day -1 are both stock market open days. If day -1 is a stock market closed day, then the event window is just day 0 provided that this is a stock market open day. If day 0 is a closed day then the event window is day *t* where *t* is the first stock market open day after day 0 if day -1 is also a closed day. If day 0 is closed day but day -1 is an open day then the event window consists of day -1 and day *t*.

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DECISION SCIENCES INSTITUTE

An information theoretic approach to treat inverse S-shaped probability weighting problems

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Abstract

The aim of this article is to provide a decision making approach to treat empirically observed probability weighting problems. We develop an approach to treat empirically documented inverse S-shaped probability weighting problems. We assume that decision makers pick set measures by maximizing entropy under the constraint of the observed dataset. In a sense, the decision maker maximizes uncertainty given the dataset at hand and thus puts more weight on the extremes. The approach is potentially useful to treat many kinds of financial problems when decision makers are uncertainty averse. .

KEYWORDS: Ambiguity, Rationality, Behaviour under risk and uncertainty.

JEL classification: G11, D81, C11

INTRODUCTION

The standard Expected Utility (EU) approach in modelling behaviour under uncertainty has been the paradigm in behaviour under uncertainty since the seminal works of (Von Neumann & Morgenstern, 1953) as well as (Savage, 1954). Yet, (Allais, 1953) pointed out that, Decision Makers when faced with choices under uncertainty, violated the postulates of EU. Later on, (Ellsberg, 1961) also showed that Decision Makers (DMs) faced with ambiguous lotteries do not act according to EU theory. Basically, the DM distinguishes between roulette and horse lotteries (Anscombe & Aumann, 1963). This evidence has led to the distinction between risk and uncertainty, where the latter is also known as ambiguity. Decision theorists thus developed theories of rational decision making when the DM is faced with sets of probabilities.

(Gilboa & Schmeidler, 1989) as well as (Schmeidler, 1989) developed two alternative approaches of decision making under uncertainty. Both approaches relax the independence axiom. (Gilboa & Schmeidler, 1989) show that if independence only holds when risky acts are mixed with constant acts, then the DM's decision problem can be represented as maximizing the EU given the least favourable probability distribution from a set of probability measures. This model is known as maxmin EU (MEU). (Schmeidler, 1989) presumes that independence only holds for so-called comonotonic acts, when acts cannot be used to hedge against each other. The decision problem can then be modelled as maximizing utility with respect to a non-additive set measure, called capacity. This is the Choquet expected Utility (CEU) model.

These decision theoretic models, however, are not consistent with experimental evidence. Since the seminal work of (Kahneman & Tversky, 1979;1991) it is well known that DMs transform probabilities and value deviations with respect to a subjective benchmark. The empirical literature documents that the probability transformation is inverse S-shaped. The probability weighting function (PWF) is extensively discussed by (Prelec, 1998). Prelec suggests that the probability weighting dimension dominates the impact of the value function and that behaviour can be represented with a power utility function and a PWF.

More recently, (Ghirardato et al., 2004) develop an approach known as $\alpha - MEU$ which consists in mixing maxmin behaviour with maxmax behaviour. Within this framework, DMs face a set of probability measures and according to their ambiguity aversion α they choose a certain combination of the most optimistic and pessimistic scenarios. (Amarante, 2009) shows that $\alpha - MEU$ preferences can be modelled with Choquet capacities and there thus exists a mapping between the $\alpha - MEU$ model and the CEU model. Moreover, there are α's for which the capacity is neither globally convex nor concave. This is a very useful property which implies that in principle inverse S-shaped probability weighting could be modelled with $\alpha - MEU$ preferences.

The aim of this article is to develop a decision theoretic approach to treat experimentally documented inverse S-shaped probability weighting problems. Probability distributions are indexed by states of nature. DMs maximize entropy as this maximizes uncertainty given the observed data. We show that we can recover the probability weighting function as maximum entropy implies that the DM puts more weight on the extremes of the probability distribution.

We start by introducing some notations in the next section. We then present the literature on Neo-Bayesian statistics and its relation to capacities. Follows an exploration of the relation between capacities and Cumulative Prospect Theory. We then discuss the empirical features of the probability weighting function. The following section introduces the concept of entropy and imprecise probabilities. We then formulate the statistical decision problem of a DM facing imprecise probabilities and relate violations of the independence axiom to violations of the weak conditionality axioms in statistics. The final section indicates how probability weighting can be deduced from a constrained maximum entropy approach, which can be used for many decision making problems under uncertainty.

PRELIMINARIES AND NOTATIONS

We will consider the following environment. There exists a set of states of the world S and an algebra Σ of subsets of S as well as a set of consequences X. The decision maker chooses elements among a set of simple acts $\mathfrak{I}$. Simple acts are finite-valued Σ-measurable functions $f : S \to X$. The subset of constant acts is identified by elements $x \in X$ such that $x(s) = x \ \forall s \in S$. We will also consider the possibility where X is a set of lotteries like in the (Anscombe & Aumann, 1963) horse-roulette lottery framework. X is then a convex subset of a vector space. Mixed acts can then be defined in the following way:

$$\forall f, g \in \mathfrak{I} \text{ and } \lambda \in [0,1],\ \lambda f + (1-\lambda) g \in \mathfrak{I}. \quad (1)$$

Such a mixed act assigns the outcome

$$\lambda f(s) + (1-\lambda) g(s) \in X \text{ to } s. \quad (2)$$

Preferences are modelled as binary relations $\geq$. Now, consider $B(\Sigma)$ the set of all real-valued Σ-measurable simple functions which is equivalent to the vector space generated by the indicator function 1_A of the events $A \in \Sigma$. A utility function is a mapping from the consequence set X to the real set:

$$u : X \to \Re, \quad \forall f \in \mathfrak{I},\ u(f) \in \mathbf{B}_0(\Sigma) \quad (3)$$

and is defined by

$$u(f)(s) = u(f(s)) \ \forall s \in S. \quad (4)$$

The set of all finitely-additive and bounded set functions on Σ is denoted by $ba(\Sigma)$. A nonnegative element of $ba(\Sigma)$ which assigns proba 1 to S is called a probability measure *P* or *Q*. Elements

$\varphi \in B_0(\Sigma)$ and $m \in ba(\Sigma)$ can thus be combined to give $\int \varphi dm$. We will be interested in the existence of a functional $I : B(\Sigma) \to \Re$. This functional is said:

Monotonic if $I(\varphi) \geq I(\psi)\ \forall \varphi, \psi \in B(\Sigma)\ s.t.\ \varphi(s) \geq \psi(s)\ \forall s \in S$ (5)

Constant additive: if $I(\varphi + a) = I(\varphi) + a\ \ \forall \varphi \in B(\Sigma)\ and\ \ a \in \Re$ (6)

Positively homogeneous: if $I(a\varphi) = aI(\varphi)\ \ \forall \varphi \in B(\Sigma)\ \ and \quad a > 0$ (7)

It is said constant linear if it is constant additive and positively homogeneous.

NEO-BAYESIAN STATISTICS

Following, (Ghirardato et al., 2004) and (Ghirardato & Marinacci, 2001) the following axioms are considered

A1. $\succsim$ is complete and transitive

A2. C-independence: For all $\psi, \varphi \in \mathcal{A}$ and for any constant act γ and all a$\in (0,1)$

$\psi \succ \varphi \ \Leftrightarrow\ a\psi + (1-a)\gamma \succ a\varphi + (1-a)\gamma$

A3. Archimedean property: For all $\psi, \varphi, \gamma \in \mathcal{A}$, if $\psi \succ \varphi$ and $\varphi \succ \gamma$ then $\exists a, b \in (0,1)$ such that $a\psi + (1-a)\gamma \succ \varphi$ and $\varphi \succ\ b\psi + (1-b)\gamma$

A4. Monotonicity: For all $\psi, \varphi \in \mathcal{A}$, $\psi(s) \succsim \varphi(s)\ for\ any\ s \in S \implies \psi \succsim \varphi$

A5. Non-degenerecy: $\exists x, y \in X$ such that $x \succ y$

It is well-known that by adding one of the following axioms one gets the special cases considered in the literature.

A': Subjective expected utility (SEU): For all $\psi, \varphi \in \mathcal{A}$ such that $\psi \backsim \varphi$,

$\frac{1}{2}\psi + \frac{1}{2}\varphi \backsim \varphi$

A'': Choquet Expected Utility (CEU): For all $\psi, \varphi \in \mathcal{A}$ such that $\psi \backsim \varphi$,

$\frac{1}{2}\psi + \frac{1}{2}\varphi \backsim \varphi$ if $\psi\ and\ \varphi$ are comonotonic.

A''': Maxmin Expected Utility (MEU): For all $\psi, \varphi \in \mathcal{A}$ such that $\psi \backsim \varphi$,

$\frac{1}{2}\psi + \frac{1}{2}\varphi \succsim \varphi$

(Ghirardato et al., 2004) show that preferences satisfying axioms A1 to A5 can be represented by a continuous functional $I^*: B(\Sigma) \to \mathbb{R}$ such that $\psi \succsim \varphi$ *iff* $I^*(\psi) \geq I^*(\varphi)$

Where

$$I^*(\psi) = (1 - \alpha^*(\psi))min_{\ P \in C^*} \int \psi dP + \alpha^*(\psi) max_{\ P \in C^*} \int \psi dP \quad (8)$$

$\alpha^* \in [0,1]$

Also, if $\psi, \varphi \in B(\Sigma)$ are linearly related such that

$$(\int \psi dP)_{P \in C^*} = a(\int \varphi dP)_{P \in C^*} + b\ \text{ then }\ \alpha^*(\psi) = \alpha^*(\varphi) \quad (9)$$

The set $C^* \subset ba(\Sigma)$ is typically determined from what (Ghirardato et al., 2004) call an "unambiguous preference relation".

As pointed out by (Amarante, 2009) this representation, however, is not unique. Amarante discusses $\alpha - MEU$ preferences by relating them to Choquet integration.

For $C \subset ba(\Sigma)$, consider $A(C)$ the space of all weak* -continuous affine mappings on C. Weak*-convergence is a measure-theoretic notion which designates convergence in distribution (for further details (Schervish, 1997)). The canonical mapping $\kappa: B(\Sigma) \to A(C)$ then associates to $\psi \in B(\Sigma)$ the function $f_\psi \in A(C)$ defined by $f_\psi(P) = \int \psi dP, P \in C$. Amarante shows that the functional I^* factors as $I^* = V^* \circ \kappa$ where $V^*: A(C^*) \to \mathbb{R}$ is monotone and isotonically additive. Also, a

functional V: $A(C) \to \mathbb{R}$ which is isotonically additive is comonotonically additive. Even though the IBP representation is not unique, all the representations have in common that:

- Any functional I representing IBP can be factorized as $I = V \circ \kappa$, where κ is the mapping $B(\Sigma) \to A(C)$
- The functional V: $A(C) \to \mathbb{R}$ is always monotone and comonotonic additive.

In (Ghirardato et al., 2004) the set $C^*$is interpreted as a description of the ambiguity faced by the Decision Maker whereas the function $\alpha^*(.)$ indicates the DM's attitude towards ambiguity. Amarante, however, points out that the set C^* does not necessarily describe uncertainty faced by the DM as C^* is the set of predictives used by the DM. As α^* depends on the set C^* and as there are many admissible $C's$, α cannot be interpreted as a measure of ambiguity aversion as it is indeterminate. Only, the functional form of V can be used to characterize ambiguity aversion. Thus a concave V would correspond to global ambiguity aversion. Finally, Amarante shows that every $\alpha - MEU$ preference is represented by a functional $I: B(\Sigma) \to \mathbb{R}$ of the form

$$I(\psi) = \int \kappa(\psi) dv \tag{10}$$

For some capacity $v: B \to [0,1]$, *B* being the $Borel\ \sigma - algebra$ generated by the weak*-topology on *C*. As described in the next section, this capacity is mathematical object that can be related to the PWF of Cumulative Prospect Theory.

CAPACITIES AND CHOQUET EXPECTED UTILITY

(Kahneman & Tversky, 1979; 1992) studies show that individuals first rank outcomes and then apply a non-linear PWF. However, their model is just a subcase of the general Choquet Expected Utility (CEU) model which we summarize below. A recent overview of prospect theory is provided by (Wakker, 2010). Let S be a finite set of states of nature. Let *X* be a set of monetary outcomes that includes the neutral outcome 0, all other elements are interpreted as gains or losses. An uncertain prospect *f* (act) is a function from S into *X.* To define the cumulative functional, outcomes of each prospect are arranged in increasing order. The utility that is expected by the individual depends on the ranking of the outcomes and the function is thus called (CEU). A prospect *f* is represented as a sequence of pairs (x_i, A_i), which yields x_i if A_i occurs, where $x_i > x_j$ *iff* $i > j$, and (A_i) are the events of an algebra of S. Now, let's use positive subscripts to denote positive outcomes and negative subscripts to denote negative outcomes. The positive part of *f,* denoted f^+, is obtained by letting $f^+(s) = f(s)$ if $f(s) > 0$, and $f^+(s) = 0$ if $f(s) \leq 0$. As in expected utility theory, we assign to each prospect a value $V(f)$ s.t. $V(f) \geq V(g)$ *iff* $f \geq g$. Now, we call a capacity, a non-additive set function that generalizes the standard notion of probability. More exactly, a capacity *v* is a function that assigns to each $A \subset S$ a number $v(A)$ satisfying $v(\phi) = 0$, $v(\Omega) = 1$, and $v(A) \geq v(B)$ whenever $B \subset A$. CPT asserts that there exists a strictly increasing utility function $u : X \to R$, satisfying

$u(x_0) = u(0)=0$, and capacities v^+ and v^-, such that for $f = (x_i, A_i)$, $-m \leq i < n$,

$$\begin{aligned} V(f) &= V(f^+) + V(f^-) \\ V(f^+) &= \sum_{i=0}^{n} \pi_i^+ u(x_i), \quad V(f^-) = \sum_{i=0}^{0} \pi_i^- u(x_i) \end{aligned} \tag{11}$$

$$\begin{aligned} &\pi_n^+ = v^+(A_n), \quad \pi_{-m}^- = v^-(A_{-m}), \\ &: \pi_i^+ = v^+(A_i \cup \ldots \cup A_n) - v^+(A_{i+1} \cup \ldots \cup A_n), \qquad 0 \leq i \leq n-1 \\ &\pi_i^- = v^-(A_{-m} \cup \ldots \cup A_i) - v^-(A_{-m} \cup \ldots \cup A_{i-1}), \qquad 1-m \leq i \leq 0. \end{aligned} \tag{12}$$

Letting $\pi_i = \pi_i^+ \ if \ i \geq 0$ and $\pi_i = \pi_i^- \ if \ i < 0$, $V(f)$ reduces to:

$$V(f) = \sum_{i=-m}^{n} \pi_i u(x_i) \quad (13)$$

The decision weight associated with an outcome can be interpreted as the marginal contribution of the respective event, defined in terms of capacities. The measure of an event thus depends on it's rank and this model is a generalization of expected utility called (CEU). An individual maximizing (13) is called a Choquet Expected Utility (CEU) maximizer. Under risk, where an objective cumulative distribution function exists, it may be interpreted as maximizing expected utility with respect to the transformed cumulative distribution function $v \circ F$ where *F* is the objective cumulative distribution function. This model is called Rank Dependent Expected Utility (RDEU). *v* is the PWF and it's shape seems to be rather robust across experiments (Tversky & Wakker, 1995) and (Prelec, 1998). Moreover, (Prelec, 1998) derives the functional consistent with behavioral axioms.

EMPIRICAL FEATURES OF THE PROBABILITY WEIGHTING FUNCTION

In the standard CEU model $u(x_0)$ is considered to be the minimal utility that the individual will get in the least favorable state. He then adds the increments in utility weighted by his beliefs on the future states. However, $u(x_0)$ is not necessarily the minimal utility, but may be the reference point with respect to which the individual weights gains and losses. Moreover, the model may be slightly different since the capacities are different on gains and losses. Actually, CEU is a special case where the capacity for losses is the *dual* of the capacity for gains, i.e. $v^-(A) = 1 - v^+(S - A)$. (Kahneman & Tversky, 1992) also considered a special case of CPT where $v^+ = v^-$. This property is based on preference conditions called *reflection*.

There are two possibilities to define risk (or uncertainty) aversion : via the curvature of the utility function or via the functional form of the capacities. Nevertheless, it is generally accepted that risk behavior is described by the functional form of the utility function, whereas the uncertainty (or ambiguity) aversion is given by the functional form of the capacities.

Now, let's rewrite $V(f^+)$ in a different way :

$$V(f^+) = u(x_0) + \sum_{i=1}^{n} [u(x_i) - u(x_{i-1})] v\left(\bigcup_{j=i}^{n} A_j\right) \quad (14)$$

This formula expresses the value of a prospect as a function of changes in utility and a transformation of the cumulative probability, called probability weighting function (PWF). It has been suggested that uncertainty aversion can be analyzed with a CEU model. In fact, (Schmeidler, 1989) gives the following definition of uncertainty aversion. Uncertainty aversion is equivalent to the convexity of the capacity, that is :

$$v(A \cup B) + v(A \cap B) \geq v(A) + v(B) \quad (15)$$

for all measurable events A and B. We have additivity when the right hand side and the left hand side are equal, and the individual is then uncertainty neutral. Now, experimental evidence (Tversky & Wakker, 1995), (Prelec, 1998) shows that the capacity *v* is sub-additive meaning that there exist events *E* and E' s.t.

$$v(B) + v(A) \geq v(A \cup B) \quad whenever \quad v(A \cup B) \leq v(S - E) \quad (16)$$

And

$$1 - v(S - B) \geq v(A \cup B) - v(A) \quad whenever \quad v(A) \geq v(E') \quad (17)$$

The first condition is called lower sub-additivity whereas the second is called upper subadditivity. The certainty effect is characterized by upper sub-additivity, since the increase of a high probability to certainty has more effect than the same increase in probability for a medium probability. This kind of behavior has also been documented under risk.

Empirical evidence (Prelec, 1998), Wu and Gonzalez (1996)) suggests that the probability weighting function has the following properties :

asymmetry - $v(p) = p$ approximately at $p = 1/3$, where p is the probability to get at least a certain amount.
Inverse s-shape - concave on an initial interval and convex beyond
reflectivity - assigns the same weight to a given loss-probability as to a given gain-probability.
If the preference relation satisfies a certain number of axioms given in the appendix A1, the preference relation can be represented by a sign- and rank-dependent utility function. (Prelec ,1998) provides a set of axioms needed to deduce a functional form of the weighting function that agrees with the stylized facts. The most general specification for this weighting function is given by the following form :

$$v(p) = \gamma \exp\left(-\beta(-\ln p)^{\alpha}\right) \tag{18}$$

However, if the preference relationship satisfies certain axioms, notably diagonal concavity, sub-proportionality and compound invariance (see Prelec (1998)), then the specification takes the following less complex form :

$$v(p) = \exp\left(-(-\ln p)^{\alpha}\right) \tag{19}$$

where α indicates the degree of non-linearity of the function. One typically observes risk-seeking for small-probability gains and large-probability losses, and risk-aversion for small-probability losses and large-probability gains. A linear value function would be sufficient to explain observed behavior. However, if the value function is not linear, then the probability non-linearity must dominate the value non-linearity to explain empirical patterns. Such a dominance arises when the above probability weighting function is combined with a power function of the following form :

$$u(x) = x^{\sigma^+} \ \ if \ \ x \geq 0 \ , \ -(-x)^{\sigma^-} \ \ if \ \ x < 0 \tag{20}$$

Concerning the weighting function, the values of the parameters of v can be slightly different across studies, the functional form is quite robust, see Prelec (1998).

ENTROPY AND IMPRECISE PROBABILITIES

Entropy is a concept that stems from information theory. It measures uncertainty as well as the information provided by a probability distribution. The idea behind entropy is that the least likely an event is to occur, the more information is provided by the occurrence of an event. The content of information is thus a negative function of the probability of the respective event. It can be shown that there is a unique function which respects a certain number of plausible axioms, namely, $-\log p$. The content of information in a probability distribution can be evaluated by taking the expectation of this function:

$$E_p(-\log p) = -\sum_i p_i \log p_i \tag{21}$$

This is Shannon's information theoretic entropy measure. (Jaynes, 1957) argues that a way to treat ill-posed statistics problems, is to consider observed functions, typically moments, of the possible events, as part of the available information. He suggests to consider the probability distribution that assumes the less given the data. This is done by maximizing uncertainty given the realized values of the above mentioned functions. Uncertainty is measured with Shannon's information theoretic entropy measure. In fact, even though not the only measure of uncertainty, Shannon's measure is consistent with additivity of independent risks.

The entropy measure is maximum when the distribution is uniform, in the sense that given a range of possible outcomes, we have no information on which event is more likely to occur. Conversely, the entropy is minimum when we know exactly which event is going to occur. If we maximize entropy given constraints in terms of functions of the data, it is as if we take the most uniform distribution consistent with the constraints. Another interpretation is that we get the distribution

that can be generated in the most different ways. Actually, the following entropy optimization postulate given in (Kapur & Kesavan, 1992), generalizes the principle.
Each probability distribution is an entropy optimization distribution; i.e., it can be obtained by maximizing an appropriate entropy measure or by minimizing a cross-entropy measure with respect to an appropriate a priori distribution, subject to its satisfying appropriate constraints.
A rigorous way to be robust, given partial information, is to maximize entropy under the constraint of partial information (Jaynes, 1982)).

We will consider a situation where probabilities are imprecisely known to the decision maker. In the information theoretic literature, those imprecise probabilities are typically analyzed with monotone measures μ which are not necessarily additive. The most recent contributions in generalized information theory (Klir, 2006)) refer to monotone measures as a considerably broader framework than probabilities for formalizing uncertainty. As they can be sub-additive,

$$\mu(A \cup B) \leq \mu(A) + \mu(B) \tag{22}$$

as well super-additive,

$$\mu(A \cup B) \geq \mu(A) + \mu(B), \tag{23}$$

monotone measures are more flexible in capturing different types of uncertainty. For instance, (Klir, 2006) points out that, even though additivity works well for types of measurement under idealized, error-free conditions, it is not really adequate for most measurements under real physical conditions, when measurement errors are unavoidable. When measurement errors are present, observations might provide more evidence for the joint event $(A \cup B)$ than the sum of the evidence for the events considered individually, thus:

$$\mu(A \cup B) > \mu(A) + \mu(B) \tag{24}$$

We will assume that the decision maker views probability distributions as indexed by states drawn from nature. This is the horse-roulette lottery framework developed in (Anscombe & Aumann, 1963). In order to illustrate, consider a statistical decision maker facing densities indexed by random draws of parameters θ. This is typically the way the topic is addressed in the macro-econometric literature on robust decision making. This literature, however, applies max-min behavior which presumes concave capacities and pessimism which is inconsistent with empirical evidence (for a recent discussion (Abdellaoui et al., 2010). In the next section, we describe the decision protocol of a decision maker who maximizes entropy given the observed distribution. This implies that he distorts probabilities by putting more weight on the extremes.

THE STATISTICAL DECISION PROBLEM

We consider a DM observing the multivariate process of variables, called the data generating process DGP. Standard expected utility theory would advocate estimation of a statistical model, usage of that prediction as the objective probability distribution and finally choice of an act that maximizes expected utility. This viewpoint is in line with the classical statistics approach in the sense that probabilities are presumed "objective". We argue in a neo-Bayesian flavor (Amarante, 2009), that our DM cares (and should care) about his precise decision problem and is well aware of his "imperfect view of the world". In that respect, (Al-Najjar, 2009) shows that different models can be consistent with the same empirical evidence, even with infinite datasets. Our DM internalizes the fact that his predictive model is (almost surely) flawed and knows that the estimated density of returns is not necessarily a good representation of the real DGP. We assume that this is due to parametric uncertainty and that it is as if nature drew another parameter θ from the parameter set Θ (see (Blackwell & Girshick, 1965). This is consistent with the (Anscombe & Aumann, 1963) way to model uncertainty. Individuals believe that there is a multivariate Data Generating Process (DGP). Elements θ (vectors of parameters) from Θ are the states of the world. *P* is the set of all simple distributions on the set of outcomes X. Φ is the set of all functions from Θ

to *P*. More exactly, elements of Φ have the following form: $F(X/data,\theta)$ where $F(X/data,\theta)$ denotes the estimated joint density on outcomes as a function of data and the θ drawn by nature.

Acts are thus choices of prospects as well as statistical models. At one point in time the *data* is fixed and observed by the DM. Now, elements of Φ are denoted by φ. The standard expected utility DM would maximize

$$\int u(\varphi(\theta))\pi(\theta/data)d\theta \tag{25}$$

where $\pi(\theta/data)$ is a probability measure over the events of the parameter states Θ given the observed sample *X*. We argue that this would be reasonable if the DM had a perfect knowledge of $(\Theta,\Re)$, where $\Re$ is the $\sigma-field$. However, it is very difficult, even for an expert in statistics, to grasp the underlying process. For instance, regime changes are difficult to detect and regime parameters difficult to estimate. We argue that for some regions the DM has good knowledge to form probabilistic beliefs about the events, while for some yet unseen region the DM has a blurred view and has even difficulty to define the events. In fact, given a finite sample size he has difficulties to get a clear grasp of some parameter values. We will argue later on, in line with (Jaynes, 1957; 1982), that it is rational for such a DM to deduce the posterior by maximizing entropy and that this leads to the functional form of π^* suggested by (Prelec, 1998).
The individual hence maximizes the following function :

$$\int u(\varphi(\theta))\pi^*(\theta/data)d\theta \tag{26}$$

where $\pi^*(.)$ is a (as *v* described in section 4) transformation of *F*(*X*/*data*,θ), which is a function of θ for a fixed data set *data*.

LIKELIHOOD PRINCIPLE, WEAK CONDITIONALITY AND INDEPENDENCE

As we saw in the previous section, a standard Bayesian (DM) would maximize

$$\int u(\varphi(\theta))\pi(\theta/data)d\theta \tag{27}$$

where $\pi(\theta/data)$ is a probability measure over the events of the parameter states Θ given the observed sample *data*. As is well known from Bayes Theorem :

$$\pi(\theta/data)=\frac{f(data/\theta)\pi(\theta)}{\int_{\Theta} f(data/\theta)\pi(\theta)d\theta}\propto \quad f(data/\theta)\pi(\theta) \tag{28}$$

where $f(data/\theta)$ is the density over the respective *data* for a given θ. The latter is given by the likelihood function $l(\theta)$ and this leads to the following expression :

$$\pi(\theta/data)\propto \quad l(\theta)\pi(\theta) \tag{29}$$

$f(data/\theta)$ is now considered a function of θ. Instead of maximizing the likelihood function $l(\theta)$ to recover θ, the Bayesian maximizes the generalized likelihood function $l(\theta)\pi(\theta)$.
However, this presupposes that the Likelihood Principle is not violated. Recall that classical statistics presumes randomization over the sample space. Also, recall that the Likelihood Principle stems from two axioms: sufficiency and weak conditionality. While sufficiency will not be questioned, weak conditionality seems less unquestionable. The idea behind weak conditionality is the following. Each time a statistic is observed, it is an observation of many possible realizations of the process. The Weak Conditionality Principle presumes that a DM, faced with a realization of the sample, abstracts from other possible sample realizations and infers the parameter value by considering only the sample he has observed. Hence, all relevant experimental information is contained in the likelihood function for observed *X*. The following description is given in (Berger, 1985).

The Weak Conditionality Principle. *Suppose one can perform either of two experiments E_1 and E_2, both pertaining to μ, and that the actual experiment conducted is the mixed experiment of first choosing J = 1 or 2 with probability 1/2 each (independent of θ), and then performing experiment E_J .*
Then the actual information about θ obtained from the overall mixed experiment should depend only on the experiment E_j that is actually performed.

Experimental evidence suggests that the independence axiom is systematically violated. Moreover, violations of the independence axiom are responsible for the non-linear probability weighting. As we argue below, violations of the independence axiom imply violations of weak conditionality.
More formally, let S be a general state space with elements s and Y be the set of distributions over S with finite supports

$$\left\{ Y = y : S \to [0,1] : y(s) \neq 0 \ \ for \ \ finitely \ many \ \ s \ \ in \ \ S \ \ and \ \ \sum_{s \in S} y(s) = 1 \right\} \qquad (30)$$

Convex combinations in Y are performed point-wise, i.e. for *f* and *g* in Y and α in [0, 1], $\alpha f + (1-\alpha)g = h$ means $\alpha f(s) + (1-\alpha)g(s) = h(s)$ for $s \in S$.

We can now define the independence axiom.
Definition : The individual respects the independence axiom *iff* for all *f*,*g* and *h* in Y and for all α in (0,1) : $f > g$ implies $\alpha f + (1-\alpha)h > \alpha g + (1-\alpha)h$.
Now, rewrite the problem with $\theta \in \Theta$ (parameters are the states) and the likelihood functions $f(\theta)$, $g(\theta)$ and $h(\theta)$ of experiments *f,g* and *h*. The likelihood function can be considered as the inverse of the statistical loss function. We can thus rewrite the whole axiom with the likelihood notation and parametric uncertainty. The independence axiom can be interpreted in the following way:

Ex-ante there is a probability α to draw experiment *f* (a sample in the frequency interpretation) and $(1-\alpha)$ to draw *h*. This is preferred to the mixed experiment with *g*. Assume that an experiment has been drawn. The Weak Conditionality Principle implies that the DM should not care (for parametric inference) about what could have happened had another experiment (sample) occurred. Hence, if experiment *f* is preferred to experiment *g,* then the DM should not change his preference if those experiments are potentially mixed with another experiment (ex-ante). This implies that the decision maker should not care about how the datasets have been generated. However, since the weak conditionality principle is conceptually the same thing as the independence axiom, violations of the latter imply violations of weak conditionality. Actually, it could be argued that a new random sample could bring more value in combination with one of the observed samples. Here, we will not develop that issue, but point out that this kind of behavior can lead to non-linear probability weighting. We thus discuss parametric inference within such a framework.

ROBUST BAYESIAN POSTERIOR AND ESTIMATION OF THE FORECASTING FUNCTION

From our developments we conclude that the posterior $\pi(\theta / data)$ is calculated using the likelihood function. By acceptance of the Weak Conditionality Principle a realized likelihood function is used to infer θ, without regard of the fact that another value of the likelihood may have been obtained. Nevertheless, according to experimental evidence DM's do not reason that way. We thus advocate a methodology that is consistent with violations of Weak Conditionality and

advocated behavior in terms of robustness. This technique can then be used to infer "robust" parameters. The technique is based on the information theoretic concept of entropy.

Now, we consider a DM that faces an observed likelihood function but knows that he could have drawn another sample and hence another value for the likelihood function. As argued, a rigorous way to choose robust decision rules, given partial information, is to maximize entropy under the constraint of partial information (Jaynes, 1982). We apply this method adapted to our situation, but the general developments are given in appendix A3. We can now prove the following proposition:

Proposition *A DM maximizing uncertainty, given an observed sample cumulative probability to get a certain θ, reasons with a non-additive prior on Θ. Moreover, the latter has the same functional form as the density consistent with the inverse s-shaped probability weighting function.*

Proof : The general problem of a DM maximizing uncertainty subject to constraints given by the sample is :

$$En(\pi) = -\int \pi(\theta / data) \log\left(\frac{\pi(\theta / data}{\pi_0(\theta)}\right) d\theta \tag{31}$$

s.t.

$$E^{\pi}\left[g_k(\theta)\right] = \int_{\Theta} g_k(\theta)\pi(\theta / data)d\theta = \mu_k \quad k = 1,...,m \tag{32}$$

where $g_k(\theta)$ are functions of the parameters and π_0 is a non-informative prior. The solution (see Berger, 1985) is given by

$$\pi^*(\theta / data) = \frac{\pi_0(\theta)\exp\left[\sum_{k=1}^{m}\lambda_k g_k(\theta)\right]}{\int_{\Theta}\pi_0(\theta)\exp\left[\sum_{k=1}^{m}\lambda_k g_k(\theta)\right]d\theta} \tag{33}$$

Now let's consider the following constraint $g_k(\theta) = \left(-\log cdfn\left(l\left(\theta / data\right)\right)\right)^{\alpha}$ which is a function of θ for a fixed data set, hence $l(\theta)$ is the likelihood function. Thus, $g_k(\theta) = \left(-\log cdfn(l(\theta))\right)^{\alpha}$
Notice the relationship of the function with the content of information. In fact, if you rewrite it in the following way :

$$g_k(\theta) = \left(\log\frac{1}{cdfn(l(\theta))}\right)^{\alpha} \tag{34}$$

it is a measure of information content of the distribution with respect to certainty. Now if the DM maximizes the above mentioned program under this constraint, we get the following:

$$\pi^*(\theta / X) = \frac{\pi_{0(\theta)}\exp\left[\lambda_1\left(-\log cdfn(l(\theta))\right)^{\alpha}\right]}{\int_{\Theta}\pi_{0(\theta)}\exp\left[\lambda_1\left(-\log cdfn(l(\theta))\right)^{\alpha}\right]d\theta} \tag{35}$$

Considering a value for the denominator δ (after having integrated), we recover the density in appendix A2 (equation 27), with λ_1=-1 and

$$\pi_0(\theta) = \alpha\frac{l(\theta)}{cdfn(l(\theta))}(-\log(cdfn(l(\theta))))^{\alpha-1}d\theta \tag{36}$$

The robust posterior is the following

$$\pi^*(\theta / X) \propto \alpha \frac{l(\theta)}{cdfn(l(\theta))} \left(-\log\left(cdfn\left(l(\theta)\right)\right)\right)^{\alpha-1} \exp\left(-\left(-\log\left(cdfn\left(l(\theta)\right)\right)\right)^{\alpha}\right) d\theta \quad (37)$$

and the parameter can be estimated in the following way :

$$\theta^* = \arg\max_{\theta \in \Theta} \pi^*(\theta / X) \quad (38)$$

This is consistent with our interpretation in terms of parametric uncertainty. Parametric uncertainty is taken into account in the estimation process.

CONCLUSION

Most of the academic literature in economics and finance has focused on approaches where decision makers maximize a utility function given a worst-case distribution. This implies that the probability weighting function is concave which inconsistent with experimental evidence. Inverse S-shaped probability weighting approaches, however, have been rarely applied in Economics as they are difficult to implement. We develop a tractable approach based on entropy, which could potentially explain the Inverse S-shaped probability weighting as being rational, a topic to be developed in future research.

APPENDICES

A1 :

The appendix collects axioms from (Prelec, 1998). They consist in an axiomatization of the sign- and rank-dependent representation. Let $\geq$ represent a preference relation on the set Π of probability distributions *P,Q,…* on $X = [x^-, x^+]$, with $x^- < 0 < x^+$. The following five axioms are assumed to hold on Π without restriction:

A1. Weak Order: $\geq$ is complete and transitive.
A2. Strict Stochastic Dominance: $P > Q$ if $Q \neq P$ and P stochastically dominates Q.
A3. Certainty Equivalent Condition : $\forall P, \exists x$ *s.t.* $(x) \sim P$.
A4. Continuity in Probabilities: If $(y, p) > (x)$, $0 < p < 1$, then there exists q, r s.t. $q < p < r$, $(y, q) > (x)$, and $(y, r) > (x)$. If $(y, p) < (x)$, $0 < p < 1$, then there exists q, r s.t. $q < p < r$, $(y, q) < (x)$ and $(y, r) < (x)$.
Let's define $S(k, n)$, $0 \leq k \leq n$, as the set of all k non-positive and (n,k) nonnegative rank-ordered n-tuples from X, $S(k, n) = \{(x_1,\ldots, x_n) \in X : x_1 \leq \ldots \leq x_k \leq 0 \leq x_{k+1} \leq \ldots$
A5. Simple-Continuity: For any probability vector $(p_1,\ldots, p_n)$ the preference relation induced on each S(k,n) is continuous.
Let $(x_i, p_i ; x_{-i}, p_{-i})$ denote a prospect with outcome x of rank "i" singled out, and let $\Pi(k, n, p)$ denote the set of all sign- and rank-order compatible prospects that have a p-chance of yielding a negative outcome :
$\Pi(k, n, p) = \{(x_1, p_1,\ldots, x_n, p_n) : (x_1,\ldots, x_n) \in S(k, n)$ and : $p_1 + \ldots + p_k = p\}$
A6. Tradeoff Consistency: There do not exist eight prospects, $(x, p_i; a_{-I}, p_{-i})$, $(x, p_i; b_{-I}, p_{-I})$ $(x_0, p_i)(y, q_j ; d_{-j}, q_{-j})$, such that the first four and the second four belong to the same sign- and rank-order compatible set, and that :
$(x, p_i; a_{-i}, p_{-i}) \geq (y, p_i; a_{-I}, p_{-i})$,
$(x', p_i; a_{-i}, p_{-i}) \leq (y', p_i; b_{-i}, p_{-i})$

$(x', q_j ; c_{-j} , q_{-j}) \geq (y', q_j ; d_{-j} , q_{-j})$
$(x, q_j ; c_{-j} , q_{-j}) \leq (y, q_{-j} ; d_{-j} , q_{-j})$
If A1 to A6 are satisfied, then the preference relationship can be represented by the following functional :

$$V(P) = \sum_{i=1}^{k}\left(v^{-}\left(\sum_{j=1}^{i} p_j \right) - v^{-}\left(\sum_{j=1}^{i-1} p_j \right)\right)u(x_j) + \sum_{i=k+1}^{n}\left(v^{+}\left(\sum_{j=1}^{n} p_j \right) - v^{-}\left(\sum_{j=i+1}^{n} p_j \right)\right)u(x_j) \qquad (31)$$

A2 :

Let's consider the following weighting function $v = \exp(-(-\ln p)^{\alpha})$. If we denote $cdfn(l(\theta))$ the cumulative distribution function v takes the following form
$v = \exp(-(-\ln(cdfn(l(\theta))))^{\alpha})$. We assume that v as well as $cdfn(l(\theta))$ are C^1. Differentiating v leads to

$$dv = \alpha \frac{l(\theta)}{cdfn(l(\theta))}\left(-\log\left(cdfn\left(l(\theta)\right)\right)\right)^{\alpha-1}\exp\left(-\left(-\log\left(cdfn\left(l(\theta)\right)\right)\right)^{\alpha}\right)d\theta \qquad (32)$$

where $l(\theta)$ denotes the likelihood.

A3:

We review the developments of the different Jaynes papers collected in Jaynes Papers on Probability, Statistics and Statistical Physics. First we develop the conceptually simpler discrete case. We then discuss the continuous case. Consider a quantity x that can take n different values ($x_1, x_2, \ldots, x_n$) and functions $f_1(x)$, $\ldots, f_m(x)$ where $m < n$. The idea of maximum entropy is to find a probability assignment $p(x_i) = p_i$ that maximizes uncertainty given a few functional contraints from the data. As we will see later, another interpretation (in terms of frequency) is that the maximum entropy distribution is that frequency distribution which can be realized in the greatest number of ways and hence is the most likely to occur.
More formally the maximum entropy formalism is the following:

$$\begin{aligned} & Max \ -\sum_{i=1}^{n} p_i \log p_i \\ & p_i \geq 0 \\ & \sum_{i=1}^{n} p_i f_k(x_i) = \mu_k \\ & \sum_{i=1}^{n} p_i = 1 \end{aligned} \qquad (34)$$

The solution is

$$p_i = \frac{1}{Z(\lambda_1,\ldots,\lambda_m)}\exp\left[-\lambda_1 f_1(x_i) - \ldots - \lambda_m f_m(x_i)\right] \qquad (35)$$

with the partition function :

$$Z(.) \equiv \sum_{i=1}^{n}\exp\left\{-\lambda_1 f_1(x_i) - \ldots - \lambda_m f_m(x_i)\right\} \qquad (36)$$

The Lagrange multipliers are determined from

$$\mu_k = -\frac{\partial \log Z(.)}{\partial \lambda_k} \quad k = 1,...,m \tag{37}$$

The above density is the "maximum non-commital" distribution given the sample information. Jaynes suggests the application of this method to form prior probabilities in a least ad hoc way. Notice that the above probabilities are not defined as frequencies, but are subjective "maximum non-commital" probabilities. Now, Jaynes also discusses the frequency case. Consider the above random experiment that is repeated *N* times, the result x_i will be obtained m_i times, $i = 1, 2, \ldots, n$. The probability (frequency) p_i is now given by m_i/N and m_i is not uniquely determined. Now we can ask, what is the "best" estimate? Well, in *N* repetitions of the random experiment, there are a priori n^N conceivable results. For observed m_i's, out of the original n^N, how many would lead to a given set of observed m_i's ? The answer is given by the multinomial coefficient :

$$W = \frac{N!}{m_1!.\bullet.m_n!} = \frac{N!}{(Np_1)!.\bullet.(Np_n)!} \tag{38}$$

Hence the set of p_i's that can be realized in the greatest number of ways is the one which maximizes *W* subject to the above mentioned constraints. Now, in the limit, we get, by the Stirling formula,

$$\lim_{N\to\infty} \frac{1}{N} \log W = \lim_{N\to\infty} \frac{1}{N} \log \left[\frac{N!}{(Ng_1)!.\bullet.(Ng_n)!} \right] = -\sum_{i=1}^{n} p_i \log p_i \tag{39}$$

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DECISION SCIENCES INSTITUTE
An operational approach to select CEU Portfolios

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ABSTRACT

Standard portfolio theory presumes that mean-variance optimization is a good approximation for expected utility maximization. Experimental evidence, however, points out that individuals transform probabilities in a non-linear way. This probability weighting behaviour can be viewed as an alternative way to treat risk or uncertainty aversion. The literature has not yet come up with an operational approach to select portfolios for such Choquet Expected Utility (CEU) maximizers. The paper develops a defence of the CEU approach in Finance and then develops an econometric methodology based on the method of moments to select portfolios.

KEYWORDS:: Choquet Expected Utility, Portfolio Selection, Decision Theory.

JEL classification: G11, D81, C11.

INTRODUCTION

Standard portfolio theory presumes that investors maximize Mean-Variance (Markowitz, 1989). Mean-Variance is supposed to be a good approximation of more general expected utility functions. In a recent paper, (Markowitz, 2014) makes the case for Mean-Variance optimization by discussing necessary and sufficient conditions for Mean-Variance approximations. He shows that Mean-Variance is a good approximation for most Expected Utility functions and distributions. Empirical evidence, however, largely documented in (Wakker, 2010), indicates that decision makers are not behaving like expected utility maximizers but transform probabilities. Violations of Expected Utility are well-known in the academic literature, notably violations of the sure thing principle in the Savage framework and violations of the independence axiom in the Von Neumann Morgenstern framework. For an overview of this decision theoretic literature (Gilboa, 2009). Over the last two decades and especially after Kahneman and Tversky's Cumulative Prospect Theory, a huge literature that deals with empirical modelling of probability transformations has been developed. The inverse S-shaped transformations implemented by decision makers are well documented in (Wakker, 2010). (Prelec, 1998) provides an axiomatization and potential parametrizations of the probability weighting model. However, as we will see the axiomatization and parametrization of probability weighting functions (PWF) renders non-expected utility models much more tractable and it is this fact that we exploit.

Strangely the literature on operational portfolio theory as well as professional practice doesn't seem to have developed tools to select portfolios for decision makers maximizing utility with respect to a non-additive probability measure, called a Choquet capacity (Denneberg, 1994). There exists a broad literature, called Behavioural Finance, applying such approaches to financial markets in order to describe so-called financial anomalies (Benartzi & Thaler2003). (Shefrin & Statman, 2000) have also develop a framework called Behavioral Portfolio Theory, but it is not very operational. One of the reasons is probably that non-additive probabilities are viewed as

irrational by many economists trained in the Expected Utility framework. One of the arguments is that a Dutch book could be made against such a decision maker. As (Diecidue & Wakker, 2002) have shown, however, a Dutch book can be made against Mean-Variance maximizers as well. Moreover, as (Wakker, 2010) and more recently (Wakker, 2017) argue, the non-additivity of the weighting function might be used to characterize risk aversion of decision makers.

The finance industry as well doesn't seem to be very consistent in its applications of portfolio theory. Indeed, for operational reasons and due to the portfolio delegation problem stemming from asymmetry of information problems, the industry largely uses benchmarks with respect to which they measure and constrain fund performance. It implies that fund managers' deviations with respect to the benchmark are constrained by what is called a tracking error constraint. However, as shown by (Roll, 1992) such portfolios are generally inefficient. Second, as argued by (Chow, 1995) this renders the utility function de facto state dependent. Third, (Admati & Pfleiderer, 1997) have shown that the tracking error as a control device cannot be supported as an equilibrium by an expected utility function.

This paper aims at analysing those questions and providing a framework to operationally select portfolios for Choquet Expected Utility (CEU) maximizers. We combine experimental approaches in decision making and formulate the CEU maximizers optimization in econometric terms, namely as a method of moments estimation. The first step consists in estimating the preference function by suggesting lotteries to individuals. Their choices will reveal their preference function. Given a multivariate process of asset returns, the individual would then optimize his portfolio by deriving the function with respect to the portfolio weights. This leads to a system of N (the number of assets) optimality relations, namely that the expectation of the derivative of the preference function equals 0. Assuming returns are multivariate i.i.d. the expectation of the function can be estimated by the sample counterpart, and we can use a method of moments method to estimate the portfolio weights.

Section 2 presents the static portfolio selection problem. In Section 3 we describe the tracking error variance approach used in practice. Section 4 presents the main argument and counterargument against non-expected utility models, namely the possibility to construct Dutch books. Section 5 discusses the Rank Dependent Utility (RDU) model. Observed behaviour is described in section 6. In Section 7, we explain how to estimate the preference function. Section 8 derives the optimality conditions of the Decision Maker (DM). Finally, section 9 shows how to estimate the portfolio weights.

THE STATIC PORTFOLIO SELECTION PROBLEM

This section explains the general portfolio selection approach independently of any mean-variance approximation and aims at preparing the general approach for any CEU decision maker analyzed later. Consider a set of n securities, where the one period return of security *j* is denoted by R_j. Any linear combination of these securities that has positive market value is called a *portfolio*. Economic rationality presumes that any individual's aim is to choose a portfolio in such a way that it maximizes his satisfaction, represented by a utility function. The theory imposes some structure on the preferences, namely that the individual maximizes a Von-Neuman Morgenstern expected utility function that is defined on end of period wealth. Beliefs are thus disentangled from the preference functional and such an individual is said to be *probabilistically sophisticated (* Machina & Schmeidler, 1992). The only relevant information is the subjective distribution of returns (assuming that the individual knows his preferences, which is implied by completion). Moreover, it is assumed that there exists a *riskless security* whose future return is known with certainty. The following assumptions are made about the *Capital Market Structure* (CMS) :

A1 : *Frictionless markets*, meaning that there are no transaction costs and that all securities are perfectly divisible.
A2 : The individual is *price taker,* the distribution of returns is given.
A3 : Absence of *arbitrage possibilities.* Implies that the riskless assets have the same rate of return.
A4 : *No Institutional restrictions :* The borrowing and lending rate are the same, there are no short sales restrictions.

Given the CMS and the behavioral assumptions, the portfolio selection problem can be modelled in the following way :

$$\max_{\{\theta_1,\ldots,\theta_n\}} E\left\{U\left[\left(\sum_{j=1}^{n}\theta_j\left[R_j - R\right]+R\right)W_o\right]\right\} \; subject \; to \; \sum_{j=1}^{n}\theta_j = 1 \tag{1}$$

where W_0 and *E* denote initial wealth and the expectation operator of the subjective joint probability distribution. *R* is the riskless rate. The solution to the F.O.C. are then given by :

$$\theta_j \quad s.t. \quad E\left\{U'\left[\left(\sum_{j=1}^{n}\theta_j\left[R_j - R\right]+R\right)W_o\right]\left(R_j - R\right)\right\} = 0 \tag{2}$$

Since the individual maximizes end of period wealth under the constraint that this wealth remains positive, there is another implicit constraint, namely that

$$\sum_{j=1}^{n}\theta_j\left[R_j - R\right]+R \geq 0 \tag{3}$$

at optimal θ_j with *subjective probability* one.

A feasible portfolio is said *efficient* if it respects (2) for an increasing concave function *U*. There are more effcient portfolios and each individual chooses the one that fits his preferences most. The problem is thus to choose an efficient portfolio given individuals preferences.
It has been suggested that the expected utility functional can be approximated by a linear combination of the mean and the variance of returns. Standard portfolio theory is thus based on Mean-Variance (M-V) analysis, meaning that one maximizes the return given a constraint on the variance. Since the problem is dual, one can alternatively minimize the variance under the constraint of a given expected return. This leads to a set of effcient portfolios. However, the investors' problem is to maximize his expected utility (in a general sense), not the return. It is generally accepted that M-V analysis leads to maximum expected utility when all distributions are normal (or when beliefs support a normal distribution) or when the utility function can be approximated by a quadratic function (Levy & Markowitz, (1979)). (Markowitz, 2014) points out that those conditions are sufficient but not necessary conditions and that for most Expected Utility functions, Mean-Variance optimizations are good approximations of Expected Utility. Actually, according to studies M-V analysis gives a good approximation of maximized expected utility (Levy & Markowitz, 1979; Kroll, Levy & Markowitz, 1984). In practice, however, asset managers do not maximize Mean-variance directly, but they compare their results to a benchmark. In order to implement this approach, a market benchmark such as the S&P500 is selected and the manager is forced to track the benchmark by constraining him to minimize the deviations with respect to the benchmark. This is called the tracking error variance (TEV) approach, the drawbacks of which are described in the next section.

DRAWBACKS OF THE TRACKING ERROR APPROACH

In practice, it is not easy to maximize the M-V utility function and practitioners try to find a benchmark (f.i. an index like the SP500) that suites best the M-V function of the customer. Investment professionals then compare their results with the benchmark. The approach based on benchmarks is also the result of a Principal-Agent application to the portfolio delegation model. The benchmark is a constraint that enables the investor to control that the manager does not deviate from objectives in terms of risk. The benchmark to be chosen depends on the aggressiveness of the portfolio, that again depends on the risk characteristics of the costumer. The manager is then told to minimize the variance of the tracking error, that is called the tracking error variance approach (TEV). Notice that the tracking error can be positive all the time, when the manager opts for active asset management.

In that case, the expected tracking error is above the benchmark. This is supposed to be a tractable way to maximize the mean-variance utility. Yet, as (Roll, 1992) has shown, if the benchmark is not an efficient portfolio, then all the portfolios using the TEV approach will be inefficient. Moreover, if the benchmark has greater mean return than the minimum variance portfolio, then the TEV portfolios have larger risks than large market porfolios. The unconstrained TEV managed portfolio thus generally has more market risk than the benchmark. (Chow, 1995) argues that customers care directly about the TEV and that such a term should be included in the utility function. He suggests the following utility function:

$$U(P) = E\big(R(P)\big) - \frac{V(P)}{rt} - \frac{TEV(P)}{tet} \tag{4}$$

where *P* denotes the portfolio, *V* the variance, *TEV* the tracking error variance, *rt* the risk tolerance, *tet* the tracking error tolerance. A customer who cares about the *TEV* can be described by the following behaviour.

A few months later he comes back to see the manager and argues that even though the return is satisfying, while the variance of the portfolio was not too high, the return could have been better since the Dow Jones performed much better. In our opinion, the fact that the individual cares about the TEV indicates that the individual's utility function is not independent of the states. In fact, in a sense the individual is disappointed. As we will see in later sections, non-expected utility has evolved towards modelling such phenomena (regret, disappointment, elation...). Hence, it is this family of functions that we will recommend. However, this kind of models has been questioned on the grounds that such individuals are subject to systematic exploitation. This argument and the counterargument are described in the next section.

BOOK MAKING AND COMONOTONICITY

De Finetti's book making principle implies that preferences should not be such that a linear combination of the latter leads to a loss. It is argued that uncertainty should then be expressed in terms of additive probabilities. The principle serves as a justification for Bayesianism, thus *perception-rationality*.
However, Dutch Books may obtain as the consequence of non-comonotonic random variables (Diecidue & Wakker, 2002) and attitudes to uncertainty (Kast & Lapied, 2003). Consider gambles f_i and g_i (acts) that are functions from the state space to the consequence space. A Dutch book, consists of a number of preferences that, when added outcome-wise, leads to a less preferred situation for each state of nature. More formally :

Definition : A Dutch book consists of a number of preferences $f^1 \geq g^1;...; f^n \geq g^n$ with

$$\sum_{j=1}^{n} \lambda^j f^j(s) < \sum_{j=1}^{n} \lambda^j g^j(s) \quad \forall s \text{ and } \lambda > 0 \tag{5}$$

Diecidue and Wakker (2002) analyze Dutch book making in a static single person decision context. They show that if there exist probabilities $p_1,..., p_n$ such that preferences maximize expected value

$$f = p_1 f(s_1) + ... + p_n(f_n), \tag{6}$$

then no Dutch book can be made.
In a sense, the individual evaluates the subjective likelihood of the states, then chooses the best act in every state and finally aggregates in a linear way. This formulation implies *probabilistic sophistication* and the independence axiom. Yet, when the gambles (acts) are comonotonic no Dutch book can be made and this is the condition for a CEU. Now, if we assume linearity in utility, we get Yaari's Choquet expected Value CEV model. Consequences are thus monetary values. Now consider the example taken from Diecidue and Wakker (2002):

$$\begin{aligned} &(9,9) \geq (20,0) \\ &(9,9) \geq (0,20) \quad but \\ &(18,18) < (20,20) \end{aligned} \tag{7}$$

The reader can verify that preferences are supported by MV. Think of the left hand side as given by the payoff of the risk-less interest rate, and the right hand side by payoff of assets that pay in one of both states. A Dutch-book can be made against such an individual. This kind of preferences are traditionally explained by expected utility with concave utility. However, since for modest gains utility is close to linear, an alternative explanation is plausible. The risky assets serve as a hedge against each other, and this leads to a non-linear sensitivity *vis-à-vis* risk.
The aforementioned authors point out that the Dutch-book effect in the example above is due to non-comonotonicity of acts. They define a comonotonic Dutch book as a Dutch book with the restriction that the set of acts is comonotonic. They show that :
If the binary relation $\geq$ is a weak order, for each gamble there exists a fair price, and no comonotonic Dutch book can be made, then there exists a capacity W (non-additive set function) such that preferences maximize CEV, where CEV is given by

$$\sum_{j=1}^{n} \pi_j f(s_j) \tag{8}$$

π_j are decision weights that depend on the capacities. (Kast & Lapied, 2003) give an interpretation of Dutch Books in terms of uncertainty aversion and the functional (concave or convex)form of the capacity. Capacities are described in the following section.

CAPACITIES AND CHOQUET EXPECTED UTILITY

As already pointed out in the introduction, individuals' behavior is not consistent with expected utility. (Kahneman & Tversky, 1979; 1992) studies show that individuals first rank outcomes and then apply a non-linear PWF. However, their model is just a subcase of the general Choquet Expected Utility (CEU) model which we summarize below. Let Ω be a finite set of states of nature. Let *X* be a set of monetary outcomes that includes the neutral outcome 0, all other elements are

interpreted as gains or losses. An uncertain prospect *f* (act) is a function from Ω into *X*. To define the cumulative functional, outcomes of each prospect are arranged in increasing order. The utility that is expected by the individual depends on the ranking of the outcomes and the function is thus called (CEU). A prospect *f* is represented as a sequence of pairs (x_i, A_i), which yields x_i if A_i occurs, where $x_i > x_j$ *iff* $i > j$, and (A_i) are the events of an algebra of Ω. Now, let's use positive subscripts to denote positive outcomes and negative subscripts to denote negative outcomes. The positive part of *f,* denoted f^+, is obtained by letting $f^+(s) = f(s)$ if $f(s) > 0$, and $f^+(s) = 0$ if $f(s) \leq 0$. As in expected utility theory, we assign to each prospect a value $V(f)$ s.t. $V(f) \geq V(g)$ *iff* $f \geq g$. Now, we call a capacity, a non-additive set function that generalizes the standard notion of probability. More exactly, a capacity v is a function that assigns to each $A \subset \Omega$ a number $v(A)$ satisfying $v(\phi) = 0$, $v(\Omega) = 1$, and $v(A) \geq v(B)$ whenever $B \subset A$. CPT asserts that there exists a strictly increasing utility function $u : X \to R$, satisfying
$u(x_0) = u(0)=0$, and capacities v^+ and v^-, such that for $f = (x_i, A_i)$, $-m \leq I < n$,

$$\begin{aligned} V(f) &= V(f^+) + V(f^-) \\ V(f^+) &= \sum_{i=0}^{n} \pi_i^+ u(x_i), \quad V(f^-) = \sum_{i=0}^{0} \pi_i^- u(x_i) \end{aligned} \tag{9}$$

where the decision weights are defined by

$$\begin{aligned} &\pi_n^+ = v^+(A_n), \quad \pi_{-m}^- = v^-(A_{-m}), \\ &\pi_i^+ = v^+(A_i \cup \ldots \cup A_n) - v^+(A_{i+1} \cup \ldots \cup A_n), \qquad 0 \leq i \leq n-1 \\ &\pi_i^- = v^-(A_{-m} \cup \ldots \cup A_i) - v^-(A_{-m} \cup \ldots \cup A_{i-1}), \qquad 1-m \leq i \leq 0. \end{aligned} \tag{10}$$

Letting $\pi_i = \pi_i^+$ *if* $i \geq 0$ and $\pi_i = \pi_i^-$ *if* $i < 0$, $V(f)$ reduces to:

$$V(f) = \sum_{i=-m}^{n} \pi_i u(x_i) \tag{11}$$

The decision weight associated with an outcome can be interpreted as the marginal contribution of the respective event, defined in terms of capacities (Wakker (2010)). The measure of an event thus depends on it's rank and it is a generalization of expected utility called Choquet Expected Utility (CEU). An individual maximizing *V(f)* is called a Choquet Expected Utility (CEU) maximizer. Under risk, where an objective cumulative distribution function exists, it may be interpreted as maximizing expected utility with respect to the transformed cumulative distribution function $v \circ F$ where *F* is the objective cumulative distribution function. This model is called Rank Dependent Expected Utility (RDEU). *V* is the PWF and it's shape seems to be rather robust across experiments (Tversky & Wakker, 1995; Prelec, 1998). Moreover, (Prelec, 1998) derives the functional consistent with behavioral axioms.

THE EMPIRICS OF PROBABILITY WEIGHTING

In the standard CEU model $u(x_0)$ is considered to be the minimal utility that the individual will get. He then adds the increments in utility weighted by his beliefs on the future states. $u(x_0)$ is not necessarily the minimal utility, but may be the reference point with respect to which the individual weights gains and losses. Moreover, the model may be slightly different since the capacities are different on gains and losses. Actually, CEU is a special case where the capacity for losses is the *dual* of the capacity for gains, i.e.

$$v^{-}(A) = 1 - v^{+}(\Omega - A). \tag{12}$$

(Kahneman & Tversky, 1992) also considered a special case of CPT where $v^{+}=v^{-}$. This property is based on preference conditions called *reflection*.
There are two possibilities to define risk (or uncertainty) aversion : via the curvature of the utility function or via the functional form of the capacities. It is generally accepted that risk behavior is given by the functional form of the utility function, whereas the uncertainty (or ambiguity) behavior is given by the functional form of the capacities.
Now, let's rewrite $\boldsymbol{V(f^{+})}$ in a different way :

$$V(f^{+}) = u(x_0) + \sum_{i=1}^{n}[u(x_i) - u(x_{i-1})]v\left(\cup_{j=i}^{n} A_j\right) \tag{13}$$

It has been suggested that uncertainty aversion can be analyzed with CEU model. In fact, (Schmeidler, 1989) gives the following definition of uncertainty aversion. Uncertainty aversion is equivalent to the convexity of the capacity, that is:

$$\boldsymbol{v(A \cup B) + v(A \cap B) \geq v(A) + v(B)} \tag{14}$$

for all measurable events A and B. We have additivity when the right hand side and the left hand side are equal, and the individual is then uncertainty neutral. Now, experimental evidence (Tversky & Wakker, 1995; Prelec 1998) shows that the capacity *v* is sub-additive meaning that there exist events *E* and E' s.t.

$$\boldsymbol{v(B) + v(A) \geq v(A \cup B) \quad whenever \quad v(A \cup B) \leq v(\Omega - E)} \tag{15}$$

And

$$\boldsymbol{1 - v(\Omega - B) \geq v(A \cup B) - v(A) \quad whenever \quad v(A) \geq v(E')} \tag{16}$$

The first condition is called lower sub-additivity whereas the second is called upper subadditivity. The certainty effect is characterized by upper sub-additivity, since the increase of a high probability to certainty has more effect than the same increase in probability for a medium probability. This kind of behavior has also been documented under risk.
Empirical evidence (Prelec, 1998; Wu & Gonzalez, 1996) suggests that the probability weighting function has the following properties :
asymmetric - $v(p) = p$ approximately at $p = 1/3$, where p is the probability to get at least a certain amount.
Inverse s-shaped - concave on an initial interval and convex beyond. The cumulative capacity is typically above the probability till p=1/3 and below after.
reflective - assigns the same weight to a given loss-probability as to a given gain-probability.
If the preference relation satisfies a certain number of axioms, the preference relation can be represented by a sign- and rank-dependent utility function (Wakker, 2017). (Prelec, 1998) provides a set of axioms needed to deduce a functional form of the weighting function that respects the stylized facts. The most general specification for this weighting function is given by the following form :

$$\boldsymbol{v(p) = \gamma \exp\left(-\beta(-\ln p)^{\alpha}\right)} \tag{17}$$

However, if the preference relationship satisfies certain axioms, notably diagonal concavity, sub-proportionality and compound invariance (Prelec, 1998), then the specification takes the following less complex form:

$$v(p) = exp\left(-\left(-\ln p\right)^{\alpha}\right) \tag{18}$$

where α indicates the degree of non-linearity of the function. One typically observes risk-seeking for small-probability gains and large-probability losses, and risk-aversion for small-probability losses and large-probability gains. A linear value function would be sufficient to explain observed behavior. However, if the value function is not linear, then the probability non-linearity must dominate the value non-linearity to explain empirical patterns. Such a dominance arises when the above probability weighting function is combined with a power function of the following form:

$$v(x) = x^{\sigma^+} \;\; if \;\; x \geq 0 \;,\; -(-x)^{\sigma^-} \;\; if \;\; x < 0 \tag{19}$$

Concerning the weighting function, the values of the parameters of *v* can be slightly different across studies, the functional form is quite robust, see (Prelec 1998). The next section explains how Prelec's probability weighting function can be estimated from customer data.

ESTIMATION OF THE PROBABILITY WEIGHTING FUNCTION AND CEU DECISION MAKING

We now briefly explain how the preference functional of customers can be estimated. The idea is to use the methodology used to test for probability weighting as a tool for estimating investor preferences. If we know the customers' preferences we are able to select their optimal portfolio strategies with the methodology developed in the following chapters.

In the previous section, we saw that the most general form of *v*(*p*) is the following:

$$v(p) = \gamma\, exp(-\beta(-\ln p)^{\alpha}) \tag{20}$$

where *p* is the cumulative distribution function. The certainty equivalent is given by *u*(*c*) ~ *u*(*prospect*). Assume that the utility function is x^{δ}. Since γ generally equals 1, this leads to the following relationship:

$$\frac{c}{x} = exp\left\{-\frac{\beta}{\delta}\left(-\ln p\right)^{\alpha}\right\} \tag{21}$$

Think of *x* as the return of a portfolio. We can then ask the value of the certainty equivalent *c* for different combinations of returns and probabilities. Formally we ask him what *c* were if the prospect were at least a given return with a given probability. Since β is generally equal to 1, we can transform the above relationship in the following way,

$$-\ln\left(-\ln\left(\frac{c}{x}\right)\right) = \ln\delta + \alpha\left(-\ln\left(-\ln p\right)\right) \tag{22}$$

If we are able to elicit the different certainty equivalents for different suggested probability distributions through questionnaires, we can generate sets of points that enable to estimate the

equation by OLS. We are thus able to recover the weighting function for the CEU model. Notice, that we are able to estimate the concavity of the utility function at the same time as the weighting function. In that sense, the utility function is consistent with the weighting function, which would not necessarily be the case if we estimated them in two steps.

We can now formulate the portfolio optimization problem of the investor the same way as in section 2, but for a Choquet Expected Utility decision maker.

$$max_{(\theta_1,\dots,\theta_n)} E^{CEU}\{U[\sum_{j=1}^{n}\theta_j R_j]\} \text{ subject to } \sum_{j=1}^{n}\theta_j = 1 \quad (23)$$

Let's denote the excess return of the portfolio as a function of portfolio weights by $R_s = f[\theta_1, \dots, \theta_n]$. We can now more formally represent the investor's decision problem in integral representation.

$$V(f[\theta_1, \dots, \theta_n]) = \int_{-\infty}^{B} u(R_s)dv^- + \int_{B}^{\infty} u(R_s)dv^+ \quad (24)$$

As pointed out by (Kahneman & Tversky, 1992), dv^- and dv^+ are approximately equivalent and this is the assumption we make from now on. The value function then simplifies to an expectation with respect to a Choquet capacity.

$$V(f[\theta_1, \dots, \theta_n]) = \int_{-\infty}^{\infty} u(R_s)dv \quad (25)$$

With the simplified parametrization, the weighting function takes the following form

$$v = exp\big(-(-lnp^{\alpha})\big). \quad (26)$$

If we denote $F(R_s)$ the cumulative distribution function, then the weighting function takes the following form

$$v = exp\left(-\left(-ln\big(F(R_S)\big)^{\alpha}\right)\right). \quad (27)$$

This function is smooth and differentiable and we can derive it to calculate the "Choquet" density

$$dv = \alpha\frac{f(R_S)}{F(R_S)}\left(-ln\big(F(R_S)\big)\right)^{\alpha-1} exp\left(-\left(-ln\big(F(R_S)\big)\right)^{\alpha}\right) \mathrm{d}R_S \quad (28)$$

Where $f(R_S)$ denotes the density of R_S.
Now we can rewrite the F.O.C. from section 2 in a slightly different way.

$$\theta_j \qquad s.t. \qquad E^{CEU}\{U'[\sum_{j=1}^{n}\theta_j R_j]R_j\} = 0 \qquad \forall_j \quad (29)$$

This is a system of n first order conditions with respect to the "Choquet" density which can be estimated using the method of moments approach explained in the next section.

ESTIMATION OF PORTFOLIO WEIGHTS

Consider a universe of investment of *n* assets. Let's assume that the excess return distribution *R* is drawn from an *i.i.d*. distribution. From the developments in section 2, we have *n* moment

restrictions. We can now use the *n* moment restrictions to estimate the *n* parameters θ_j. This method is called method of moments (MOM) and was originally advocated by Pearson. The values of the parameters are estimated by finding the parameter values that solve a system of equations formed by equating the unknown population moments with their sample counterparts. More precisely, the method replaces the expectation of a function by the sample mean of the function. The parameters are then estimated by solving the system formed by the sample moment counterparts. Since the number of restrictions is equal to the number
of parameters, the model is exactly identified. If our assumption of *i.i.d*. draws
is right, uniform convergence of the sample moments to the population moments is obtained. In fact, in that case the weak law of large numbers makes sure that the sample mean of the function $h(\theta,R_t)$ converges to the expectation in the following sense.

$$T^{-1}\sum_{t=1}^{T} h(\theta, R_t) \xrightarrow{p} E\left[h(\theta, R)\right] \tag{30}$$

For any continuous function *h* the estimated parameter

$$\theta = \arg_{\theta}\left[T^{-1}\sum h(\theta, R_t) = E\left[h(\theta, R_t)\right]\right] \xrightarrow{p} \theta_0 \tag{31}$$

converges in probability to the "true" parameter value θ_0. In our case the problem is somewhat different than in standard econometric identification problems since we are not trying to identify parameters but to find (estimate) the portfolio weights that most closely match the preferences of the investor.
In the standard problems we would have the following (Hamilton, 1994):

$$E(h) = \int_{-\infty}^{+\infty} h(\theta_o, R_t)\, f(R) dR = 0 \tag{32}$$

where $f(R)$ is the density of returns and R_t is the ($n\times1$) vector of returns at date *t*. $E\{h(\theta_0, R_t)\}$ is then replaced by the sample average :

$$g(\theta, R) = T^{-1}\sum_{t=1}^{T} h(\theta, R_t) \tag{33}$$

MOM estimators choose θ such that sample moments are as close as possible to the population moments. In our case the function $h(\theta, R_t)$ is given by

$$U'\left|\sum_{j=1}^{n} \theta_j R_j\right| R_j\,, \tag{34}$$

the marginal utility of the return of the portfolio multiplied by the excess return of asset *j* (from the last equation in the previous section). Since this condition has to hold for *j* assets we actually have a $n\times 1$ vector that has to equal a $n \times 1$ vector of zeros. Now, in order to keep notations simple, we continue to use the general function *h* instead of the marginal utility. Our problem is somewhat complicated by the fact that we have to determine the portfolio weights for a Choquet Expected Utility Maximizer. However, remember that we know the functional form of the S-shaped transformation. Moreover, it can be estimated in the way suggested by (Prelec, 1998).
If we consider the most plausible specification, we get the following Choquet expected utility as a function of the "objective" return distribution of the portfolio $F(R_s)$:

$$E^{CEU}\{h(\theta_0, R_t)\} = \int_{-\infty}^{+\infty} h(\theta_0, R_t)\alpha \frac{f(R_s)}{F(R_s)}(-\ln(F(R_s)))^{\alpha-1}\exp(-(-\ln(F(R_s)))^{\alpha})dR_s \quad (35)$$

In order to use the MOM, we have to transform the above relation to get the expectation with respect to the objective density (Aït-Sahalia & Brandt, 2001). This leads to the following expression :

$$E^{CEU}\{h(\theta_0, R_t)\} = \int_{-\infty}^{+\infty} h(\theta_0, R_t)\alpha \frac{1}{F(R_s)}(-\ln(F(R_s)))^{\alpha-1}\exp(-(-\ln(F(R_s)))^{\alpha}) f(R_s)dR_s \quad (36)$$

We can use the following sample moments :

$$g(\theta, R) = T^{-1}\sum_{t=1}^{T} h(\theta_0, R_t)\alpha \frac{1}{F(R_s)}(-\ln(F(R_s)))^{\alpha-1}\exp(-(-\ln(F(R_s)))^{\alpha}) \quad (37)$$

and minimize the same expression as above. If we normalize $\sum\theta = 1$, then we get the portfolio weights. However, since the DM transforms the return distribution of the portfolio, which depends on the weights we are estimating, we don't know the distribution of the portfolio R_S at once.
We hence have to use the following algorithm. Start with a vector of θ'*s* , deduce the portfolio return distribution and check whether the system is solved. We are looking for a fixed point and the problem can be solved by deriving the portfolio returns for different grids in the parameter space and the one that (almost) solves the system.

CONCLUSION

Standard portfolio theory is based on mean-variance approximations of expected utility functions. For most expected utility functions, this approach seems to be a satisfactory approximation. Most individuals, however, exhibit behavior that deviates from expected utility by transforming probability distributions. Such behavior might characterize a different way to treat risk aversion and leads to so-called Choquet Expected Utility. Portfolio choice with such a behavior has only be tentatively addressed and not in an operational way. This paper addresses the issue in developing a consistent framework to select optimal portfolios for CEU maximizers and argues why mean-variance shares the same methodological drawbacks as non-EU models. This paper focused on the theoretical optimization procedures and a companion paper will focus on the practical implementation steps. Those implementation steps consist in calibration of utility and weighting functions and selection of weights that respect the first order moment conditions. The problem is slightly more complicated than for the standard method of moments approach as the portfolio return distribution that is used to estimate the moments is not known at the beginning. An algorithmic procedure that converges to a fixed point between the moment conditions and the portfolio weights thus has to be developed.

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Analysis of Throughput Time on Quality Variability Amplification

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ABSTRACT

This paper is motivated by our observation that research on quality variability amplification across a supply chain has received limited attention. A time series model is developed to identify the influence of throughput time on the quality variability and its expected loss in a supply chain.

KEYWORDS: Quality variability; Throughput time; Supply chain management

INTRODUCTION

A considerable body of literature related to the bullwhip effect emerges with the majority focusing on quantifying the demand-order process through different types of supply chains (Agrawal et al., 2009). However, such variability amplification is not unique to demand-order management. Quality changes in a supply chain exhibit similar behavior. The variance in quality increases as materials move downstream from the supplier through successive stages of the supply chain. The objective of this paper is to conduct the numerical analysis to demonstrate the influence of throughput time on quality variability amplification.

NUMERICAL ANALYSIS

Consider a two-echelon supply chain with a manufacturer and a supplier. Assume the manufacturer receives its raw materials at time period *t*. Let d_{t+i} denote the defective rate of a batch at the manufacturing stage *i*, *i* = 1…T, where T represents the manufacturing throughput time. Let ρ be a correlation coefficient between d_{t+i-1} and d_{t+i} at two successive stages $t + i - 1$ and $t + i$, and we have $0 \le \rho < 1$. Assume that the inventory defective rate is a fixed constant, denoted by *w*. Based on the theoretical model proposed by Li and White (2008), the ratio of variance between output defective rate, *D*, and material defective rate, *d*, is expressed as

$$\frac{Var(D)}{Var(d)} \geq 1+\left(1-\frac{w(T+1)}{2T}\right)^2\left(T+2\sum_{i=1}^{T-1}(T-i)\rho^i\right)+2\left(1-\frac{w(T+1)}{2T}\right)\frac{\rho^2\left(1+\rho^{T-1}\right)}{2}.$$

To gain a better understanding of how some parameters affect the quality variance fluctuation in a supply chain, numerical analyses are conducted for w = 0.05% with different ρ and T values.

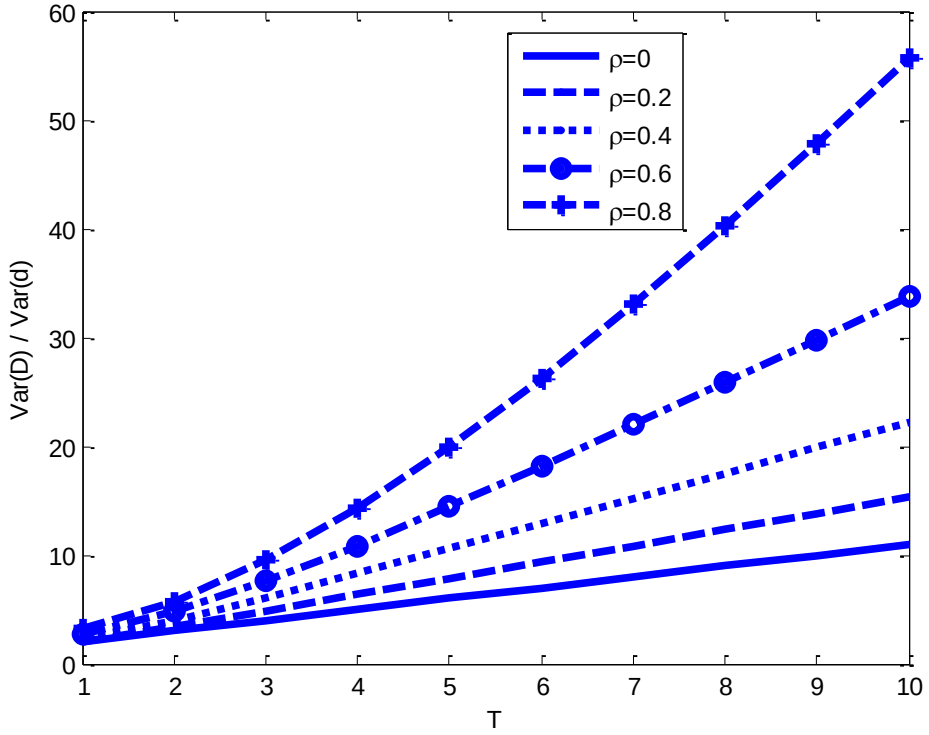

Figure 1 $\frac{Var(D)}{Var(d)}$ vs. T and ρ with w = 0.05%

Several observations can be made in Fig.1. Firstly, for any given values of ρ and w, $\frac{Var(D)}{Var(d)}$ is an increasing function of T. Secondly, for any given values of T and w, $\frac{Var(D)}{Var(d)}$ is also an increasing function of ρ. in a special case with ρ = 0, we have $\frac{Var(D)}{Var(d)} \geq 1+T\left(1-\frac{w(T+1)}{2T}\right)^2$. It suggests that, even when the physical operation activities are independent at two successive manufacturing stages, the variance in the output defective rate is still amplified compared to the variance in the raw material defective rate.

DISCUSSION AND CONCLUSION

Some limitations and future research directions should be mentioned here. First of all, in this paper, we primarily focus on the effect of throughput time on quality variability in a supply chain

for manufactured products whose value will not increase with time. Therefore, products such as wine or cheese which are expected to have higher quality as they age are excluded from this model. Secondly, the present paper may be extended to a more general setting where the manufacturer purchases the same raw material or component from multiple suppliers.

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DECISION SCIENCES INSTITUTE
Analytics, evidence, and the quest for rational decision making

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ABSTRACT

Evidence-based decision making seems both desirable and inherently rational. New analytical tools for investigating “big data” promise to provide additional evidence. Concurrently, technological advances for improving decision making reopen issues of epistemology and ontology related to fact and belief. Decision support has aimed to enhance effectiveness of human decision-making processes, foster rational thinking, and avoid biases and errors. Cognitive neuroscience research highlights issues of implicit cognition, physiological and naturalistic processes, and social cues as elements of human thought. Now decision support builders and data scientists must consider epistemological issues, social factors, and technical capabilities when developing cognitive and decision support.

KEYWORDS: Decision Support Systems, Analytics, Collaborative Decision Models, Decision Support, and Cognition and Reasoning

INTRODUCTION

Large data volumes, high data variety, and increasing data velocity have raised hopes for making better informed decisions that use evidence and facts. The flood of data and evidence-based decision making using analytics also raises some concerns for some people. For example, in late 2017, *The Washington Post* reported that “Trump administration” officials had “forbidden” the phrases “evidence-based” and "science-based” in Centers for Disease Control and Prevention (CDC) official budget documents (Sun & Eilperin, 2017). This prohibition was quickly attributed to the current administration’s penchant for “declining to acknowledge scientific findings” (Anapol, 2017). The actual story seems less sensational: career officials worried that these trigger words might draw Republican opposition (Engber, 2017; Levin, 2017). But, the point remains that professional policy communicators acknowledged that evidence-based decision making is not valued in all situations by all audiences.

For many professionals, the descriptor, evidence-based, presumes a noble goal to make decisions based solely on the “facts and information” when determining whether “a belief or proposition is correct, true or valid” (Power, 2018). The term evidence-based decision making

(EBDM) is most often associated with decision-making in education, law, medicine, and science. EBDM has also been promoted for management decision making (Pfeffer & Sutton, 2006). The synonyms for EBDM most used in the business world emphasize a presumption of objective truth: fact-based, data-driven, data-based. The concept of EBDM equates evidence with objectively verifiable truth that is independent of a decision-making process, and hence the process cannot alter or change the evidence.

Management thinkers seem to have embraced analytics and data science, convinced of the value of evidence-based decision making. Many people are surprised that any rational person could question the value of evidence and facts. News reports that link objections to evidence based decision to Republican political strategy (Mooney, 2005) or religious fundamentalism (Pigliucci, 2005) seem reasonable to many as well. This argument over the value, nature and possibility of objective "Truth" is not new and is the subject of several thousand years of Western philosophy. For philosophers, theoretical physicists, and cognitive scientists, the relationships among decision-making, rational thought, evidence and objective reality remain open questions that have been newly energized by advances in computing technology, digitization, and global communication networks.

Ontology, the study of the nature of being, becoming, existence, or reality, might seem unrelated to the concerns of information technology and decision sciences, but business analysts, data scientists, and decision support builders necessarily make assumptions about the characteristics, behaviors and attitudes of those who will use the analyses, systems, outputs and results. Emerging computational techniques appropriate for "big data" exacerbate these concerns in newly unavoidable ways. The big data discussion currently ranges across academic, legal, business, and political venues around fundamental issues of epistemology, technology, methodology, cognition, and aesthetics (Ekbia et al., 2014; Kitchin, 2014). Epistemology investigates what distinguishes justified belief from opinion. Some critics predict these analytical tools will lead to the destruction of clear thinking, reasoned discourse, and moral behavior (Boyd & Crawford, 2012; Ekbia et al., 2014; Gregg, 2015). Decision Support Systems (DSS) are not isolated from the epistemological issues inherent in the decision method and tools used, and DSS builders might offer assistance in an era in which critical thinking has become more valued than data (Mayer-Schönberger & Cukier, 2013).

Management theorists might have embraced an ideal of evidence-based reasoning, but the range of fundamental issues involved in effective implementation of the ideal calls for some attention. Effective decision support must acknowledge biases, preferences, and capabilities of users involved in decision making, as well as the DSS builder's own assumptions about the value of the data and evidence. This article identifies epistemological, cognitive, and social issues involved in designing effective decision support and in applying business analytics. Data Scientists and DSS builders cannot look only at technical delivery of data (big or otherwise) or at facilitation of a decision process. The issues raised by philosophers and cognitive psychologists are important in understanding how people can be supported in decision making most effectively in any given situation.

The next section reviews issues and positions surrounding data, rational argument, and human decision making processes. From that foundation, the following section reviews the implications for effective business analytics technologies that might account for the complex, social nature of decision making, as well as the multifaceted nature of evidence that is an integral part of effective decision making.

EVIDENCE-BASED DECISION MAKING CONTROVERSY

Decision Scientists and DSS builders recognize the value of understanding the biases and limitations of decision makers, which often represent the problems a system attempts to solve. Equally important, however, DSS builders must understand their own assumptions and preferences about alternative decision-making methods or the value of various types of evidence.

Proponents of evidenced-based decision making generally use the term *evidence* to mean facts and information that prove or substantiate an assertion or a conclusion, which may then be used in a comprehensive, systematic and thoughtful decision-making process. The process uncovers and gathers together evidence to inform a reasoned choice among relevant alternatives. Within such a decision process, evidence provides the reasons for concluding that something is true or false. Evidence is not always complete or conclusive, so evidence may be supplemented by reasonable assumptions.

In contrast to judicial settings, where statute and case law define formal rules of evidence, business decision-making processes rarely include an evaluation of forms of proof. Controversies can arise over the validity of evidence because people often disagree about the reliability, value, or relevance of specific data or forms of data. Arguments about evidence are exacerbated by misunderstandings over terminology as well as procedural disagreements.

In a business setting, the term evidence is often used interchangeably with facts or data, which neglects the important process by which observers perceive, interpret, and assign meaning to their observations (Gitelman, 2013). In most cases, decision-makers act as both observers of data and judges of its meaning, value, and relevance, leading to potential disagreement on all three points. Only when all participants in the process agree that a point of fact has been rightly interpreted and holds some relevance for the decision issues at hand can it be rightly considered *evidence*.

Additional disagreements and misunderstandings arise when participants differ in their assumptions about how the decision-making process ought to work. In specialized contexts, rules of law or parliamentary procedure govern the decision process, but otherwise customs and processes vary widely. Considerable research addresses the diversity of rational thinking at a cultural level (Briley, Morris, & Simonson, 2000; Cole, 1996; Cole & Scribner, 1974; R. B. Kaplan, 1976), but even within the relative homogeneity of the Western business community, individuals ignore—and even resist—accepted problem-solving methods.

John Dewey's (1910) prescription for problem solving involved six steps, problem definition, solution criteria, causal analysis, solution identification, and solution evaluation, has since been taught as the basis for critical thinking and problem solving discussions (Keith, 2007). Prescriptions for managerial problem solving reflect the familiar six steps (Young, Wood, Phillips, & Pederson, 2001), although business practitioners typically add a final step of evaluating the implementation of the chosen solution (Drucker, 1973). The model reflects the now widely accepted view of effective, rational, managerial decision making. Despite the agreement on principles, however, wide variations in decision making practice demonstrates that not everyone agrees on the functional meaning of rational thought or a rational process. Furthermore, the era of big data has renewed some seemingly intractable controversies. This

section considers the historical reasons individuals might resist formal, systematic decision making, as well as issues raised by the advances in Big Data.

Contested history of rational decision making

Business users might use the terms *rational* or *analytical* as synonyms for the methodical, evidence-based decision making advocated by John Dewey, but that model is not descriptive of how human beings actually make decisions. Herbert Simon, upon accepting his Nobel Prize in Economics (1979), acknowledged the "strikingly simple and beautiful" nature of the "classical theory of omniscient rationality" along with the penchant of economists for using it to "predict (correctly or not) human behavior without stirring out of our armchairs to observe what such behavior is like" (p. 496). Rhetoric scholar Michael Calvin McGee (1982) classified such theories of public decision making as "idealist" projects based on philosophical presumptions and preferences as to how humans ought to decide, judging them "not theory at all, but a set of technical, prescriptive principles which inform the practitioner while, paradoxically, remaining largely innocent of practice" (p. 24).

Methodical, explicit rules of deductive logic were derived by ancient Greek philosophers (Aristotle and Plato) as a remedy for public decision making contaminated by the emotional intensity of poetry and theater (Havelock, 1968; Lentz, 1989) and the political dangers of cultural relativism (Poulakos, 1995). Prevailing across four thousand years of philosophical alternatives, Western analytical thinking came to define rationality itself—at least in the minds of Western academicians, scientists, and legal theorists—and continues to be taught as the ideal thinking process. Over the past two hundred years, however, breakthrough research in multiple disciplines has demonstrated that the ancient ideal of explicit, deductive reasoning describes just one tool of human decision making—and a somewhat limited tool at that, useful only under specialized conditions.

Some trace the collapse of Western analytics to Gödel's (1931)) momentous proof of uncertainty (Kline, 1980), the discovery of the quantum (Prigogine, 1997) and computing breakthroughs that made nonlinear analysis and complexity science possible (Cilliers, 1998; Scott, 2007; Wolfram, 2002). Others point to the postmodern deconstruction of patriarchal Western political, cultural, and social structures, which maintained power by dismissing the epistemologies of other cultures and communities (Belenky, Clinchy, Goldberger, & Tarule, 1986; Foucault, 1973; Lyotard, 1979/1984; Simons, 1990). Perhaps most tellingly, advances in our understanding of tacit knowledge and implicit cognition (Reber, 1993), physiological factors in decision making (Damasio, 1994; Todo, 1980), and socially distributed knowledge (Cole, 1996; Freeman, 1995; Resnick, 1991; Weick, 1979) demonstrate the erroneous assumption that rational thinking is a well-defined individual endeavor.

Those who seriously study pragmatic decision-making processes have had to set aside the ancient assumptions. Economists were among the first to seriously consider the pragmatic implications of "post-rationality" (Arthur, 2013; Colic-Peisker & Flitney, 2017; Thaler, 2015). Meanwhile, researchers in naturalistic decision-making continue to demonstrate that implicit, non-linear cognitive processes allow people to "quickly match the situation to the patterns they have learned. If they find a clear match, they can carry out the most typical course of action" and thus make "extremely rapid decisions" (Klein, 2008, p. 457). In situations with higher time pressure, higher stakes, or increased ambiguities, experts use intuitive decision-making processes rather than structured approaches with great effectiveness (Gladwell, 2005; Klein,

1998, 2009). Similarly, management studies were quick to adapt to a growing understanding of how groups interactively think, learn, and decide (Engeström, 1992; Weick, 1993, 2000; Weick & Ashford, 2001).

Big data and the "end of rational thought"?

On technical, social, legal, and philosophical levels, big data has been lauded — and condemned — for its potential to change human society on a scale to rival the invention of the printing press (Mayer-Schönberger & Cukier, 2013). These issues are multifaceted and lie far outside the scope of this article, but recent controversies offer insights into the nature of evidence-based decision making and the quest for rationality and help illuminate the significance of technical advances for builders of decision support systems.

For some, big data represents a major advance for evidence-based decision making (LaValle, Lesser, Shockley, Hopkins, & Kruschwitz, 2011; Provost & Fawcett, 2013). Data-driven management yields performance benefits, and with big data technologies, management "can measure and therefore manage more precisely than ever before" (McAfee & Brynjolfsson, 2012, p. 4). Even those who recognize the complications of gathering accurate data and using it effectively conclude that human-kind stands at the brink of a revolution (Mayer-Schönberger & Cukier, 2013). One long-standing criticism of data-driven decision making, of course, has been the potential over-reliance or excessive dependence upon quantification and quantitative data. Two maxims capture the gist of this concern: "What gets measured gets managed," sometimes to ill effect, and, "Not all that counts can be counted." The well-known dangers of relying on financial results to the detriment of society and the environment (Elkington, 1994), the social costs of chasing economic indicators (Karabell, 2014), and the strategic importance of qualitative factors (Kaplan & Norton, 1992) suggest that bigger data might just create bigger problems. Technical advances offer promise, but the excitement over bigger data highlights known dangers of relying too heavily on data in the first place.

Meanwhile, Joel Shapiro (2017) critiques dashboard visualizations, warning that design defaults or choices can draw management attention to data that does not align with business priorities, to neglect information that does not appear, or to infer causality from visual patterns and groupings. The simplicity and elegance of big data visualization can tempt managers to bypass the crucial work of critical thinking. The implicit, intuitive and sometimes mystifying processes of visual analytics demand critical attention (Thomas & Cook, 2005). Concerns that visualization allows quick, intuitive decisions reopens ancient debates about the relationship between "data— what the world presents to us through our senses and instruments" and "knowledge of the world— how we understand and interpret what we get" (Ekbia et al., 2014, p. 1528).

Perhaps most significantly, the technical capacity to process Big Data challenges traditional assumptions of scientific thinking. Chris Anderson (2008), editor of Wired magazine, prompted a firestorm when he proclaimed Google's predictive analytics success as evidence the scientific method is obsolete. In response, critics charge that reliance on big data demolishes or destroys "instrumental reason" (Fuchs, 2017, p. 54) by replacing public discourse with decision algorithms. To be sure, a scientific method designed to maximize the value of evidence when data was difficult and expensive to collect, becomes obsolete and limiting when data are abundant, timely and dynamic (Kitchin, 2014). Yet, when "n=all", the sample size is the entire data set (Kitchin, 2013), decision making requires even more comprehensive analytical support (Driskell & Salas, 2006). Ubiquitous examples of specious uses of big data underscore the

point that critical thinking and instrumental reason are more important than ever (Mayer-Schönberger & Cukier, 2013).

Big data solves no inherent weaknesses in evidenced-based decision making. Nor does big data represent a new challenge to rationality. Rather, the sheer magnitude of available data, coupled with the human capacity for quick, implicit, visual analytics highlight the need for carefully designing decision making processes to account for these new challenges. Further, solutions involve careful attention to the complicated relationships among reality, data, perception, interpretation, knowledge, understanding, and belief.

IMPLICATIONS FOR DECISION SUPPORT

Decision support has been an ongoing effort to enhance, support, and facilitate a rational decision-making process. Working within the familiar frame of logical positivism, DSS developers exhibited an optimistic belief that "human limitations…may be overcome with information technologies and DSS" (Power, 2010). Some observers have questioned the possibility of decision augmentation and decision support. As Ekbia and Reynolds (2007) noted, "Various writers have criticized the classical rational/technical solutions commonly employed in DSS," concluding that "perceived limitations of rational models in contemporary DSS might be more a consequence of our methods or of how we have chosen to employ them" (p.497).

We might, however, describe technological decision support as the continuation of longstanding efforts to help human decision makers in their quest for rationality. The quest for better decision making began with ancient attempts to identify and promote effective methods. Aristotle's treatises on logic functioned as pedagogical tools—guides for those intent on learning the cutting edge thinking processes of the day. Subsequent philosophers, Thomas Aquinas, Francis Bacon, Rene Descartes, among many others, have offered updated advice, models, and guidelines for best practices in critical thinking, logic, rational problem-solving, or decision making. Vocabularies and method have varied over the millennia, but the goal remains the same: help individuals to avoid the pitfalls of human error, emotion, bias, laziness, or confusion to optimize their decision-making effectiveness.

DSS might be understood as a continuation of this effort, albeit with previously unimaginable technological tools to assist in the effort and potentially expanded scope with the assimilation of Big Data.

Some proponents of evidence-based decision making have embraced the promise of Big Data, but "big" does not guarantee better evidence or better evidence-based decision processes. There seems to be no doubt that data has become more abundant and computing technology more capable of analyzing it, but these factors further complicate the issues of evidence-based decision making. Perhaps the most immediate realization has been that evidence and data are not, in fact, synonyms (Hammond, 2013). The ubiquitous adoption of semi-structured and unstructured big data sources highlights the degree to which a complete, accurate understanding of decision making—not merely the idealist presumptions of classical Greek philosophers — must guide decision support efforts.

Data analysts always needed to make certain that any data utilized as evidence would be relevant to the decision question and that facts had been (or could be) verified as true. To the

extent that new data analytic tools like artificial intelligence (AI) and machine learning have begun to emulate, imitate and even surpass the black box of human cognition, these developments give rise to condemnations of Big Data as unsystematic, atheoretical, and dangerous to rational thought (Fuchs, 2017; boyd & Crawford, 2012). Technology advances are making Licklider's (1960; 2001) predicted man-computer symbiosis a real possibility, and the more data analytics are embedded within human systems, the more important an understanding of decision making becomes.

One immediate consequence of technology improvements has been a shift in the locus of decision making. When management both collected and analyzed data, the decision process could be observed as a management activity, but the distributed, fungible, and outsourced processes of advanced analytics (Mayer-Schönberger & Cukier, 2013) distributes decision making across a chain of contributors, from the business analyst charged with wrangling and visualizing the data to the company that monetizes those results by packaging them as information, to the client who buys and ultimately uses the insights. Decision support might provide value or mislead at any point.

For many corporate entities, the concern has been the capacity of an individual analyst to critically and effectively analyze the vast amounts of data that have become available. Business and data analytics require application by a person with sophisticated critical thinking capabilities (Shah, Horne, & Capella, 2012), narrative skills (Brumberger, 2015; Cyphert, 2017; Hammond, 2013; Shoztic, Bible, Nelson, & Stein, 2016) and contextual knowledge (Ernst and Young Foundation, 2015). While the era of digital data can make facts—verifiable data points—more abundant, the path between raw data and rational evidence seems to have grown more convoluted and far more problematic.

Decision scientists, management scientists, and information systems developers had not yet completed the task of predictably and effectively building computerized support systems for the limited, linear steps of logic thinking, classical argumentation, or collaborative group decision making. Now, with advanced analytic tools, virtually infinite data stores, and fast, distributed computing technology at our disposal, we can contemplate scientific advances that will likely demonstrate the vast range of what we still do not understand about human cognition. Cognitive computing is in its infancy. Firm conclusions seem well beyond the scope of this article—or any article, at this moment in time — but we offer a few possible next steps.

First, since the traditional understanding of reason and rationality might no longer represent an appropriate or exclusive goal for decision making behavior, we might redefine good decision making to focus on concrete results rather than idealistic prescriptions of how rational thinking ought or should look to an observer. Decision support designers might focus on imitating decision making processes that yield a desired result rather than presupposing that a specific process will yield effective decision making. Even within this limited scope, there are caveats. Choosing a goal necessarily involves making a decision, and a decision support builder must carefully define a specific system's scope and purpose. Further, effectiveness itself must be contextually understood.

Those who build decision support and analyze data might define their assumptions about targeted decision makers, defining their goals in terms of compiling or analyzing factual data, reconciling diverse stakeholder values, negotiating common interests, developing sustainable goals, and so on. Targeted users of decision support and analytics differ based upon the

specific system that is being built for a specific organization. Some decision support could focus on increasing traditional forms of rationality in a specific situation. Other analytics and systems might foster extended discussions around the interpretation or value of proposed forms of evidence. Some might emulate extended forms of rationality to enhance the rational options of decision makers. Analytic tools and models can be selected for the appropriateness to the type of decision or to supporting a specific element or step of a process. Analysis might uncover patterns, relationships, or correlations that can best be approached with analogy-based reasoning or another implicit reasoning tool? Data may not be relevant to every part of a decision process.

Second, decision support architects, builders and designers might build tools that facilitate broader human decision-making tasks rather than fostering a single, limited type of reasoning. Design of any DSS necessarily encompasses epistemological, social, and human as well as technical design factors. Effective business analytics technologies must account for the complex, social nature of decision making as well as the multifaceted nature of evidence. In general, we cannot and should not design technology decision augmentation and support without a thorough understanding of the broad use case, which is human decision making.

Some support systems might aim to assist just one part of the decision-making process, displaying a certain kind of data more effectively, for instance, or collecting stakeholder perspectives in a systematic way, but the more a designer understands about the overall process, the better the system can support decisions in a real context. Data Scientists and DSS builders should reinforce rational decision making as needed by the targeted user and avoid introducing errors into the analysis. Such efforts depend, however, on presumptions we make about rationality—in all its forms and uses.

Third, and finally, strides in the scientific understanding of the human decision-making process does not imply that all humans are competent decision makers. Decision support arose in response to research and theory of those who recognized systematic failures in the classical decision-making model. If anything, embracing the complexity of implicit and distributed cognitive processes simply introduces more opportunities for failure to occur. Managers, whether they are described as logical data processors, members of a sensemaking organization, or intuitive processors of implicit knowledge, are not infallible decision makers. People, groups and organizations will continue to commit errors in the decision-making process. The goal of decision support remains to help human decision makers avoid the most important biases and errors when possible and to in general minimize the probability that bias and errors of analysis, logic, and reasoning will occur in semi-structured and unstructured decision situations.

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Antecedents and Consequences of Blockchain Technology in Food Supply Chains: An Exploratory Study

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ABSTRACT

Blockchain is the new buzzword in business and speculations are rife about its impact on operations. The technology is paving way for novel innovations and challenging the traditional modus operandi. However, blockchain cannot be blindly adopted. This paper explores the antecedents and consequences of blockchain adoption in context of Food supply chains. Since the technology is in nascent stage, an exploratory approach is employed using expert interview technique including experts from blockchain solution providers and supply chains in Food sector. The results highlight the significant factors impacting the Blockchain adoption and paves way for advancement of research in the area.

KEYWORDS: Blockchain, Food Supply Chain, Antecedents, Consequences, and Expert Interview

INTRODUCTION

It is tough to escape blockchain in the current business landscape as it makes inroads in every sector. Each industry is considering the technology as potentially revolutionary. Even though the blockchain revolution started from banking and finance industry (Underwood, 2016), other industries like healthcare, energy, retail, governance, supply chain and agriculture are staring at major disruptions in their operations by blockchain application. The blockchain is a distributed ledger technology that allows all members to record transactions in a decentralised data log maintained on a network of computers, rather than a physical ledger or a single database (Tapscott & Tapscott, 2016). Transactions must be approved through consensus, and everything is secured through cryptography. The data is embedded on the network as a whole and is transparent and incorruptible.

With rising consumer consciousness towards food safety, blockchain application can play a vital role in solving many food-related problems. The global food supply chains have become increasingly complex and it has become almost impossible for food producers and retailers to guarantee the provenance of their products. The Grocery Manufacturers Association (GMA) estimated that food fraud costs the global food industry between $10 billion and $15 billion annually. As per GMA estimates, the cost of one adulteration verdict can be up to 15% of annual company revenues in terms of lost sales, not to mention the damage to organisational reputation and brand loyalty that inevitably occurs. It is becoming apparent that the current food safety and quality management systems are not designed to detect, nor sophisticated enough to prevent fraud occurring in our food (Ruth at al., 2017). Recent food fraud scandals have further increased the need to combat fraud across supply chains (Manning & Soon, 2014). Supply chain transparency is one of the most important and hardest to achieve improvement areas for logistics and SCM (Abeyratne & Monfared, 2016). Hence blockchain provides a transparent, reliable and trustworthy alternative to the current technologies.

The paper aims to explore the antecedents and consequences of adopting the blockchain technology in the context of food supply chain. Since the technology is in a nascent stage, with

a limited number of research papers and use cases available, an exploratory approach employing expert opinion technique has been adopted to unveil the significant factors that influence the adoption of this technology. The rest of the paper is structured a follows: Section 2 provides a brief literature review on the Food supply chain and the Blockchain technology, section 3 discusses the research objective followed by Section 4 and 5 that describe the research methods and results. Section 6 includes the discussion of results and managerial implications.

LITERATURE REVIEW

Blockchain is a digital and decentralized ledger that records all transactions. It is shared with all participants in the network, with each participant holding their own copy through replication. It was first introduced to a larger audience around September 2015 when nine financial companies including Goldman Sachs, Barclays, J.P. Morgan, and others joined forces to build a new blockchain based infrastructure for financial services (Underwood, 2016). The logistics and supply chain management (SCM) community later realized the impact blockchain might have on their industry.

There are three basic pillars on which the blockchain is based: a) Consensus, b) Provenance, and c) Immutability. a) One or more transactions are grouped together to form a new block. All members of the network can verify the transactions in the block. If no consensus on the validity of the new block is reached, the block is rejected. Likewise, if consensus exists that the transactions in the block are valid, the block is added to the chain. b) The transactions, once added to the ledger, cannot be deleted, modified or inserted. Hence each item can be traced back to is source providing provenance. c) A cryptographic hash is generated for each block added to the ledger. Each block not only holds transaction records but also the hash of the previous block. This creates a block interdependency linking up to a chain – the Blockchain. Altering a transaction on the blockchain retroactively would require not only to alter the local records on most of the networks members' devices but also altering the cryptographic hash of every block down the chain. This provides immutability to the ledger.

There are several benefits that the blockchain claims to provide that makes it preferable over the traditional systems. One major promise is to increase trust in the network – by providing transparency in transactions and reduce risk of tampering, fraud and cyber crime. Every member of the network has access to the same data, providing a single point of truth (Tapscott & Tapscott, 2016). The distributed digital ledger of transactions cannot be tampered with due to the use of cryptographic methods (Pilkington, 2016). It also reduces transaction cost and time. The ledger is updated on a real-time basis, thus eliminating the wait times encountered in the traditional systems. Owing to these benefits, some logistics and supply chain experts are considering Blockchain to offer "enormous potential" (O'Marah, 2017), to be a "much-needed platform for economic renewal" (Casey & Wong, 2017), and to "transform the supply chain and disrupt the way we produce, market, purchase and consume our goods" (Dickson, 2016).

The concept of blockchain can prove to be effective in addressing the issues in the Food supply chain. Food Supply Chain Management (FSCM) has been coined to denote the activities from production, distribution, and consumption in order to keep the safety and quality of various foods under efficient and effective modes (Marsden et al., 2000; Blandon et al., 2009). The differences of FSCM from other supply chains are the importance reflected by factors like food quality, safety, and freshness within limited time, which make the underlying supply chain more complex and difficult to manage (La Scalia et al., 2016). Added to this are the issues of food fraud, food adulteration, counterfeiting and food crime. Most organizations in this area, such as the Global

Food Safety Initiative (GFSI), the Grocery Manufacturers Association (GMA) in the United States (US), the US Pharmacopia (USP) and reports of the European Parliament consider food fraud as “an intentional, deceptive misrepresentation of foods for financial gain” (Spink et al., 2017). Current food safety management systems are not specifically designed for fraud control or mitigation. Due to the intentional nature of fraud, it requires an approach that differs from the common safety ploys (Spink et al., 2017). In order to tackle food fraud, the system needs to shift from the safety-based approach to the fraud prevention and vulnerability reduction approach and take into account these deliberate and disguising aspects. This is where the blockchain comes into picture.

RESEARCH OBJECTIVE

The blockchain technology is revolutionizing the way businesses are operating. The technology, though started in financial sector, is exhibiting promising turnarounds in other industries as well. As discussed above, the Food supply chains currently are facing multifaceted challenges in terms of growing concerns over food traceability, safety and quality. The consumers are becoming increasingly aware of the source of the food that they consume. There is a huge scope of improvement in the operations of the food supply chain. Blockchain technology addresses many of these challenges. However, adopting this technology needs a synergy amongst various elements of the system and requires a systems approach. There are certain pre-requisites of adopting the blockchain technology is a supply chain to ensure smooth operation and successful outcomes. The paper is exploring these antecedents of applying blockchain technology in food supply chains. Also, the consequences of this adoption are also explored. So the research objective is *“To determine the antecedents and consequences of Blockchain technology in the Food supply chains”*

RESEARCH METHODOLOGY

The methodology employed in this research was Expert Interviews. Expert interview method is especially useful when historical data is insufficient or a new phenomenon is being explored and is an effective and concentrated method to gather data in exploratory phase (Bogner, Littig and Menz, 2009). The research objective being addressed in the paper is exploratory and the phenomenon is novel. Hence expert interviews were an appropriate method for addressing the objective.

Defining and selecting an expert for collecting data is the most important step in expert interview technique, since the knowledge and experience of the expert can impact the effectiveness of the method. An expert, for this research, has been defined as a person “who is responsible for the development, implementation or control of solutions/strategies/policies or has privileged access to information about groups of persons or decision processes” (Meuser and Nagel, 1991). Experts in this research were Blockchain Solution providers (BSP) and Supply chain professionals in the Food industry. While choosing the experts, the criteria of experience and domain expertise were used. A total of 9 experts were interviewed to gain a holistic view of the phenomenon. Table 1 below provides a glimpse into the profile of the experts.

Table 1: Profile of Experts interviewed

S. No.	Label	Designation	Total Years of Experience
1	EXP1	Supply Chain Manager	10
2	EXP2	Logistics Head	12
3	EXP3	CTO (BSP)	11

4	EXP4	Project Manager (BSP)	7
5	EXP5	CEO (BSP)	14
6	EXP6	Senior Manager	15
7	EXP7	Procurement Manager	13
8	EXP8	Supply Chain Head	12
9	EXP9	AVP, Procurement	16

DATA COLLECTION AND ANALYSIS

Data were collected using semi-structured and open ended in-depth interviews with the experts. An interview guide was developed beforehand for the same (Meuser and Nagel, 1991). Some interviews were conducted in person by visiting the site of the expert and others were telephonic. The interviews were conducted over a period of two months (Mar-Apr, 2018) and the average duration of each interview was about an hour. To secure the contents, the interviews were recorded under the premise of anonymity and transcribed immediately afterwards.

The interviews were analyzed with the aid of qualitative data analysis (QDA) tool NVIVO11. Data analysis was carried out using following steps:

i. *Transcription of the recorded interviews*: The recorded interviews were transcribed from an audio to a text format.
ii. *Reading through the Data*: To understand the overall meaning of the data, multiple readings were given to the transcribed interviews. It also helped in the recognition of pertinent codes and themes.
iii. *Generating Codes and Themes*: Coding may be described as “the process of organizing the material into chunks or segments of text before bringing meaning to information” (Rossman and Rallis, 2009). Relevant codes were identified from the interviews which were then classified to different themes.
iv. *Interpreting the meaning of the themes*: As per Creswell (2009), “qualitative research is interpretative research”. The researcher assigns meanings to the coded data against the background of “her or his own culture, history and experiences” and compares these findings “with information gleaned from the literature or theories”.

Word Frequency search and Text Search queries were used to identify the most frequently occurring words in the data and their corresponding contexts. Table 2 below provides a snapshot of the comments made by the experts.

Table 2: Expert Comments

Experts	Comments	Factors
Project Manager (BSP)	“*As the size of the blockchain grows, the requirements for storage, bandwidth, and compute power required by fully participating nodes in the network also increase.*”	Scalability
Logistics Head	“*The technology that supports the business should have minimal downtime. In this global and fast paced business environment, even small technical failures and glitches may translate into business losses*”	Reliability
Senior Manager	*“In Blockchain, every player along the supply chain holds a complete copy of the data. So it is important to define specific access rights to ensure that confidential*	Privacy

	corporate information is kept private."	
Procurement Manager	"*Supply chains have always been attempting to become more connected and visible. RFIDs, IOT, POS data are a few steps taken in this direction. Blockchain would provide a new dimension to enhancing the supply chain visibility*."	Supply Chain Visibility
Supply Chain Head	*"As a distributed ledger that ensures transparency and security, the blockchain shows promise to fix the current supply chain problems. A simple application of the blockchain to the food supply chain would be to register the transfer of goods on the ledger as transactions that would identify the parties involved, as well as the price, date, location, quality and state of the product and any other information that would be relevant to managing the supply chain."*	Supply Chain Traceability

RESULTS AND DISCUSSION

The agenda of the paper was to identify the significant antecedents and consequences of adopting blockchain for Food supply chains. The first significant antecedent that emerged was Scalability. Blockchain works on the principle of decentralization, which effectively means that the every single node on the network is responsible for securing the system by processing every transaction and maintaining a copy of the entire state. It limits the number of transactions that can be processed to the slowest node of the network. This might lead to low processing capability and slower transaction times. Since typically in a supply chain, the numbers of transactions or data exchanges are quite high, scalability is an issue that needs careful consideration. The supporting infrastructure, nodes with high processing speeds and capabilities, are a pre-requisite of adopting this technology in supply networks. Another important factor was reliability of the system after adoption of blockchain technology. Supply networks, especially global food supply chains, are quite complex and distributed. Transactions happen on a continuous basis and businesses require a high rate of reliability of the underlying system. Any downtime would convert to a loss in the business. Would blockchain be able to provide that level of reliability on a continuous basis need to be explored before taking the plunge? Security of data and privacy are the other two factors that emerged. Data in a blockchain is "final" and "immutable" making it secured against tampering. However, carefully determining the rules of who can access which data is important. In a supply network, there are multiple tiers of suppliers, buyers, distributors, retailers etc. More often than not, there is an overlap of these entities amongst competitors. Having a shared, decentralized ledger with all the transactions visible to everyone in the network would not be desirable for the businesses. Hence protection of data from misuse and restricted access to view the data for different levels are very important features to be taken into consideration while adopting the technology. And lastly, since the technology is new, the businesses would aim at a slow and phase wise implementation rather than a big bang. Businesses would prefer to use blockchain on a limited basis and gradually expand their usage, but there might be challenges with linking one blockchain to another and with coordinating blockchain with the existing systems, which should be taken into account.

On the consequences end, enhanced supply chain visibility and traceability are the most important factors. The items in a supply chain can be accurately traced back to their origin using the blockchain technology. The records are reliable, since they are added to the chain only after

verification or “consensus”, tamper-proof, as they cannot be altered once added and visible to all on the distributed ledger. This provides more transparency to the supply chain operations and the assets become easily traceable. These features of blockchain would help in fighting against the food fraud and adulteration. The authenticity of the food items, tracing them back to their origins has a special significance for the complex and global food supply chains. Since the ledger is shared amongst all the parties in a network, it would lead to inventory optimization and cost savings. The suppliers, given controlled access, would be able to see the actual levels of inventories and plan their delivery schedules accordingly. This would be an advanced stage of Vendor Managed Inventories (VMI) where instead of buyer controlling the centralized database, the suppliers are also a part of the network. Another important aspect is risk management. With everyone in the network having the data backup and visibility, the business and political risks associated with a centralized system are reduced for blockchain. Another important advantage of blockchain is the near real time transaction updates. In a centralized system, it may take days before a transaction is approved and updated in the database. Additionally, there are multiple check points and redundancies. For instance, a purchase order raised from a buyer will go to supplier. The supplier would dispatch the material and send an invoice to the buyer. The buyer in return would send an acknowledgement or receipt of goods. Then the payment would be released. All these transactions would be updated in the central database sequentially. However, with blockchain, the suppliers and buyers can simultaneously access the shared ledger and after consensus, the transactions can be added to the shared ledger on a near real time basis. This eventually leads to enhanced efficiency and cost savings.

Table 3: Antecedents and Consequences of Blockchain in Supply chain

Antecedents	**Consequences**
Scalability	Supply Chain Visibility
Security	Supply Chain Traceability
Reliability	Inventory Optimization
Privacy	Risk Management
Migration to new system	Real time Speed

CONCLUSION

Blockchain is the buzzword in the business and technology space these days. A lot is being said about its tremendous potential to solve a number of business challenges. In the context of food supply chains, blockchain looks promising to address the mounting challenges of food fraud and adulteration. In the light of several recent food scandals, food traceability is becoming increasingly important for the consumers and businesses alike. However, there is no one size fits all strategy as far as technology is concerned. It needs to be carefully evaluated before adoption in any industry or domain. The contributions of the paper are threefold:

a) The paper contributes towards the general understanding of the blockchain technology and discusses its relevance in the context of food supply chains. The fundamental features of blockchain are discussed and how those features contribute in addressing the complexities of the food supply chains are explored.
b) The paper explores the significant antecedents and consequences for the application of blockchain in the food supply chains. Expert interviews with blockchain solution providers and food supply chain experts were conducted to identify the relevant factors. The results help in providing an overview of the significant aspects that need attention while adopting the technology to the food supply chain context.

c) Blockchain is still in its nascent stage with a limited number of research papers and use cases available and the industry is actually leading the academia in the area. The paper is an attempt towards bridging this gap and contributes towards the advancement of the understanding of blockchain technology and its application in the food supply chains.

The paper paves way for further research in the area. Going forward, the factors can be extended and explored in greater detail. Expert's views have been sought to shortlist the most relevant factors, which may have introduced some element of bias. A focus group, with all the experts at one location, could not be organized due to constraints on time and resources. This can be addressed in future research as it would enhance the confidence in the results. Future research can also explore the blockchain adoption in different supply chain contexts, other than Food supply chains.

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Appeals to Ownership of Automobiles in Style Magazines of the U.S. and U.K., 1930-2000

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ABSTRACT

We report an analysis of attribute and motive content of appeals to automobile ownership in print advertising of style magazines in the U.S. and U.K. Results of the analyses show significant country differences in appeals to technology, status and subcategories of motivation.

KEYWORDS: Cross-national advertising content, automobile advertising, content analysis, consumption artifacts, and time trends in advertising content

INTRODUCTION

A basic difficulty in studying relationships between culture and consumption has been in defining dimensions of consumption (Silver 2002). We will suggest that these dimensions can be usefully defined in attributes or characteristics of differentiated goods (Bajari and Benkard 2005). Among the contributions of studying differentiated goods is the increased likelihood that they include the range of functional and stylistic contrasts in attributes that have been a mainstay in the study of consumption artifacts (Bettinger 1996; Stoetzel 2017).

As has been recognized, that cultural variation in the importance of or preference for attributes of goods and services can meaningful be studies in the content of advertising (Borèus and Bergström 2017). In addressing cultural variation in ad content, there is some advantage to studying countries that have a commonality in language and a correspondence in legal and social institutions but have acknowledged variation in aspects of informal culture that are important to personal consumption. U.S.-U.K. comparisons of the content of print ads provide these conditions. Our interest will be in testing whether measures the importance of attributes of a differentiated good and motive content inferred from advertising content are consistent with oft-cited cultural differences in comparison societies. Following a review of background studies of U.S.-U.K. comparisons in thematic content, we will define the sampling and content analyses methodology. Results of the coding and analyses will then be reported. Finally, results will be interpreted in national contexts for the relevant study periods.

BACKGROUND STUDIES

Available studies of U.S.-U.K. thematic content that relate to culture differ in method, content and dependent variables. While not entirely consistent in their results, these studies offer background for contrasts between countries. Czellar (2003) has studied U.S.-U.K. differences in prestige judgments using a word association text. He found that U.K. respondents were higher in “exclusivity” and “quality” themes but lower in “personal success themes” than U.S. respondents. Caillat and Mueller (1996) in their study of TV beer advertising in the U.S. and U.K. found that American ads exhibited more individualism/independence, modernity/newness, and achievement

content than U.K. ads. Although Tansey, Hyman, Zinkhan and Choudhury (1997) did not find consistently significant differences in work themes they studied in U.S. and U.K. print ad content, they did find that a higher proportion of automobile ads with achievement themes in the U.K. sample than in a U.S. sample. Koslow and Costley (2010) indicate that U.K. ads in general tend to be more focused on overall product quality while U.S. ads tend to have more specific information and price content. Results of these studies suggest composite profiles of the U.S. as a society that is higher in individualism and entrepreneurial "spirit" and aspects of achievement motivation but lower in collectivism, explicit status marking and quality and workmanship orientations than U.K. society.

Benefits of restricting content analysis to a single product category have been noted by Caillat and Mueller (1996); Neuendorf (2016) and Tansey, Hyman, Zinkhan and Choudhury (1997). The functional and symbolic importance of automobiles as a consumer good has been well recognized (Conley 2016; Gartman 1994; Hensher, Barnard, Smith and Milthorpe 1989; Thoms, Holden and Claydon 2016). While available cross-national studies of automobiles have most often addressed country-of-origin effects in communication (Ahmed and d'Astours 1993; Nagashima 1970; Haubl 1996), we study automobiles as a differentiated durable good across a set of representative attributes. Such a more extensive representation of the good can support more definitive identification of societal differences and their interpretation.

Analysis of media content has been a common method used for imputation of cross-national variation in both product attributes and the preferences they imply for a range of products (e.g., Boréus and Bergström 2017, Samiee and Jeong 1994). In this tradition, the study of magazine print advertising can provide data on both cultural and historical variations in attributes of a differentiated good and is unmatched in its continuity and diversity. The significant differences in country comparisons that have been reported in previous studies further indicate that analysis of print advertising can be an important contributor to documenting and interpreting cross-national differences in appeals to the use of consumer goods and motive content in ad copy.

"Efficient market" accounts (e.g., Fama 1998) can support an assertion that competition among producers results in ad content that is shaped to closely reflect consumer preferences. In addition to the importance of attributes to inferring preferences among those who study culture and consumption, attributes that underlie preferences have been of continuing interest to those who design and manage differentiated consumer products (Tai 2004). Although we also recognize that there are intermediary processes that determine how preferences are manifested in choice (e.g., Horsky, Nelson and Posovac 2004), we follow assumptions of previous investigators that the study of attribute content in artifacts and advertising supports inference on the underlying preferences of those who own and use the goods (e.g. Conley 2016). We study what can be designated as style magazines with a readership that has higher education and income than median national levels. The designation of style magazine indicates that they introduce directions for life style and consumption in humor, fiction and reporting.

Magazine Sources and Ad Sample

Unlike the U.S., there are few popular magazines with continuous publication histories that span many decades in the U.K. We will sample ads from the humor, fiction and style or fashion magazine *Punch* in a series for the U.K. The higher mean income and education of the readership of this magazine is likely to allow a wide range of attributes to be manifested in advertising.

Clearly, *Punch* does not have an exact correspondence in a U.S. magazine title. We will study the U.S. magazine that is likely to be most comparable to *Punch* over the study period, *Esquire* magazine has been a publisher of American fiction and an indicator of fashion to the demographic of its readership for much of its history. We designate both titles as style magazines. The demographics of its readership have a direct correspondence to *Punch* in the relative income and occupation/education positions for years in which data is reported. *Esquire* was published in 1933. Punch ceased publication in 2002. Our study period will span the decades of 1930s to 1990s.

HYPOTHESES

We offer the following hypotheses on attributes and motive content in U.S. and U.K. print ads for the differentiated good of automobiles.

h_1: Technology as an attribute is expected to be more frequent in appeals to automobile ownership in U.S. ads than in U.K. ads.

Technology has been often cited as the engine of growth in the U.S. economy in the post-war period under study (Baily 2004; Mundlak 2005; Fernald and Rarnmath 2004). The importance of a technology-based "ethic" in the U.S. in observing the rapid growth of the U.S. economy over most of the post-WWII period (e.g., Litan 2001). In contrast, a decline in technology-related ethic in the U.K. over this time period has been cited (e.g. Collins and Robins 1990).

h_2: Style and comfort as attributes are expected to be more frequent appeals to automobile ownership in U.S. ads than in U.K. ads.

Style and comfort are often considered to be hallmarks of an affluent American society (Cole 1991). The U.S. has been described, as one in which there is more status competition through ownership and use of consumer goods than alternative Western societies. Other authors (e.g., Silver 2015[2002]) have discussed the possible basis for this in terms of differences in the formal status-granting institutions put in place by cultural histories of societies. We expect status competition to be manifested in appeals to style and comfort.

h_3: Quality and efficiency as attributes are expected to be more frequent in appeals to automobile ownership in U.K. ads than in U.S. ads.

Workmanship and its contribution to quality and reliability has also been discussed as a traditional value of British industry (e.g., Collins and Robbins 1990; Greasley and Oxley 1998), although the extent to which it has declined in the post-WWII period and the reasons for the decline (e.g., Collins and Robins 1990; Raven 1989) have been debated. In contrast, the U.S. has been described as an individualistic, entrepreneurial society (e.g., Han nad Shavitt 1994; Sagie, Elizur and Yamauchi 1996) over the study period. There also are bases to expect that differences in income and the prices of fuel and maintenance between countries in the periods under study will result in differences in the importance of the attribute of efficiency.

h_4: Achievement related appeals to meeting or exceeding a "standard of excellence" are expected to be more frequent in U.K. ads than in U.S. ads (e.g., Winter 1984).

h_5: Achievement related appeals of "winning and competing" are expected to be more

frequent in U.S. ads than in U.K. ads.

The importance of workmanship we cite in U.K. history is expected to be reflected in the "standard of excellence" component of the achievement construct. While we consider "standard of excellence" to be a workmanship-related motive, we consider "winning or competing" to reflect individualistic and competitive orientations in American society.

METHOD

Product Attributes and Motives in Ad Content

Our initial pool of attributes is from those that have been identified in a range of previous studies (e.g., Fernandez-Castro and Smith 2002; Hensher et al 1989) or are reported by agencies that compare automobiles (e.g., *Crain Automotive* and *Wards Automotive Yearbook*). We also represent the achievement motive (e.g. Winter 1984) as a motive that relates to workmanship and quality in goods and services in our coding of ad text and have been previously studied in advertising content (e.g. Tansey et al 1997).

Attributes and motives under study are listed and defined in Table 1

Table 1
Coding Attributes of Automobiles in Magazine Ads

Attributes of Automobile	*definition*
Value	mention of quality for Price
Technology	mention of a technology – general or specific e.g., dual diagonal brakes
Style	mention of style/appearance
Durability/Reliability	mention of longevity, durability, consistency, dependability
Efficiency	mention of low cost in operation, maintenance, mileage per gallon
Performance	mention of power, acceleration
Comfort	mention of interior room, comfortable seating or operation
Quality	mention of very high standards; price not relevant
Safety/Security	mention of safety/security – general or specific – e.g., side airbags
Handling	mention of control, responsiveness
Price	mention of low or moderate price, low price as an explicit appeal
Achievement Content	*definition*
1. Standard of Excellence	meets or exceeds certain high standards, can be in mention of brand e.g., Bosch parts, Body by Fisher
2. Winning or Competing with others	favorable comparison to other cars; awards or honors
3. Unique Accomplishment	only brand to offer feature or form; first to introduce it

Sampling Procedure.

For each of the years in which the magazines were published between 1930 and 1999, ten ads of at least half a page were selected from both *Punch* and *Esquire* magazines according to a random procedure. Random numbers between 1 and 20 were drawn for two issues in each year; one closest to the date March 15, the other to October 15. The first five ads in the number sequence were used to select the ads in an issue. If a number in the random sequence was greater than the number of ads in an issue, the next number in the random sequence was drawn.

Esquire did not have automobile ads for World War II years of 1942-1944 in the early 1940s. *Punch* did not have automobile ads between 1941 and 1945. A total of 580 ads for *Punch* and 614 for *Esquire* were used in the analysis.

Coding Procedure.

The ads were coded on the set of attributes and the motive in achievement content listed in Table 1. Two coders each coded more than .7 of the total ad sample with the overlap used to assess reliability. Ads were assigned to each coder following a stratified time sample procedure so that each coder received the same number of ads in a year for each country. Both coders were initially trained with coding of a sample of ads from each magazine that were not part of the sample used in the study we report.

Coding scales.

In pre-study investigation, we found that the difference between low and high importance of an appeal to ownership could be reliably discriminated. Each attribute was consequently coded on a three-point scale of absent, present-low importance and present-high importance. Achievement sub-categories were coded for their presence or absence in an ad following the procedure outlined by Winter (1984).

A recursive partitioning algorithm (CART: Breiman, Friedman, Olshen and Stone 1984; Rutkowski, Jaworski, Pietruczuk and Duda 2014) was used to identify the splits in the attribute and motive coding categories that best classified countries. CART develops a classification or branching scheme that predicts a dependent variable based on the levels of multiple independent variables. Whereas stepwise regression methods pick the independent variable to enter from the reduction in total variance in the dependent variable in the next step, CART has superior procedures to “look ahead” at subsequent splits any candidate split will result in and select the splits that minimize a measure of variation in the dependent variable.

CART constructs a large tree from sample observations by minimizing at each step some “impurity” function for the unexplained variation. The constructed tree is then “pruned” with a penalty criterion in which the penalty is proportional to the number of leaves (nodes) in the tree to obtain more parsimonious specifications of splits in the independent variables. We use CART as exploratory methodology to guide splits in coding categories used in logistic regression.

A classification tree based on a binary classification of the attributes of the presence or absence of technology, comfort and efficiency, the achievement sub-categories of standard of excellence and unique accomplishment, and style-appeals as high importance vs. low importance or absence was found to generate a discrimination of country that minimized the residual variation in CART. Collinearity is unlikely to affect these results since none of the attribute and motive variables evidence a coefficient greater than .24.

Logit Model of Country Attribute Profiles in Print Ads

We use the binary logit model in eq. (1) to predict country of origin from coded attributes and motives.

(1) pr (j = countryA) = F ($\beta_0 + \beta_1$ att$_1$ + … + $\beta_n att_n$)

where F is the cumulative logistic distribution function

F(z)=1/(1+e^{-z}), z = log [pr (j=A)/Pr (j=B)] = $\beta_0 + \beta_1 att_1 + ... + \beta_n att_n$.

β_0 is an intercept and β_k, k=1, ..., n are coefficients for the n attributes in Table 1.

Equation (1) can be estimated with data from procedures that we next describe. The sign and statistical significance of the coefficients for attributes and motives in the estimated model will be used for hypothesis testing.

RESULTS

Coder Reliability

Agreement between coders on a binary categorization of absence or presence of appeals to an attribute were assessed with intra-class correlation methods. These methods as applied in an interval scale by Shrout and Fleiss (1979) have been extended to binary scales (e.g., Ridout, Demetrio and Firth 1999). For the 160 ads that were coded by both coders, the coder agreement on the absence-presence categorization of attributes and motives was between .82 and .94. Coefficients exceeded .85 for all but the status attribute for which they were .81.

Logit Models of Country Differences in Attribute and Motive Content

Estimation of a logit model of country-preferred attributes was undertaken with maximum likelihood procedures of SAS for the binary classification of country. Consistent with the results of the CART recursive partitioning, our backward stepwise procedure of model estimation indicated that only the presence or absence of technology, comfort and efficiency and the binary classification presence of style-appeals-high importance vs. low importance or absence and the motive content of the presence of achievement sub-categories of standard of excellence and unique accomplishment significantly increased model fit.

Measures of overall model fit all show highly significant increases from the attributes and motives we include in the final model (Final -2log likelihood=728.70; Pseudo R^2 =.218, Cox and Snell R^2 =.172, Nagelkerke R^2 =.230). Removal of any of the attributes and motives in the final model all result in a highly significant (p<.001) decrease in model fit (*i.e.,* a significant increase in the -2log likelihood). The absence of a significant Hosmer and Lemshow (1989) statistic (χ^2 = 6.85, df = 7, p>.25) also supports our inference on adequacy of model fit.

Figure 1 shows a profile of the mean proportions in which coded attributes and motives were present in the ad sample for the U.S. and U.K. Table 2 reports the coefficient estimates for the

set of attributes and motives in the final model. Coefficients are for the U.S. with the U.K. as the comparison country.

Figure 1: Overall US-UK Comparison in Attribute and Motive Profiles

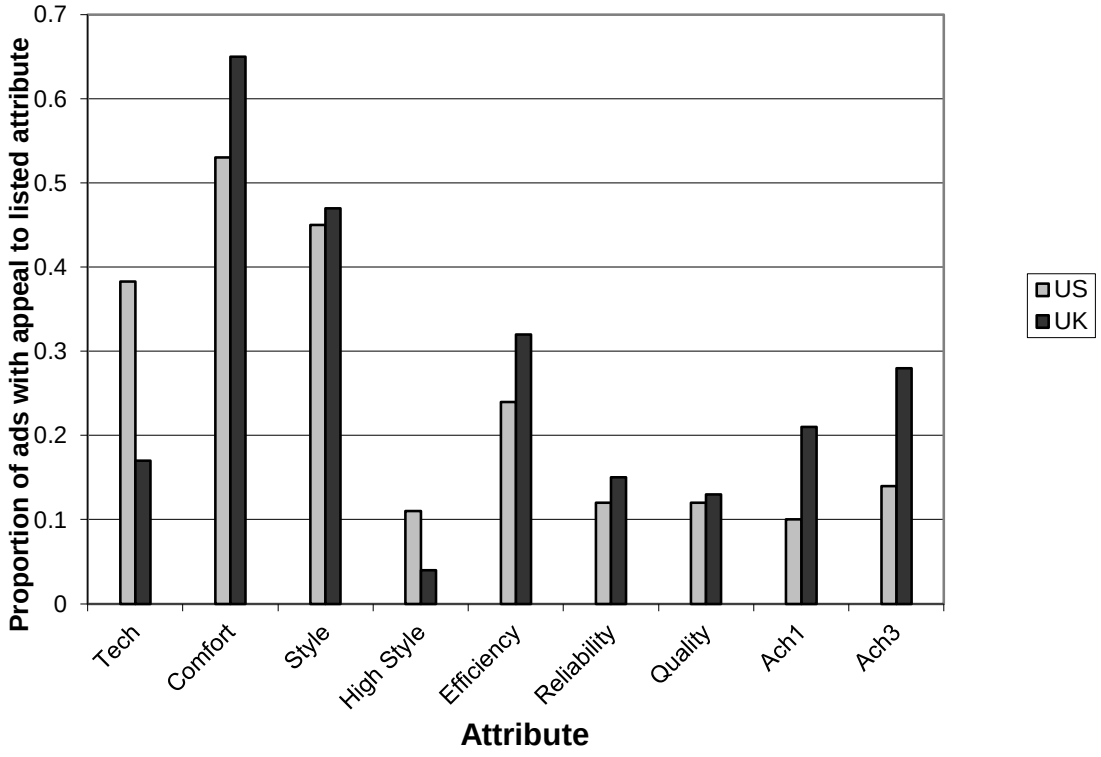

Table 2

Coefficient Estimates for Attribute and Motive Variables in the Model

	B	S.E.	Wald	df	p	Exp(B)
tech	1.692	.165	105.590	1	.000	5.433
style_h	1.119	.272	16.872	1	.000	3.060
comf	-.689	.131	27.661	1	.000	.502
effic	-.462	.142	10.654	1	.001	.630
ach1	-1.206	.195	38.123	1	.000	.299
ach3	-.959	.173	30.541	1	.000	.383
Constant	.039	.351	.013	1	.911	.040

Note: B = logistic coefficient; S.E. = standard error; Wald = Wald statistic; p = significance level; Exp(B) = exponentiated coefficient.

Results for the accuracy of classification of country by attributes and motive in ad content are reported in Table 3.

Table 3
Classification Table: Entire Sample

Observed			Predicted		
			US=1, UK=2		Percentage Correct
			1.00	2.00	
Step 1	US=1, UK=2	1.00	400	214	65.1
		2.00	172	408	70.3
	Overall Percentage				67.7

In addition to the "jacknifed" procedure for results in Table 3, we also cross-validated the classification of country in the logistic regression model with split-sample methodology (e.g., Huberty 1984). Our procedure was to first randomly assign the ads in a sample to a main sample and a hold-out sample with a stratified sample design in which half the ads in each year of the overall sample were assigned to one of the two sub-samples. Results for the analysis and hold-out samples we obtained are presented in Table 4.

Table 4. Classification Table: Hold-out Sample Results

	Predicted Group Membership					
	Analysis Sample			Holdout Sample		
Actual Group	Group 1	Group 2	Total	Group 1	Group 2	Total
Group 1: U.S.	197	115	.63	198	104	.66
Group 2: U.K.	75	214	.73	75	216	.73
Total	272	329	.68	273	320	.69

More than two-thirds of the sample was correctly classified by the study variables in the hold out sample. This is in comparison to correct categorization of .51 by a proportional chance criterion or the assignment of all ads to the country with the larger number of ads in the sample. Press' Q statistic as a measure of classification accuracy yielded a chi-square of 146.67 for the entire sample, 102.95 for the analysis sample and 79.93 for the holdout sample. Each of these χ^2 levels exceeds the critical value for $\alpha = .01$ ($\chi^2 = 6.63$). Thus we conclude that the classifications of ads in both the analysis and holdout sample were significantly better than chance or an assignment of all ads in the respective sample to the country with the larger ad sample.

DISCUSSION

We have reported results of a study of cross-national differences in appeals to ownership of print advertising for automobiles in style magazines of the U.S. and the U.K. over the decades 1920-1990. While previous studies have focused upon content inferred in values and motives from

communication variables, we directly study a set of product attributes that are invoked in appeals to automobile ownership as a differentiated good. In our initial review, we noted bases to hypothesize that U.S. ads would have higher frequencies of technology, style and comfort appeals but lower frequencies of efficiency, quality and reliability appeals than U.K. ads would have. In achievement motive content, a number of previous studies predict higher frequencies of ads with achievement content in U.S. ads. We disaggregated components of achievement and predicted U.K. ads to have higher frequencies of ads with a mention of a standard of excellence but lower frequencies of ads with mention of winning or competing.

Our results indicated that among the attributes we study, the presence of technology appeals was significantly more frequent in U.S. ads than in U.K. ads and was the best discriminator of country in the logit models. Technology has been seen as a dominant theme in the U.S. as commonly designated entrepreneurial society for the period we studied. For the contrast in the attribute of style, we found the high importance of style in an ad to be more frequent in U.S. ads and to also significantly contribute to the discrimination of country. Fewer institutional status contests in the U.S. have been suggested as basis for the increased importance of style in the U.S. consumption ad appeals (Silver 2015[2002]). The above results are consistent with study hypotheses. The presence of appeals to comfort was not found to significantly discriminate countries. This is contrary to our hypothesis for this attribute.

We also found that U.K. ads more frequently had achievement content than U.S. ads. Disaggregating achievement content, both “standard of excellence” and “unique accomplishment” were more frequent in U.K. ads than in U.S. ads. Differences in “competing or winning competition” did not discriminate country. The results we report encourage further comparative study of product attributes for differentiated goods and application of methodology for using historical record for inference on time trends in preferences. As noted in our review, there have been few comparative studies of consumption with the scope in attributes of the one we report. We have also noted the distinct advantages in studying a differentiated good in terms of attributes.

Results do indicate that even countries with high commonalities in language and institutions significantly differ in the attributes that predominate in their market appeals to consumers for differentiated consumption goods with functional and symbolic importance. These results further encourage social theorists to more explicitly include them in conjecture on how culture maps preferences in consumption. They also suggest that multinational companies continue to differentiate product classes by countries of different appeals, attributes and appeals to ownership even when as in the case of automobiles there are substantial correspondences in underlying product forms.

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DECISION SCIENCES INSTITUTE
Attitudes toward Business Statistics Learning:
Gender Differences among U.S. and Chinese College Students

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ABSTRACT

Female and male students may have different attitudes toward business statistics class that offer an explanation of some of the differences in their course performance. This study investigates gender effects on attitudes toward statistics among undergraduate students in introductory Chinese and U.S. business statistics classes.

KEYWORDS: Business Statistics, Attitudes toward Statistics, Statistical Instruction and Learning, Gender

INTRODUCTION

Learning statistics requires a different type of thinking as compared to traditional mathematics courses. Student misconceptions in statistical reasoning have been recognized and studied in numerous research papers (e.g., Carmona, Martínez, & Sánchez, 2005; Chiesi & Primi, 2010; Gal, et al. , 1997; Onwuegbuzie & Seaman, 1995; Schutz, et al.,1998; Tremblay, et al., 2000; Wisenbaker & Scott, 2000).

Along with cognitive difficulties in the statistics course, students also suffer from a range of non-cognitive limitations. It is common for students to have predetermined attitudes toward the subject even before the first class session. These attitudes depend on their personal beliefs about statistics as well as expectations about the course, their ability to do well in it, and the usefulness of statistics in their future life or career (Gal, et al., 1997). Previous experience with statistics, or lack thereof, also affect students' attitudes prior to and throughout the course (Schau, 2003a).

Research suggests that attitudes toward a statistics course and student's overall performance and learning may be related, suggesting a link between cognitive and non-cognitive factors (Chiesi & Primi, 2010; Harlow, et al., 2002; Lalonde & Gardner, 1993; Schutz, et al.,1998; Tremblay, et al., 2000). There is also evidence that male and female college students exhibit varying attitudes toward statistics (Bechrakis, et al., 2011; Hilton, et al., 2004).

As one of the required core courses in business curricula, many students find this pre-requisite to be a major hurdle to business school admission. With increasing globalization in business school programs, we were interested in cultural differences and their potential for interactions with gender in attitudes toward statistics. The focus of our study is a comparison of

male and female U.S. and Chinese students' attitudes toward statistics in undergraduate introductory business statistics courses.

LITERATURE REVIEW

Development of Schau's SATS

One popular instrument for research on students' beliefs about statisitcs is the Survey of Attitudes Toward Statistics (SATS) (Schau, 1995, 2003b). The SATS was designed based on Eccles Expectancy-Value Theory as it assesses multiple components of students' attitudes (Vanhoof, et al., 2011). Schau (2003a) states "We need to better understand students' attitudes toward statistics and their interrelationships with achievement and eventual use in life, and we need to find more methods for promoting positive attitudes. I believe that assessing our students' attitudes and creating, considering, and testing models such as the one I've presented here will help us understand the nature of students' attitudes toward statistics as well as their statistics learning".

The SATS-28 uses 28 Likert-scaled questions to measure four different components that make up students' attitudes toward statistics: affect, value, cognitive competence, and difficulty. An extension, SATS-36, has additional questions to measure the two components of interest and effort (Nolan, et al., 2012). The SATS also has pre- and post-versions for use at the beginning and end of a statistics course, respectively.

Cultural effects

A comparison of U.S. and Chinese cultures shows major differences in several of Hofstede's dimensions (Hofstede & Bond, 1984; McFeeters, 2003), such as individualism versus collectivism and power distance. Cultural variations can also be seen between U.S. and Chinese college students. (Lu, 2014) cited six major differences, including more pressure on Chinese students from their parents, more respect for social hierarchy among Chinese students, and more encouragement of independent thinking by U.S. students (Bechrakis, et al., 2011; Hilton, et al., 2004).

Hypotheses

1) There are no gender differences in attitudes toward business statistics among U.S. students.
2) There are no gender differences in attitudes toward business statistics among Chinese students.
3) There are no differences in attitudes toward business statistics among male U.S. and Chinese students.
4) There are no differences in attitudes toward business statistics among female U.S. and Chinese students.

RESEARCH METHODOLOGY

SATS-36 Instrument

There are six components in Schau's survey instrument (Schau, 2003b):

- Affect—students' feelings concerning statistics, with six question items such as "I am scared by statistics"
- Cognitive competence—students' intellectual knowledge and skills when applied to statistics, with six question items such as "I can learn statistics"

- Value—students' perceptions of usefulness, relevance, and worth of statistics in personal and professional life, with nine question items such as "I use statistics in my everyday life"
- Difficulty—students' beliefs about the challenge of statistics as an academic subject, with seven question items such as "Most people have to learn a new way of thinking to do statistics"
- Interest—individual interest in statistics, with four question items such as "I am interested in using statistics"
- Effort—the amount of work students expect to put in to learn statistics, with four question items such as "I plan to work hard in my statistics course"

Data Collection

The instrument was translated into Chinese and pilot tested before data were collected. The original survey instrument and the Chinese translation were approved by the University's institutional review board. Data were collected from undergraduate students in business statistics classes in the U.S. and China during the first week of the semester using paper versions of the instruments.

PRELIMINARY RESULTS

We will present preliminary results from testing hypotheses using structural equation modeling for latent mean differences. Statistically significant differences and their implications for improving instruction and learning in business statistics classes will be discussed.

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Building Organizational Agility via Firms' IT Capability and IT Ambidexterity: Moderating Role of IT Infrastructure Flexibility

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"ABSTRACT"

Drawn on the capability building mechanism, this research investigates medium firms' flexible capacities on the organizational agility by conceptualizing the IT competencies and IT ambidexterity as lower-order functional capability which enhance the organizational agility as higher-order dynamic capability and organizational performance. To catch up with the dynamism of business environment, IT infrastructure flexibility becomes critical, should play a more sophisticated role in capability building process. Within this research, we propose that IT capabilities and IT ambidexterity enhance the organizational agility; while IT infrastructure flexibility enhances the organizational agility both directly and indirectly as a moderator.

KEYWORDS: IT capability, IT ambidexterity, IT infrastructure flexibility, organizational agility, organizational performance

INTRODUCTION

In today's modern business world, technology is constantly under innovation and business environment is simultaneously changing. Organizational agility thus becomes crucial for building competitive advantage (Neirotti & Raguseo, 2017) and winning competition because it reflects the firm's capabilities to continuously detect and effectively and timely respond to environment changes (D'Aveni, Dagnino, & Smith, 2010). To obtain such ability and agility, firms depend on its IT ambidexterity, which is defined as the firm's ability to flexibly balance the combination of the continuous exploration of new IT resources and practices and the exploitation of current IT assets (Lee, Sambamurthy, Lim, & Wei, 2015). Parallel with IT ambidexterity, firms also need to enhance their IT competency, which is categorized into IT infrastructure and IT capabilities (Chakravarty, Grewal, & Sambamurthy, 2013). When a firm can optimize its resources to sense business opportunities and challenges, outperform its rivals to react to customer demands, business partners, and business operations (Sambamurthy, Bharadwaj, & Grover, 2003), organization agility is reached which in turn will enhance not only the firm's performance but also create a sustainable competitive advantage.

According to World Bank, small and medium enterprises (SMEs) create up to 60% of total employment and 40% of GDP in developing countries. Thus it is natural that SMEs are receiving more and more attention from researchers (Malekifar, Taghizadeh, Rahman, & Khan, 2014; Neirotti & Raguseo, 2017). For medium firms, the balance of IT investments and agility is one of

their biggest competitive advantages. When compared to small enterprises, medium maintain an adequate investment on IT, assuring an adequate IT infrastructure that facilitates its business operation. At the same time, the relatively compact size of a medium enterprise compared to the heavily structured of large firms, make medium firms more agile and flexible in responding to market changes. Thus, it is crucial for medium firms to maintain and enhance their IT competencies to build better IT agility.

Capability-building mechanism (Grant, 1996; Makadok, 2001), is a process where lower-order functional capabilities act as the enablers of the higher-order dynamic capabilities. In IS strategic literature, a number of capabilities is identified as enablers, including IT infrastructure (Lu & Ramamurthy, 2011), IT ambidexterity (Lee et al., 2015), IT alignment (Tallon & Pinsonneault, 2011), IT service climate (Jia & Reich, 2013). According to Chakravarty et al. (2013), IT competencies compromise of IT infrastructure and IT capabilities, whereas IT infrastructure flexibility and efficiency are two most important characteristics of IT infrastructure (Byrd & Turner, 2001). We, however, propose that in today's modern economy, when IT activities are fundamental to all business operations, IT infrastructure is required to be more flexible and IT infrastructure flexibility plays as a catalyst, a "new competitive weapon" (Davenport & Linder, 1994) for the capability-building process. That is why, within this research, we conceptualize the moderating role of the IT infrastructure flexibility of the relationship between IT capabilities and IT agility, as well as between IT ambidexterity and IT agility.

Based on previously mentioned of research background and research motivation, the objectives of this research include: to propose (1) the impact of IT competencies and IT ambidexterity (functional capabilities) on organizational agility (dynamic capabilities) and organizational performance; (2) the moderating role of IT infrastructure flexibility on the relationship between functional capabilities and dynamic capabilities; (3) the mechanism in the context of medium firms where balance between IT investment and IT agility is vital for business success.

The rest of the paper is structured as follows: first, capability-building mechanism is discussed, followed by the discussion of IT capabilities related literature and proposal of research propositions. Finally, conceptual model is presented with proposed construct measurements.

LITERATURE REVIEW

Capability-building Mechanism

Strategic management literature identified two mechanisms that managers can utilize to create economic rents for their enterprises (Makadok, 2001; Teece, Pisano, & Shuen, 1997). The first mechanism is resource-picking. In this mechanism, managers will select and analyze available information so that they can effectively pick resources and outperform their opponents. The second mechanism is capability-building; managers design and set up internal systems and external forces to effectively deploy the firms' resources for better productivity in short run and long term competitive advantages (D'Aveni et al., 2010).

There are two hierarchs of organizational capabilities in the capability building process: functional capabilities at lower hierarch and dynamic capabilities at higher hierarch (Grant, 1996). In information systems literature, ITs, IT competencies, and IT management capabilities were categorized as lower-order functional capabilities; while higher-order of dynamic capabilities were conceptualized as the organizational agility (Grant, 1996; Lee et al., 2015; Sambamurthy et al., 2003). Under the capability building perspective, the functional capabilities are the drivers of the dynamic capabilities, enable firms to identify threats and opportunities, optimize the utility of resources to swiftly react to changes and achieve success (Sambamurthy et al., 2003).

Within this research, we choose to focus on the agility and flexibility aspects of the capabilities that enable the organization agility and performance. Driven on the capability building mechanism and IS literature, functional capabilities are conceptualized as IT infrastructure flexibility, IT capabilities, and IT ambidexterity and dynamic capabilities as organizational agility.

Organizational Agility

Organizational agility has long been an important topic of the IS research and it has rich literature investigating not only the agility concept but also the antecedents that lead to such agility. Because of the rich literature, organizational agility is defined in various ways. Sambamurthy et al. (2003) investigated organizational agility in terms of a firm's responsiveness to its customer demands, its partnerships with other business counterparts, and business operation. Lu and Ramamurthy (2011) identify and conceptualize two types of agility: market capitalizing agility, referring to the ability to quickly capture and capitalize the changes so that it can effectively respond the customer demands (Volberda, 1997); and operational adjustment agility, referring to the ability to adjust its internal process to react to external changes (Sambamurthy et al., 2003).

Fink and Neumann (2007) define organizational agility as "the ability to respond operationally and strategically to changes in the external environment through IT" and conceptualized organizational agility into three varied factors: system, information, and strategic agility. The system agility is defined as "the ability to accommodate change in information systems through activities of system development, implementation, modification, and maintenance". Information agility refers to ''the ability to accommodate change in the way organizational users access and use information resources". And strategic agility is the ''ability to respond efficiently and effectively to emerging market opportunities by taking advantage of existing IT capabilities" (Fink & Neumann, 2007). IT capabilities are important enabler of the organizational agility and also mediate the relationship between IT personnel capabilities and IT agility (Fink & Neumann, 2007). Within this study, we adapted this way of conceptualization of organizational agility to investigate the relationship between capabilities and organizational agility.

PROPOSITION DEVELOPMENT

IT Ambidexterity

IT ambidexterity is defined as a firm's capability to explore new IT resources and exploit current IT resources in managing IT resources and practices (Lee et al., 2015). IT exploration involves with a firm's efforts in understanding and obtaining new ITs, testing them in the firm's systems, and select the most suitable ones to apply in their current and future management and operations; while IT exploitation relates to a firm's capability to control its current IT assets and reuse them in different operational activities to improve their productivity and overall integration (Andriopoulos & Lewis, 2009; March, 1991).

In modern firms where management facing frequent changes, the concurrent utilization of exploration and exploitation, or in other words ambidexterity, is a crucial issue (Raisch & Birkinshaw, 2008). For example, a telecommunication company might need to constantly explore recent technologies and update its IT infrastructure to align with its customers' update; but also need to exploit its current IT infrastructure, e.g. its network, or customer database to improve the services that it provides. Thus, both IT exploration and exploitation are used to improve a firm's performance (Hammer, 2004). IT ambidexterity is considered to be lower-order functional capability and was found to enhance the organizational agility as higher-order dynamic capability (Lee et al., 2015). Thus, we propose the following proposition:

Proposition 1: The ambidexterity of IT infrastructure exploration and exploitation positively shapes the organizational agility.

IT Competencies

IT competencies are widely conceptualized to consist of IT infrastructure and IT capabilities (Chakravarty et al., 2013; Piccoli & Ives, 2005; Sambamurthy et al., 2003). IT capability is defined as "a firm's ability to acquire, deploy, combine, and reconfigure IT resources in support and enhancement of business strategies and work processes" (Lu & Ramamurthy, 2011). IT capabilities are pivotal for firms to shape their business value and long-term competitive

advantage, which is why such capabilities are treated as a source for strategic agility (Weill & Vitale, 2002). IT infrastructure, another core IT competence, is defined as (Broadbent, Weill, Brien, & Neo, 1996):

> "IT infrastructure is the shared IT resources consisting of a technical physical base of hardware, software, communications technologies, data, and core applications and a human component of skills, expertise, competencies, commitments, values, norms, and knowledge that combine to create IT services that are typically unique to an organization. These IT services provide a foundation for communications interchange across the entire organization and for the development and implementation of present and future business applications."

More than IT capability, IT infrastructure receives even bigger attention from researchers and practitioners, especially on the two most important characteristics of IT infrastructure, namely IT infrastructure flexibility and IT infrastructure efficiency. According to (Byrd & Turner, 2000, 2001), IT infrastructure flexibility is defined as:

> "IT infrastructure flexibility is the ability to easily and readily diffuse or support a wide variety of hardware, software, communications technologies, data, core applications, skills and competencies, commitments, and values within the technical physical base and the human component of the existing IT infrastructure."

Within this study, instead of considering IT infrastructure flexibility as a characteristic of IT infrastructure, we propose that it is not IT infrastructure but IT infrastructure flexibility that should be considered as the core competency, in accordance with Davenport and Linder (1994), alongside IT capabilities.

In modern society, IT competencies are crucial for organizations to detect and effectively react to threats and opportunities. A firm's data source and business information are enormous that requires IT competencies to organize and process. If IT competencies can effectively interpret the information, a firm can quickly detect threats and opportunities for quick reaction. IT competence and IT infrastructure have been found to enable and facilitate the organizational agility in terms of entrepreneurial and adaptive agility both directly and indirectly (Chakravarty et al., 2013). Thus, we argue that the higher the IT competencies, the firm will have better ability in response to market forces or enhance the IT agility and propose the first hypothesis:

Proposition 2: IT infrastructure capabilities positively shapes the organizational agility.
Proposition 3: IT infrastructure flexibility positively shapes the organizational agility.

Many research have focused on the IT infrastructure and found that IT infrastructure is the core of IT competence and capability. One characteristics of IT infrastructure, IT infrastructure flexibility is becoming more important nowadays when IT infrastructure presents at every firms but to gain the flexibility, it takes more efforts and management.

IT infrastructure flexibility is measured in terms of scalability and adaptability (Bhatt, Emdad, Roberts, & Grover, 2010; Tallon & Pinsonneault, 2011). Scalability is the extent to which a firm can expand its IT capacity by upgrade or downgrade its hardware capacity, network bandwidth or software licenses. Adaptability is the extent to which a firm can utilize its current IT assets to support different IT needs. Sambamurthy et al. (2003) in their research have conceptualized scalability and adaptability as the reach and richness.

IT infrastructure has long been proven to be the core of IT competencies and influence and IT infrastructure flexibility were found to have direct with agility (Sambamurthy et al., 2003) and moderate the relationship between alignment and agility (Tallon & Pinsonneault, 2011). Within this research, we argue that IT infrastructure flexibility moderate the relationship between IT capabilities and IT ambidexterity with organizational agility. IT infrastructure is the fundamental of IT activities, it might lead to competence and agility of a firm but more importantly, the flexible ability to scale and adapt the IT infrastructure into business operations makes the firm better building the agility based on IT capacities. Thus, we propose as follows:

Proposition 4: IT infrastructure flexibility enhances the relationship between (a) IT infrastructure capabilities and (b) IT ambidexterity and organizational agility

Organizational Performance

Organizational agility can improve a firm's productivity and performance and building the sustainable competitive advantages (Sambamurthy et al., 2003). Firms with good agility have better ability to respond the market's changes and control the uncertainty (Benaroch, Lichtenstein, & Robinson, 2006). Such flexible and agile responses to market changes help firms outperform its rivals and quickly swift away from threats yet grasp the opportunities.

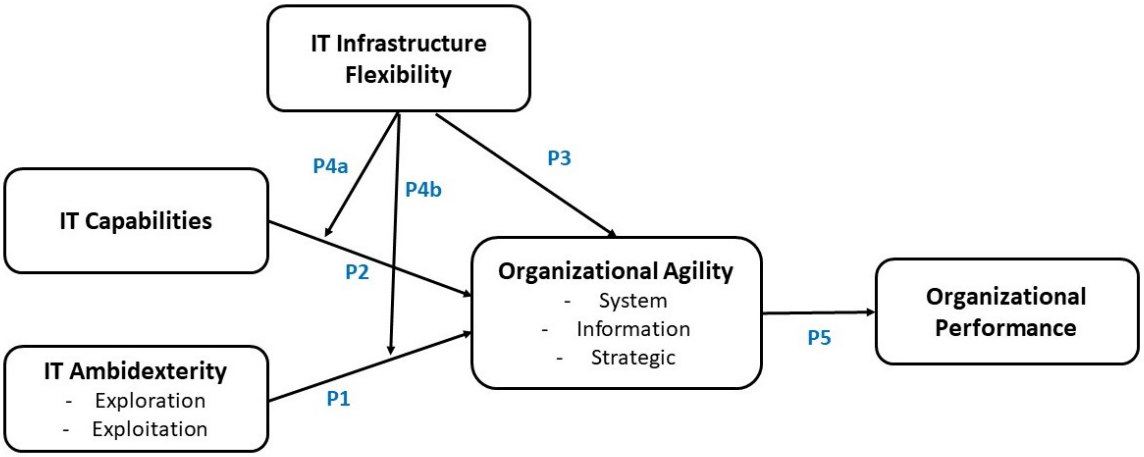
The exploration and exploitation factors of IT ambidexterity are characteristics of a learning and knowledge application process. In their research, Cegarra-Navarro, Soto-Acosta, and Wensley (2016) found that organizational agility facilitates the application of relevant knowledge into operations to improve the firm performance. Based on these arguments, we propose the final proposition as follows:

Proposition 5: Organizational agility has positive influence on organizational performance

CONCEPTUAL FRAMEWORK

Figure 1 below illustrates our proposed conceptual framework, how organizational agility is formed via IT capabilities and IT ambidexterity while IT infrastructure flexibility aside from directly forming the organizational agility, moderates the former mentioned relationships; and increase in organizational agility in turn raises the organizational performance.

Figure 1: Conceptual framework



Construct Measurements

Table 1 below summarizes the proposed measurements for each construct as well as the adopted sources. All question items are measured by 7-point Likert scale with 1 equals to strongly disagree and 7 equals to strongly agree.

Table 1. Construct Measurements

Factors	Items	Source for Adaptation
IT Ambidexterity Relative to other firms in your industry, please indicate the ability of your IT unit(s) to		
	Acquire new IT resources (e.g., new generation of IT architecture, potential IT applications, critical IT skills)	(Lee et al., 2015)

Table 1. Construct Measurements		
Factors	**Items**	**Source for Adaptation**
IT exploration capability	Experiment with new IT resources	
	Experiment with new IT management practices	
IT exploitation capability	Reuse existing IT components, such as hardware and network resources	
	Reuse existing IT applications and services	
	Reuse existing IT skills	
IT Capabilities Relative to other firms in your industry, please indicate the ability of your IT unit(s)		
	We have strong technical IT skills	(Chakravarty et al., 2013)
	We have adequate knowledge about IT	
	Our IT skills are comparable with the best in the industry	
	We invest heavily in our IT human resources	
	We have a good understanding of the possible benefits of IT applications	
IT Infrastructure Flexibility Relative to other firms in your industry, please indicate the ability of your IT unit(s)		
General	Our information systems are scalable	(Bhatt et al., 2010)
	Our information systems are compatible	
	Our information systems are adopted to share information	
	Our information systems are modular	
	Our information systems can handle multiple business applications	
Hardware compatibility	Software applications can be easily transported and used across multiple platforms	(Tallon & Pinsonneault, 2011)
	Our user interfaces provide transparent access to all platforms and applications	
	Our firm offers multiple interfaces or entry points (e.g., web access) to external users	
	Our firm makes extensive use of middleware to integrate key enterprise applications	
Software modularity	Reusable software modules are widely used throughout our systems development unit	
	Legacy systems within our firm do not hamper the development of new IT applications	
	Functionality can be quickly added to critical applications based on end-user requests	
	Our firm can easily handle variations in data formats and standards	
Network connectivity	Our company has a high degree of systems inter-connectivity	
	Our systems are sufficiently flexible to incorporate electronic links to external parties	
	Remote users can seamlessly access centralized data	
	Data is captured and made available to everyone in the firm in real time	
Organizational Agility		

Table 1. Construct Measurements		
Factors	**Items**	**Source for Adaptation**
Relative to other firms in your industry, please indicate the ability of your firm		
System agility	IT shared across the organization saves money by reducing system modification or enhancement costs.	(Fink & Neumann, 2007; Lowry & Wilson, 2016)
	IT shared across the organization allows other applications to be developed faster.	
	IT shared across the organization allows previously infeasible applications to be implemented.	
	IT shared across the organization provides the ability to perform maintenance faster.	
Information agility	IT shared across the organization enables faster retrieval or delivery of information or reports.	
	IT shared across the organization enables easier access to information.	
	IT shared across the organization presents information in a more concise manner or better format.	
	IT shared across the organization increases the flexibility of information requests.	
Strategic agility	IT shared across the organization enhances competitiveness or creates strategic advantage.	
	IT shared across the organization enables the organization to catch up with competitors.	
	IT shared across the organization aligns well with stated organizational goals	
	IT shared across the organization helps establish useful linkages with other organizations.	
	IT shared across the organization enables the organization to respond more quickly to change.	
Organizational Performance Relative to other firms in your industry, please indicate the ability of your firms		
	Our return on investment relative to objective is satisfactory	(Chakravarty et al., 2013)
	Our sales relative to objective is satisfactory	
	Our profit relative to goals is satisfactory	
	Our growth relative to objective is satisfactory	
	Our general success is satisfactory	

Besides the main questionnaire items, demographic information of the respondents and the characteristics of the firms where they are working at should also be collected as control variables for later analysis.

CONCLUSION

In the era of dynamic business environment, flexible and agile capabilities are becoming critical for firms, especially SMEs, to shape the competitive advantage and enhance the firm performance. Thus, instead of considering the static competence such as IT infrastructure, we propose to focus on the agile competences and flexibility as the key drivers in the capability building mechanisms.

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Business Process Management: A Car Reservation System Case Study

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ABSTRACT

Business Process Improvement can be a sustainable competitive advantage on the market place. In recent year, technology is the main drive to enable the reengineering process. In this paper, we use a highly competitive car reservation system as an example, to show how Gap analysis can build the links between process improvement and competitive advantage. The goal is to provide a practical case that can be used in graduate level courses for business schools.
KEYWORDS: BPM, Car Reservation Systems, Competitive Advantage

INTRODUCTION

The purpose of this case study is to provide an example of process re-design using BPM techniques and tools to achieve maximum value for the business. The case we studied is MSB Car Rental Company. This company provides a variety of vehicles where a customer can book a rental car online. MSB rental cars provide a unique experience to its customers with its nationwide infrastructure and enormous inventory that permits them to supply rental cars to the customers when booked online. With car rental business being fiercely competitive, the prices offered after considering many factors become extremely crucial for car rental business. To achieve this, the executive team has to showcase great vision, deliver superior products and provides resilience for high-quality service. The goal of this project is to improve the overall sales by 80% when compared to current process. If the sales on an average day is not even 25, our goal is to make at least 40 sales in a day.

THE DYNAMICS OF CAR RENTAL BUSINESS

Rental business or industry is one of the most challenging businesses due to competitions. Car rental systems are one of the most complex processes or business models in the car rental industry. In order to increase the sales and improvising swiftness in car rental websites, Information Systems has a crucial role. The process design of car rental business is a time-consuming procedure because it involves variety of factors such as location, time. It is also a heavily loaded system because many users are constantly trying to find the best prices of good deals for any given day. In this highly competitive market, pricing strategies and service quality

are critical success factors for car rental industry as they offer more and more products to the customer (George & Xia, 2011).

Capacity planning is another challenge in the Car rental business. For any car rental companies, determining the number of fleet of cars and allocating them in the appropriate stores is major operational design issue. Initially many organizations involve in vehicle sharing system, in such system many customers choose to rent car in one store, use the car for certain amount of time and return the car in another store according to their convenience. If the car rental organization has many stores and many vehicles, then managing such huge logistics and making them profitable is huge challenge. One of the primary concerns in enabling those system or program to be profitable is determining the range of fleets that needs to be stationed across all stores (Juan & Ou-Yang, 2004).

Internet reservation systems in Car Rental business has strategic significance, especially for price-sensitive market segment. By using the information provided over the internet, customers can compare the information of one car rental service provider with another and make optimal decision of the choosing the rental provider. Hence it becomes very important for car rental companies to have better customer service as they are looked up on the internet and if there are any negative feedbacks, customers might have reservations about choosing that particular car rental provider (Suriadi et al., 2014).

Subsequently, website and mobile app design become very important. Having a website but not able to navigate easily or not able to provide complete information will do no good for customers and sometimes customers don't even think of specific car rental due bad website and confusing design on their apps. Hence better design features along with easy navigation enhances the online reservation experience and for this to happen latest web technologies and tools must be utilized (Pazour & Roy, 2015; Juan & Ou-Yang, 2004; Suriadi et al., 2014).

Website and mobile app design is usually part of overall business process reengineering initiative. In order to increase the sales, organizations have to clearly understand the process workflow and identify the drawbacks. Integrating the customer requirements and providing additional resources along with present products in rental car business would do wonders to start off with for organizations (Fink & Reiners, 2015).

In car rental business, business process design is constrained by capacity management issues. It is very hard to manage cars and allocate them across various stores since they are all connected and interlinked to multiple groups, store networks and laying out minute details of logistics involves number of varied cases of rental car. At the same time appropriate governance policies and compliance should be in place for all the necessary regulatory requirements from the government (George & Xia, 2011; Pazour & Roy, 2015).

Safety and reliability are two important factors in managing user's expectation toward a web-based system. By providing great experience through website and apps, it creates a sense of safety and reliability among customers. It not only attracts the customers but gains trust among customers and enables them that the site is dependable. This positive experience with customers will increase the brand knowledge among the customers and increases their association to next level (Suriadi et al., 2014).

In addition to the efficiency and effectiveness of the business, process, our design goal also put customer satisfaction as one important evaluating criteria. Customer satisfaction differs from

dealing with online business to that of offline business. In addition to safety and reliability, convenience, ease of use (from the Technology Acceptance Model), availabilities (always online) are all relevant variables. Communication plays a very important role in achieving customer satisfaction at each level. As the customer plays the role of the ruler, the dynamics of the marketplace keep changing accordingly. The market deliberately acts a forum where customers play a dynamic role in creating and challenging for value. The main principle is to encourage customer participation to propose a logic that is service oriented for marketing. Companies need to study from and collaborate with their customers to create and identify values that meet every need. Consumer who undertake the value creation role as prosumers, who consume products eventually and bring out the consumer experiences. Basically, this is a cycle which starts with customers and ends with customers itself which determines the customer satisfaction levels (Chen, 2016).

BPM AS AN INITIATIVE

Business Process Management is a business solution which explains business as a set of processes and workflows. It is a software which enables the business to understand, analyze, execute, implement, monitor and optimize the processes. Implementing the right business process business management tool will always transform the organization. Business Processes is not something which it does to the organization but it is very core of the business. BPM is usually executed through graphical modeling. The graphical notations will help to understand the performance collaboration and business transactions between the organization which will in turn helps the organization to understand themselves and the participants so that they can adjust to the internal and Business to Business acts very quickly (Cochran, 2004).

There are three kinds of BPM frameworks.

1) Horizontal BPM Suite
2) Vertical BPM Suite
3) Full Service BPM

Horizontal BPM Suite: It is a framework which focuses on technology and reuse. It mainly deals with the design and development of business process.
Vertical BPM Suite: The ready to deploy pre-built templates are easily configured and used.
Full Service BPM: It carries all the features of the company where a process is required to achieve the goals.

BPM Model:

BPM Models primarily concerned with the mapping and workflow to enable and understand analysis or the positive changes. The primary step in analyzing the process is to create an outline of the current state. The As-IS map represents what happens, not what should happen or could happen. The main feature of as-is event is to recall the actual event.

Undertaking the Gap Analysis through four steps that is by understanding, and considering the holistic approach to the environment, determining the framework for analysis and finally compiling the data will help to obtain the complete information about the key areas to focus on the process or quality improvement project. Once all the possible reasons are studied and root causes are recognized the next step is to undertake the suitable action which can be identified to remove, fill and mitigate the gap.

The To-Be Process defines the future of the business process. It defines the concept of existing process and identifies if they are effective or need improvement. The analysis is to clarify how the business processes will work once changes are made. The changes made can be technological based or business changes (Estublier, 2003).

To provide better communication between customers and business entities. Customer Relationship Management should be included as part of the TO-BE system. Customer Relationships are strongly subjective to Information and Communication Technology (ICT) (Osterwalder, 2003).

MSB's main business strategy is cost leadership. Organizations who use this strategy has to ensure that their products meeting the minimum requirements of the customers, if not the company is forced to drop the prices of their products eventually loosing profits and slowly losing to the competition (Brown, 2013).

Most organizations misunderstand the concept of Cost Leadership. The problem is many organizations think to work the strategy by charging more for the product and the other by charging less for the product. Charging more works when the company is single mindedly focused on Cost leadership. Many organizations want to pursue this strategy by eventually end up aiming at low cost. With advancements in technology the companies acquire suppliers, parts and distributors but lesser costs than at the initial stages of business. However, they still charge more for their products, while on the other side of the spectrum are companies that take advantage of this technology to deliver similar or better products at a lower cost, thus gaining the market share by Cost Leadership.

To organizations that would like to use the cost leadership strategy for staying competent below are some key strategies to keep in mind.

- Companies need to lead on low price only when they can lead on low cost. This means companies have to make sure they can manage the low costs of production before going with the lost price strategy. If the company cannot manage low price, they need to have a lot of cash lying around to manage the organization standing in the market.
- Step into areas where the employees specialize in. For example, if the organization is packed with innovators, efficient engineers and knowledge workers, it is suitable for such firms to invest into R&D and create innovative products at a lower cost. This will enable the company to charge their customers less and thus attract more customers towards the brand.
- Organizations have to understand that to succeed some markets will force them to be a Cost Leader. In markets where the product yield is low and costs are certain, companies can focus on reducing the costs by making processes efficient and reducing the effort incurred. Suppose the company sells corn, the only way to earn market superiority is to sell corn at a lower price than the competition. There is not much the company can do to innovate with corn being their product and the only thing to do is cost leadership (Jacob, 2014).

GAP ANALYSIS

Gap analysis is an analysis which is helpful in identifying the gap between a company's original performances against the potential performance. In this particular sort of analysis, the association's present state or current state and future state or desired state are initially listed out alongside with the planning which tends to fill out the gapping between both those states. In

general gap analysis is performed to calculate and evaluate the performance differences to conclude and figure out whether the requirements are met or not. For an instance, if the business requirements are not met, then compulsory steps should be taken to make sure that they are met successfully.

State Description:

A. Current State: Each and every single Gap analysis tends to start with a self-analysis approach. Actually, every gap analysis layout is supposed to begin with a division called as 'Current state' and from there you further drill down the attribute that you would interested in. Gap analysis in general can be both quantitative and qualitative or both as well. The very important thing to examine in this analysis is weakness.

B. Future State: The future state in the gap analysis determined the final state or the desired state that you want your company to be in. keeping it short it can be highly specific or highly generic in nature. The table template that you record all the values for the gap analysis should record all the desired attributes that takes current state into picture. Sometimes you may not even have clear idea of the future state in that case just record the values as 'NA'.

Bridging the gap:

A. Gap Identification: The following area in your Gap examination format should record whether a gap exists between the present and future state. A fundamental "Yes" or "No" can suffice (a delineation of the crevice will be made in the following portion).

B. Gap Description: This specific area ought to record all the conceivable components that make a gap between current state and the future state. This specific portrayal ought to be sufficiently clear. This specific area ought to just give a depiction however not a cure

Variables and Remedies:

A. Factors in charge of Gap: This specific segment ought to be next a portion of format and ought to rundown all the capable elements that are in charge of Gap recognized in the past section.

B. Remedies: This is the last stride in the Gap examination and this segment ought to drill down all the conceivable cures that can cross over any barrier between the present state and the sought state or the perfect state. [8]

Improving Current Sales Process:

Since the current process in the company takes 18 minutes for the customer to book a rental car online and because of this time lag and on an average day the company is not even making 100 sales in a day. This is where the Gap analysis comes into picture. Gap analysis helps to

bridge the gap between the present state and the future state where the company has to identify the gap that needs to be filled.

Gap analysis is done in three steps. Notably

1. State description
2. Bridging the Gap
3. Factors and remedies.

As-Is model

The word as-is itself says that it is indicating the “Current figure/situation” and it shows that the results are to be improved. As-is model helps us in identifying the current problem and the following factors. Based on that the problem can be solved and the process can be improved. I would like to give a simple example, Let us suppose there is a manager who is responsible for managing particular project. In order to go forward with the project implementation the manager communicates with the clients and gathers all the requirements in the form of a document. Once the as-is document is ready, based on that the to-be document is prepared.

AS -IS process

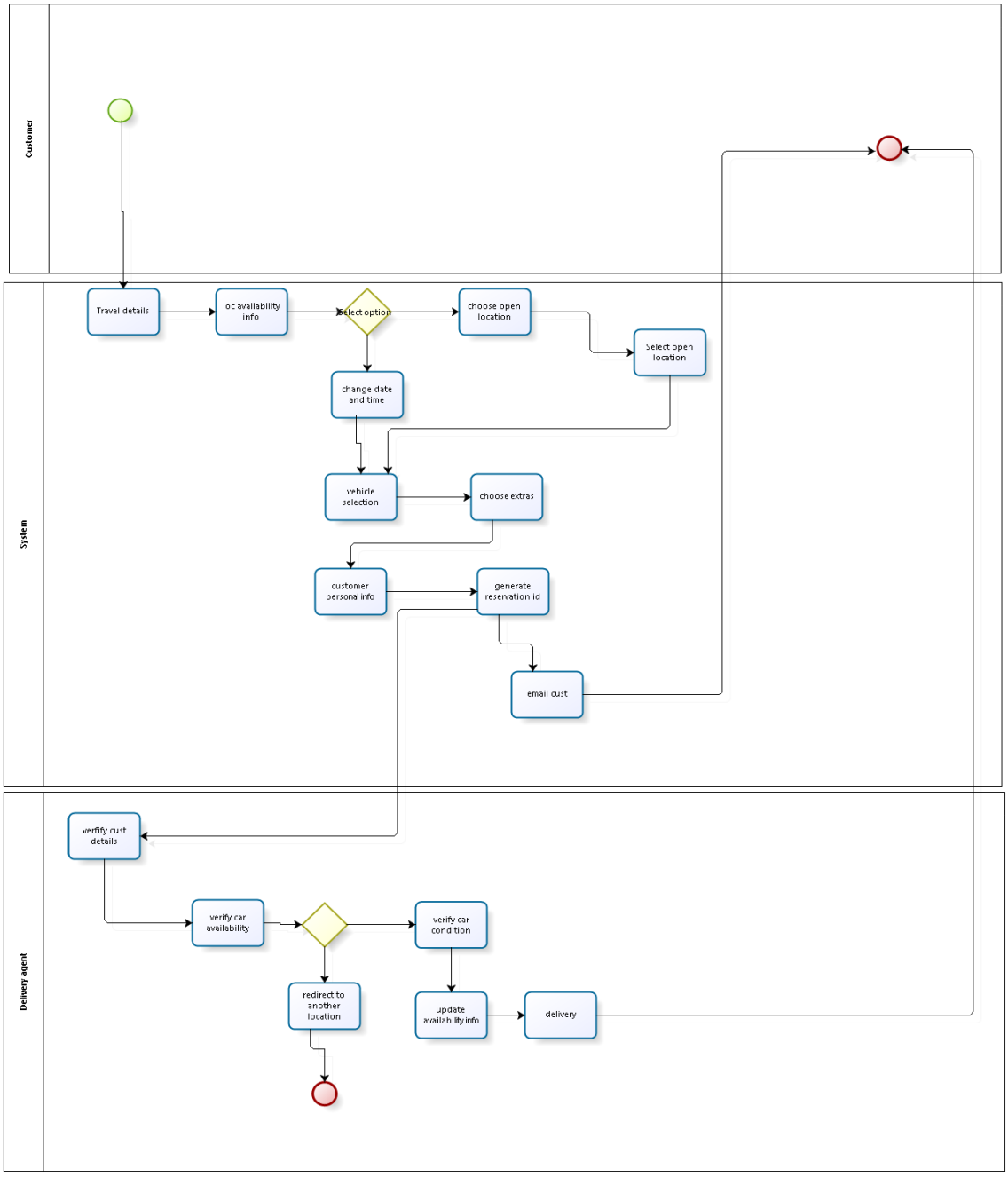
Figure 1 is the process map using BPM 1.0 Notation stating the As-Is model of the design of automated car reservation.

In this process there are three players involved which are Customer, System and Delivery agent. In a typical As-Is model, we capture the existing process which is in the current production. The process initially starts from the customer swim lane, the customer initially enquires the system with desired travel details and then proceeds to the next task i.e. Location availability information. In the next step customer gets a choice to decide between two dimensions whether to choose an open location or change date/time dimensions. If a customer selected an open location dimension then the next step is vehicle selection where the customer can select a vehicle based on their preference and then can select additional accessories by selecting an option “choose extras”. The customer needs to provide personal information and submits the form, a reservation id is created through this process which sends an email to the customer .In the backend, the process flows through the delivery agent .The delivery agent verifies the customer details and then verifies the availability of the car ,verifies the car condition ,updates the availability information and then deliver to the customer .If the car is not available then the delivery agent redirects the reservation to another location which is other sub-process that is to be followed.

To-Be model

The To-Be model integrates the business model into the additional systems that are necessary to get an analysis of As-Is model which optimizes them. The revisions and analysis are done until improvements are resulted from analyzing To-Be model. Numerous organizations are emphasizing "changes" in different perspectives consistently, yet it is unrealistic to accomplish compelling "enhancements" without unmistakably understanding the perfect circumstance and distinguishing issues to be understood to fulfill that objective. To-be precisely implies the focused on perfect circumstance, which is an extreme objective. Then again, As-Is means the present circumstance. Enhancing exercises are characterized as exercises to persuade nearer To-be from As-is.

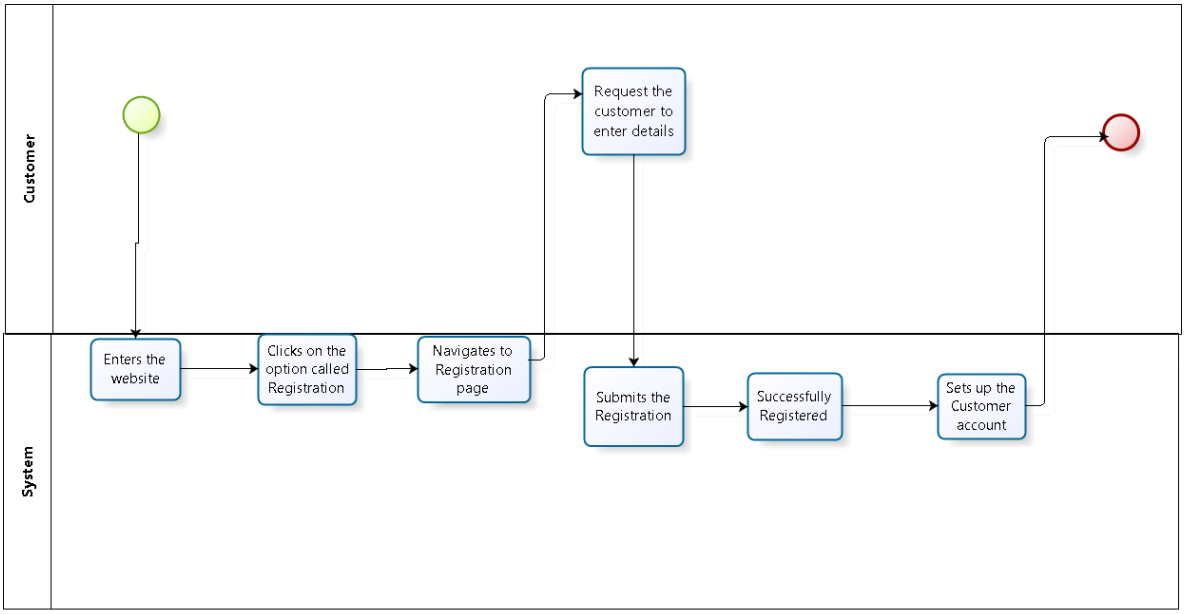
Figure 1. AS-IS Model



To-be solution

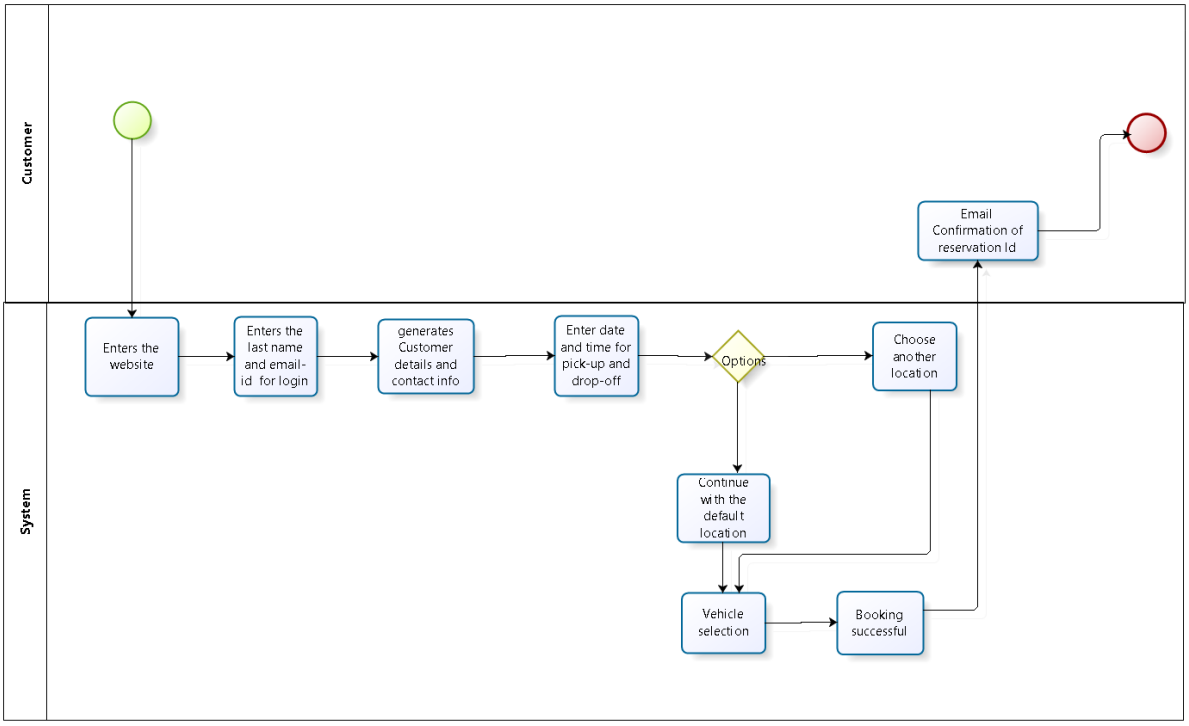
In the To-be solution we are going to introduce a feature called “User Registration”. When a customer enters into the website, person will see the option to register and become as a member of the organization. After the register option is clicked, the person will be redirected to the registration page where his details are asked. The details include primary details, location details, contact information. Primary information includes, first name, last name, license number, date of birth. Location information includes permanent address location of the customer and also the pickup location priorities where the customer is asked to enter his top 4 prioritized pickup locations where he actually rents a car from. Then the third set of details asked for are the contact details which actually include, email address and contact number. Once the registration is done the customer gets his account set up with the organization and he get benefits for being a member. The above approach is going to save ample amount of time for a customer while doing a car reservation. The above process is going to reduce the booking time by not asking customers to enter their personal information and location information. Figure 2 is the process map which depicts only the process which is related to Registration of the customer.

Figure 2. Registration of the customer process



After being a registered customer, it is so easy process to book a car. The customer has to enter his last name and email id to login to the account. Once the customer is logged in the primary details and the contact information is automatically seen. Three things that a customer should choose are, first, pickup and drop off dates. Second one, pickup location from the drop down of preferred locations. If the customer wants a complete new pickup location then he has an option of entering a new location from the drop down. Third one, type of car. After all these steps are completed the customer will receive an email confirmation that the car is booked. Figure 3 is the process map about how the booking process flows when a registered user book a car.

Figure 3. Booking Process



By implementing this process, both customers and organization is beneficial. Customers get good rewards, deals and discounts for being a loyal member and organizations get reputation alongside with good business because of huge members.

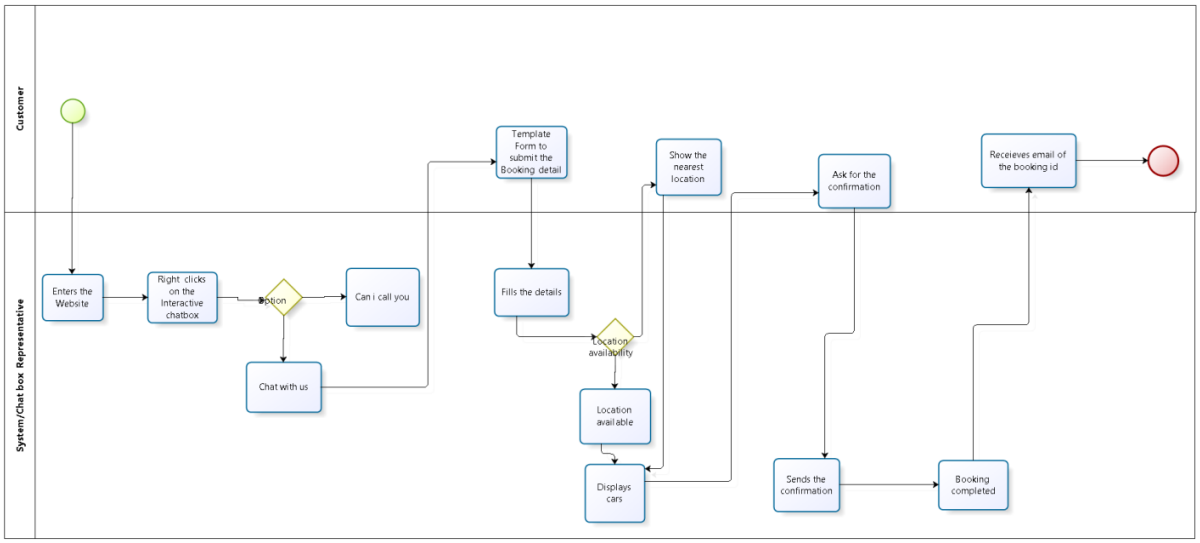
Implementation of a live chat support system:

When a customer visits the website, the person comes across a chat box at the bottom right position called Interactive Box where the customer can talk to the representative to book a rental car. When the customer right clicks on this chat box there will be two options available. One is “chat with us “ and the other options is “can I call you?”. The customer can choose any of these two options where a representative interacts with the customer who books a car on behalf of the customer.

When the customer clicks on Chat with us option, it unveils a rich Textbox where the person can chat with the customer. Here, a pop message is displayed saying that how can the representative assist the customer and answer the questions. The representative sends a template form in the chat box where the customer can fill in the details such as Location, date and time for the pick-up and drop-off and the type of car (Standard/Intermediate etc.). The representative immediately responds to the form, If the requested location is not available then the customer instantly recommends a nearest location and displays a list of cars based on the request .When the customer confirms with the price quoted then the representative will go ahead, submits the request in the backend and confirms the booking.The customer receives a booking id via email and the process flows through the delivery agent as mentioned in the as-Is

process. Figure 4 below explains the process when the customer selects the option called “Chat with us”.

Figure 4. Chat with us process

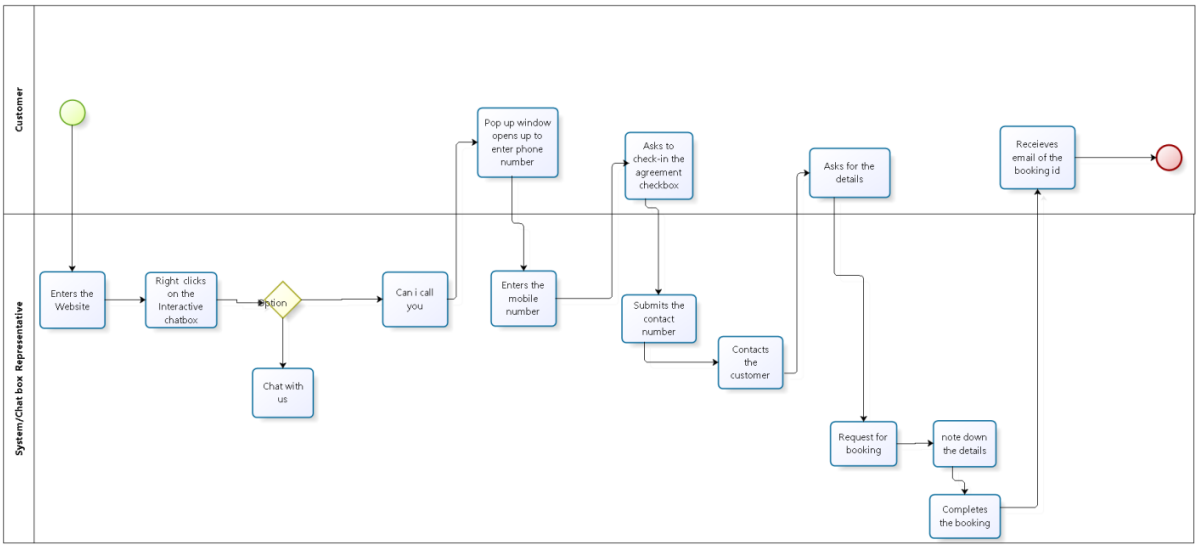


If the customer rights clicks on the option called “Can I call you?” A pop up window opens where the customer has to enter the phone number and click agreement checkbox saying that our company is authorized to make a phone call and then submit the request. The representative contacts the customer over phone, takes the details and does the booking for the customer. The customer receives a booking id via email and rest of the process is same. Figure 5 below explains the process when the customer selects the option called “Can I call you?”

This Interactive chat box can be used both for the new customers as well as the existing customers. By introducing this feature, we are completing the booking process on behalf of the customer where they don’t have to navigate through each and every page of the website to complete a booking.

In all these process maps we haven’t included about the how the flow of events work with respect to the deliver agent since ,it is similar to the As-Is process and there are no changes made with respect to the delivery agent.

Figure 5. “Can I call you?” process



Gap Analysis of the scenario:

Table 1. Gap Analysis

FUTURE STATE	CURRENT SITUATION	REMEDIES/PROPOSALS
1. Sales should be more than 40. 2. The website can be accessed by the prospective users as well as the current users. 3. The booking should be flexible and should not be more than 7 minutes. 4. Recommend a nearest possible location when the requested location is not available	1. Sales are not even close to 25. 2. There is no concept called registered users. 3. It takes 15-18 minutes to complete a single booking. 4. The customer has to go back and navigate the webpages and select another location or change the date/time when the preferred location is not available.	1. Developing a user interface by changing the existing website to a major extent. 2. In order to improve the efficiency and increase the sales on an average day. Providing special discounts to the registered users is a new strategy that can be implemented. 3. Introduce a new feature called live support chart with the help of which a customer can communicate better.
1. A additional cost should be spent on purchasing and integrating the required software	1. Costs are with respect to the existing process. 2. No Proper assessment or	1. Use of Standard help-desk solutions or any other live chat tools should be integrated to communicate with

which will ultimately result in increasing the sales. 2. Improving the customer relationship	customer service provided.	the customer. And also .the live analytics to gain further insights on the visitor's. 2. Technical team is responsible for the flow of events and teamwork is important when working with different departments.

RECOMMENDATIONS

Scope Clarification:

As per our analysis, the process change is a bit difficult as it involves major changes in the user interface and implementing a different approach which changes the way we communicate with the customer's. It is quite difficult to change the entire architecture as there is some cost involved with respect to the enhancements in the existing process. This kind of investment is a must in order to stay ahead of our contemporaries in the market. The additional features that we have presented in our solution will improve the overall efficiency.

In order to add additional features and Redesigning the current process there has to be the required scope to do that. Re-designing the whole process is a bit difficult since it is time consuming and expensive. When the scope is limited, the better way is to change the existing process step-by step by focusing on one particular enhancement at a time.

If MSB organization has to re-design their entire current process, then working on the scope clarification and provided process improvements is the only way to go. Overhauling the entire current process to new process and deploying the new process at once would create lot of disruptions in operations and possibly might not deploy as expected which can also prove to be expensive. MSB cannot afford to lose revenue because of failed process deployment or for any other reasons since their sales progress is as it is very bleak. Having scope clarified incrementally can help MSB organization to address one concern at a time and eventually deployment of re-designed process can be accomplished easily.

CONCLUSION

In our scenario, initially we have identified important elements like the turnaround time and process flow for a single booking reservation to improve the process. We have implemented the Gap analysis model using which the gaps were identified in the current process. While doing the Gap analysis, we have realized that the content of the website should answer all the questions with respect to the customer within a specified time and that is the reason why we have implemented the Live support system in the website using which there will be a two-way communication between the customer and the representatives of the organization.

By implementing the above AS-IS model, the sales target for a day would be considerably increased and even the addresses the concerns of better UI for the website and its content. The

Live support system would also include call option using which the customer can speak to the representative instantly and need not explain the entire scenario to new representative.

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CABALONGA AVENTURA ECUADOR: SEEKING SUSTAINABILITY AND SELF-SUFFICIENCY

4 AM, Sunday, November 12, 2017. As Diego Losada-Vasquez, co-owner of *Cabalonga Aventura Ecolodge* boarded the bus to begin his twelve hour commute from the seaside village of Puerto Cayo to the Ecuadorean capital, Quito, he reflected on the past twenty four hours he had spent entertaining his guests. His business partner, Maria-Elena Alvarado-Villon had met a group of university students from Canada at the international airport in Guayaquil around 1 AM Saturday morning, to accompany them on the four hour ride to the beach resort lodge that she and Diego had established in Puerto Cayo. She returned to Guayaquil later that same morning to begin a twelve hour shift with Latam Airlines, where she worked as a flight attendant. Diego arrived at Cabalonga a few hours after Maria-Elena had left and entertained their guests until early Sunday morning when he began making his way back Quito for work. During the four years since Cabalonga was established, it had never turned a significant profit, while occupying 40 to 50 hours of Diego's 90+ hour work week. Diego wondered how to make the business more financially sustainable, and to alleviate the burden on himself and Maria-Elena.

Diego, Maria-Elena and Cabalonga

Diego Losada-Vazquez grew up in Ecuador's largest city, Guayaquil. He had a happy and fulfilling childhood, blessed by his family's relative prosperity in the largely agrarian economy of Ecuador. He attended good schools and graduated from a top university, along the way becoming one of a minority of Ecuadorians fluent in the English language. His mother grew up in the highlands city of Jipijapa, a thirty minute descent from the Andes Mountains to Puerto Cayo on the coast, where her family owned beachfront property. Upon graduating from university, Diego entered the workforce where, in 2007, he met Maria-Elena. Together they decided to start a business based on their shared love of nature, adventure and travel. Perennial entrepreneurs at heart, the pair has several more business ideas in mind, but are not ready to take them forward until their hostel is running without their constant attention.

Like Diego, Maria-Elena Alvarado-Villon (known simply as Ma-Elena by many) was also a native of Guayaquil. As a child she remembers playing happily, and always fantasizing about travel. Her playful and positive disposition is readily apparent, as her effervescent personality constantly bubbles over into exclamations of 'It's really great!' As Ma-Elena grew up, she knew she didn't have the resources to achieve all her dreams, and so she had to plan carefully and commit fully to anything she chose to do. She graduated from university with a degree in Business Administration, intent on one day opening a business. While she had little opportunity to travel when she was younger, it was now her full time job at Latam Airlines, where she works as a flight attendant. Passionate about snorkeling, kayaking and diving, Ma-Elena explains that "Diego brings the nature to our business, and I bring the adventure." She is sociable, loves entertaining and loves spending hours sharing travel stories with her guests at Cabalonga.

The Founding of Cabalonga Aventura Ecolodge

Diego had many fond memories of his time spent on the beach as a child, during summer vacations from school, eating fresh fruit picked from the trees, spending nights by candlelight, watching crabs running about the tranquil beach. He would spend up to three hours with his family in the waters of the Pacific Ocean, followed by lunch at local restaurants. When his father passed away, he inherited part of the family's land in Puerto Cayo. He and Ma-Elena originally planned to build a small vacation house on the beachfront property, but the demands of work and travel left them with little time, and so they decided to build a hostel instead.

While Cabalonga was still just an idea, Diego and Ma-Elena participated in a contest organized by the national government to encourage local entrepreneurship. Cabalonga was one of the 200 winners out of 2,000 submissions. One reason they won was that the government was, and still is, trying to promote tourism in order to build the economy. Moreover, their project was situated in a rural community that did not usually attract tourists, despite being on the popular *Spondylus* seaside route. Winners were to make a payment to the government and receive help developing their business plan, but since Ma-Elena had graduated from a business administration program, she decided to complete it herself. The main value of this competition was that it helped Diego and Ma-Elena realize that the idea was viable and attractive. When reflecting on this experience she says "this was a wonderful idea, it still is. That is why we won."

In 2013, the young entrepreneurs obtained a small bank loan, which they anticipated paying off by the end of 2018, and Cabalonga S.A. was founded, with ownership split evenly between the two. Meanwhile they continue to invest their own money to improve the property, with plants and water saving devices. In Ecuador, the S.A. (Sociedad Anonima) legal designation is typically used by large companies to create private, joint stock companies, but there isn't any similar legal figure yet for smaller businesses. Due to this, Cabalonga must remit several taxes, including a 12% VAT, retain an accountant to audit its books and, as well as meet other legal requirements. María Elena says that it is a huge challenge, but also better positions them for growth.

In April of 2016, a 7.8 Mw earthquake devastated buildings in part of the province of Manabí, and the Minister of Tourism subsequently called Cabalonga seeking help with the relief efforts. Cabalonga received owners of different hostels and hotels that had been destroyed by the earthquake and taught them how to recreate the Cabalonga business model as a means to restore some capacity in the reeling tourism industry. In exchange, photographers were sent to Cabalonga to create promotional material, although more than a year later Diego and Ma-Elena have yet to see the results. As part of the relief effort, the national government raised VAT from 12% to 14% for all businesses in the country, except those in the provinces of Esmeraldas and Manabí, which were to receive the extra taxes to fund rebuilding efforts. Having escaped the earthquake unscathed, mainly due to the simple, resilient design of its structures, Cabalonga did not receive any of the additional tax money.

Mission and Vision

Mission: "We will make your stay a unique ecoadventure experience in Ecuador"[1]

Vision: "Being one of the most innovative eco-tourism hostel franchises of nature and adventure in South America, which offers a comfortable stay, and unique and enjoyable experiences for our visitors.[2]

The founders' *eco-mission* is evident in their design and operation of Cabalonga. Other than the 'furnished' tents used to house guests, the compound is made almost entirely of bamboo and palm leaves, with some concrete pads for the main structures. Rain and used water is recycled to irrigate the plants and trees growing on the property. These include trees such as banana, mango and papaya, along with oregano and mint used to season meals made in the small, quaint, bamboo kitchen. Likewise, kitchen waste is composted to reinvigorate the soil used for growing. Cabalonga runs campaigns such as "save the turtles, no cars on the beach" to gain attention for causes which Diego and Ma-Elena feel connected to. It feels good to do be doing something, and their efforts have created feelings of solidarity amongst the Cabalonga staff, who themselves are able to influence the opinions and behavior of the local community. The many efforts of Cabalonga, especially their policies of hiring workers and sourcing food locally, have earned them an *Eco Lider Bronze* certification by Tripadvisor. They continue to improve their environmental impact with the goal of eventually obtaining Gold certification.

Cabalonga has achieved steady growth in revenues since 2016 (see Exhibit 1). In 2017 revenues grew approximately 22% and the owners expected an equal growth in 2018.

Infrastructure and Operations

The 1350 meter^2 site hosts a bamboo structure comprising the administrative office, storage and utility room, kitchen, bar and two covered patios; one for dining, the other located next to the bar which was housed in the same simple structure as the kitchen. Two bathrooms each for women and men shared the main structure, one of each equipped with warm showers. The bamboo and palm used in construction not only lowered the environmental impact of the structure, but was also necessitated by the entrepreneurs' limited finances.

Lodging consists of four small tents accommodating couples or 'lonely' travelers, and four larger tents with two beds for groups and families. Each tent has hammocks in front, and is protected from the wind and rain by a three-sided, roofed bamboo and palm leaf structure. For guests preferring more privacy, there is also a bamboo guest house with accommodation for up to four, which boasts a private bathroom. In total, there is lodging for 28 guests, plus an additional six travelling with their own tents. Once or twice a year a large group will arrive while touring the coast, forcing the owners to turn away additional guests, but typically the hostel doesn't operate at full capacity.

[1] http://cabalonga.com/index.php/en/about-us-2
[2] ibid

All accommodations include electricity, bedside tables and free Wi-Fi. The compound is fully enclosed within a bamboo fence, with two gates offering a security and privacy. Typically the gates are locked only at night.

All meals are made from locally sourced fish, shrimp and vegetables, especially the ubiquitous plantain. Using local foods is not always cheaper than shopping in grocery stores, but produce grown locally tends to be fresher and is often grown organically. Shrimp in Puerto Cayo is of the highest quality available in the country. Meals are provided to guests, as well as to anyone else stopping in. Sample pricing and costs information for meals is provided in Exhibit 2.

Tours

Cabalonga arranges transportation and/or guided tours of attractions in the surrounding area. It is located close to popular destinations such as Pacoche (30 minutes), Agua Blanca in Machalilla National Park (20 minutes), and the city of Jipijapa in the highlands (30 minutes). Numerous activities can be arranged, including snorkeling, diving at Isla de la Plata, and whale watching tours. Currently a total of 22 programs are offered to guests and other tourists. Since costs are negotiated with guides and tour operators, Cabalonga is able to earn a small margin on the sales, while tourists receive a discount. In addition, taxis in Puerto Cayo meet tour buses to offer rides to Cabalonga for $1.

Due to the extensive use of flat fees, there are significant economies of scale for larger groups, or when accommodating multiple guests. For example, one trail guide charges a flat fee of $20 regardless of the number of guests on the tour. Roundtrip transportation for this particular tour is $35 for a taxi (up to four people) or $60 for a bus to accommodate larger groups. Diego and Ma-Elena have considered operating their own tour boat, but ultimately decided the payback period was too long. They also feel bound to their operators in the region, considering them part of the extended Cabalonga ‘family’. While staff are able to book tours for guests that had not reserved them, standalone prices for tours are not always available, and it is difficult for the staff to therefore come up with a price without consulting the owners. Cost and pricing for tours is depicted in Exhibit 3.

Hospitality

Hospitality at Cabalonga is comprehensive and free, with the proprietors attending to any and all needs of their guests, in person or via email, phone or WhatsApp when not on site. It is not unusual for Diego or Ma-Elena to host karaoke parties, tell fireside stories and play guitar. Following each dinner, a complimentary cocktail is offered, made from local fruit juices and Ecuadorian spirits.

The staff can accommodate most visitors independently, but it is a challenge when they are not Spanish speakers. Maria-Elena and Diego spend about 40% of their time at Cabalonga and hospitality is not quite the same when they are not there. Nonetheless, they are constantly in touch with their guests via phone, text and social media to ensure their stay meets their expectations. Ma-Elena is the primary interface with local suppliers, challenged by her

unpredictable work schedule at LatAm. She accomplishes this by conducting business via text messaging and working with all invoicing 'in the cloud', literally and figuratively.

Sales and Marketing

Diego is primarily responsible for bookings, sales and marketing. He works from 8:30am to 6pm Monday through Friday in Quito. During the workday he takes calls about Cabalonga and in the evenings, manages promotion, publicity and bookings from 7pm to midnight, manages the Facebook (about 15-20 threads with about 100 messages requiring responses daily), Twitter and Instagram accounts, booking guests and so forth. Both owners' cellphone numbers are provided in all advertising and they take business calls and text messages through WhatsApp. Social media is the primary mode through which customer satisfaction is monitored, and Diego will personally respond to all compliments and complaints.

Cabalonga maintains a website (cabalonga.com) that lists pricing information, activities and contact information, as well as links to the Facebook, Twitter, YouTube, Instagram, TripAdvisor and a blog spot pages. Diego takes bookings directly, or they can be completed through Booking.com or Priceline. Tripadvisor rates Cabalonga "#1 of 5 Specialty Lodging in Puerto Cayo" based on ratings posted by guests.

Promotions are rarely used. At one point, Diego offered a free night at Cabalonga but there were no takers. He decided that since discounts are not effective, he focused on creating awareness and curiosity amongst more adventurous travelers. There are no radio or television campaigns and no plans for them. Diego estimates that for $400-500 he could reach about 9,000 to 20,000 people in three days. With Facebook, he reaches the same number of people for a mere $20.

Staffing

The first employee hired by Diego and Ma-Elena did not work out, having made several rather large mistakes that resulted in substantial losses for Cabalonga. They worked with the Ministry of Puerto Cayo to find employees, eventually hiring Johnny, who Diego describes as "a good father, son, fisherman, he is everything!" Johnny selected Nicole and later her sister Yomaira. Together these three are the full time custodians of Cabalonga, cooking meals, entertaining guests, and performing maintenance. There are two part time staff, Diana and Penelope.

Many people from abroad (Colombia, Venezuela, etc.) have acquired about working at Cabalonga, but the policy is to hire only from Puerto Cayo and neighboring communities so as to retain the EcoLider certification. Indirectly, Cabalonga provides income to tour operators, guides and transportation (buses and taxis of various sizes available as needed). In addition to those working directly for Cabalonga, other families in the community have an opportunity to generate small incomes, by purchasing food and running errands, hiring tourist guides from the same region, transportation, maintenance charges and other services which contribute to economic development in Puerto Cayo. The total labor costs for these staff are $2,334 per month, though the salary cost is only totaled at $1,382.50[3]

[3] Cabalonga company documents, 2018

The Ecuadorian Tourism Industry

Tourism is a growth market. Younger generations are more likely to spend their vacation time and money abroad than staying at home. To capitalize on this, many countries, including Ecuador, have invested substantial funds in developing their tourism sector. Ecuador's largest industry is petroleum, at 5.96% ($5.83B), while tourism accounts for 5.1% of GDP ($5.1B).[4] In 2016, Ecuador invested $1.2B into developing their tourism sector. Tourism is forecasted to continue to rise by 4.5% per annum until 2027, topping out at 9.4% of total GDP.[5]

Tourism accounted for about $5.7 billion US, or 5.5% of Ecuador's GDP in 2015. The industry grew from 684 thousand employees in 2007 to 732 thousand in 2015, and revenues have increased over the same period from $626 million US, providing a 12% CAGR.

In 2013, Ecuador tourist arrivals came in at 1.36 million. From 2014 to 2016 this declined from 1.56 million to 1.42 million, with the decline attributed to the devastating earthquake on April 16.[6] The total receipts from tourism in 2014 was 1.25 Billion, peaking at 1.56 billion in 2015 and dropping to 1.45 billion in 2016.[7] International tourist arrivals are forecast to reach 2.8 million by 2027.

In 2015, of the 1.55 thousand tourists visiting Ecuador, 225 thousand were specifically visiting the Galapagos National Park. Seven countries accounted for over 70% of all international tourist: the USA accounted for 37%, UK 8%, Germany 6%, Canada 6%, Australia 5%, Argentina 4%, and France 3%.[8]

One of the ways that Cabalonga stands out is there commitment to being environmentally sustainable. Ecotourism has grown to become a trend worldwide, especially in South America. While lacking a precise definition, ecotourism involves environmentally friendly and sustainable accommodations, and nature-based activities such as fishing, hiking or boating. Most also involve local cultural experiences. The overall philosophy of ecotourism is to leave a site the same or better than you found it.

For Cabalonga, the months of January, May and November are considered low season because in January people tend to have reduced purchasing power after the holiday season and the continuation of the school period. May and November are months in which children return to

[4] AJG Simoes, CA Hidalgo. The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence. 2011, accessed May 19, 2018, https://atlas.media.mit.edu/en/profile/country/ecu/.

[5] World Travel & Tourism Council, *Economic Impact 2017 Ecuador*, 1;6;7;9, March 2017, accessed May 19, 2018, https://www.wttc.org/-/media/files/reports/economic-impact-research/archived/countries-2017-old/ecuador2017.pdf.

[6] World Travel & Tourism Council, *Economic Impact 2017 Ecuador*, 1;6;7;9, March 2017, accessed May 19, 2018, https://www.wttc.org/-/media/files/reports/economic-impact-research/archived/countries-2017-old/ecuador2017.pdf.

[7] World Bank, DataBank Ecuador, accessed May 12, 2018.

[8] Juan Carlos Izurieta, "Behavior and trends in tourism in Galapagos between 2007 and 2015," *Galapagos Report 2015-2016* (2017): 83-85, accessed May 21, 2018, https://www.galapagos.org/wp-content/uploads/2017/12/3-GR-2015-16-Tourism-section.pdf.

school, and is the beginning of the rainy season when travel is less desirable. The months of February, April, June, September, October and December are considered medium season because occupancy is higher, at about 20%. This is due to holidays in February and December, the beginning or end of the whale watching season which is also the beginning of summer vacation period in the US (June and July).

The high season results in about 60% of occupancy because it takes time to develop a good market position and there is currently little developed tourism in Puerto Cayo. July and August are considered the high season, due to the highland region vacation time, and the whale and giant stingray sightings. Taking into account the different seasons, the annual occupancy of Cabalonga is 40%.

The monthly number of travellers booking various Cabalonga accommodation and/or tour packages is shown in Exhibit 4.

Hostels in Puerto Cayo

About nine hostels operate in Puerto Cayo (population 5,000) but Cabalonga is the only one which is open all year round, and offers personalized 'high touch' service by the owners. Other hostels are rarely visited by their owners and have been in operation for as many as 25 years. These businesses are neither growing nor contributing to the growth of the local economy.

Diego estimates about 75% of guests are from Ecuador, another 5% from Spanish speaking countries such as Colombia and Venezuela. The other 20% are international travelers from Asia, North America, Europe & Russia. Most international travelers book through Tripadvisor. A lot of the marketing is by word of mouth, primarily in the form of social media.

Conclusion

As Diego's bus wound through the mountains and into the rising sun, he realized there would be little chance for sleep until he arrived back in Quito later that evening. He was in the business of hospitality, with a strong personal touch, but he wondered if there was a way the business could be more self-sustaining so that he and Maria-Elena could squeeze in the occasional vacation for themselves. While creating an enterprise that could be independently run by the staff was his main priority, Diego had to acknowledge that a bit of income also wouldn't hurt, given the amount of time and effort he and Ma-Elena had put into the venture. And then there was always the call of their many other business ideas.

EXHIBIT 1: CABALONGA S.A. 2017 INCOME (US$, Company Documents)

Revenue	93,869
Direct Costs	40,960
Gross Margin	52,909
Overhead	
Employee salaries	28,001
Managers' salaries	4,800
Occasional help	3,000
Utilities & supplies	5,412
Auditing	3,000
Maintenance	1,200
Advertising	3,600
Total Expenses	49,017
Earnings	3,893

EXHIBIT 2: CABALONGA MENU OF MEALS, 2017 (Company Documents)

Meal	Price ($US)	Cost ($US)	Margin (%)
Fish Ceviche	6.70	3.35	50%
Seafood Rice	8.93	4.46	50%
Garlic Shrimp	7.59	3.79	50%
Shrimp Ceviche	7.59	3.79	50%
Fish Crackling	6.70	3.35	50%
American Breakfast	4.02	2.01	50%
Manabita Breakfast	4.96	2.48	50%
Fillet of Corvina	6.70	3.35	50%
Lobster	16.07	8.04	50%
Cheese	3.13	1.56	50%
Shrimp Rice	7.59	3.79	50%
Breaded Shrimp	7.59	3.79	50%
Steak and Wine	6.70	3.35	50%
Fried Chicken	4.46	2.23	50%
Grilled Fish	6.70	3.35	50%
Fish Al Pesto	6.70	3.35	50%
Steamed Fish	6.70	3.35	50%
Plantain Stew	3.57	1.79	50%
Toast	1.34	0.67	50%
Average	$6.51	$3.26	50%

EXHIBIT 3: CABALONGA PACKAGES AND TOURS, 2017 (US$, Company Documents)

	Accommodations	Meals Included	Price	Cost
Lodging-only Packages				
Beach Package: 1 night	Tent	All Meals	$ 34.82	$ 10.00
Romantic Package: 2 days 1 night	Bamboo Hut	Seafood dinner, wine, Breakfast	$ 116.07	$ 34.00
Relaxation Package: 2 days 1 night	Tent	Breakfast	$ 15.00	$ 2.50
Tour + Lodging Packages				
Snorkeling and Kayak tour: 2 days, 1 night	Tent or without lodging	All Meals	$ 74.82	$ 27.25
Los Frailes Beach and Snorkeling tour: 2days, 1 night	Tent or without lodging	All Meals	$ 69.82	$ 26.55
Whale Watching and Isla Salanga Beach: 2 days, 1 night	Tent or without lodging	All Meals	$ 79.82	$ 33.14
Whale Watching and Isla Salanga Beach: 3 days, nights	Tent or without lodging	All Meals	$ 111.07	$ 43.14
White Water Aqua Blanca, Cultural tour and hot spring: 2 days, 1 night	Tent	All Meals	$ 60.82	$ 35.00
Isla de la Plata Snorkeling: 2 days, 1 night	Tent or without lodging	All Meals	$ 95.82	$ 59.50
Isla de la Plata Snorkeling: 3 days, 2 nights	Tent or without lodging	All Meals	$ 127.07	$ 69.50
Machalilla National Park horseback riding and camping: 3 days, 2 nights	Forest Camping and lodging at Cabalonga	All Meals	$ 103.25	$ 38.50
Machalilla National Park horseback riding and camping: 2 days, 1 night	Forest Camping Tent	All Meals	$ 69.82	$ 33.50
Four island, aquatic adventure, snorkeling and kayaking: 3 days, 2 nights	Tent or without lodging	All Meals	$ 141.07	$ 80.00
Four island, aquatic adventure, snorkeling and kayaking: 2 days, 1 night	Tent or without lodging	All Meals	$ 109.82	$ 73.75
Pacoche Forest, Monkey Wildlife Refuge tour: 2 days, 1 night	Tent	All Meals	$ 69.82	$ 40.00
Horseback riding tour Machalilla National Park: 2 days, 1 night	Tent or without lodging	All Meals	$ 81.79	$ 66.25
Bike tour, monkey sighting: 2 days, 1 night	Tent or without lodging	All Meals	$ 55.82	$ 17.50
Los Ahorcados Scuba Diving: 2 days, 1 night	Tent or without lodging	All Meals	$ 129.82	$ 75.00
Isla de la Plata Scuba Diving: 2 days, 1 night	Tent or without lodging	All Meals	$ 199.82	$ 155.00

EXHIBIT 4: 2018 TOUR / ACCOMMODATION DEMAND FORECAST (Company Documents)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Lodging Packages													
Beach	20	20	20	20	20	20	20	20	20	20	20	20	240
Romantic	2	2	2	2	2	2	2	2	2	2	2	2	24
Relax	24	24	24	24	24	24	24	24	24	24	24	24	288
Shared Room	2	2	2	2	2	2	2	2	2	2	2	2	24
Shared Tent	2	2	2	2	2	2	2	2	2	2	2	2	24
Tour Packages													
Snorkel	32	32	32	32	32					32	32	32	256
Los Frailes Beach	16	16	16	16	16	16	16	16	16	16	16	16	192
Whale Watching 1N						24	24	24	24				96
Whale Watching 2N						4	4	4	4				16
White Water Agua Blanca	2	2	2	2	2	2	2	2	2	2	2	2	24
Isla de la Plata 1N	4	4	4	4	4	4	4	4	4	4	4	4	48
Isla de la Plata 2N	4	4	4	4	4	4	4	4	4	4	4	4	48
Trekking 2N			2	2	2								6
Trekking 1N			2	2	2								6
Aquatic Adventure 2N	4	4	4	4	4								20
Aquatic Adventure 1N	4	4	4	4	4								20
Pacoche Forest										2	2	2	6
Horsebacking Riding 1N										2	2	2	6
Horsebacking Riding 2N										2	2	2	6
Bicycle										2	2	2	6
Scuba Diving A	2	2	2	2	2	2	2	2	2	2	2	2	24
Scuba Diving B	2	2	2	2	2	2	2	2	2	2	2	2	24
Monthly/**Grand** Total	120	120	124	124	124	108	108	108	108	120	120	120	**1404**

Teaching Note

CABALONGA AVENTURA ECUADOR: SEEKING SUSTAINABILITY AND SELF-SUFFICIENCY

SYNOPSIS

CABALONGA ECOADVENTURE ECUADOR (CABALONGA S.A) is a unique, low-cost hostel located in the small seaside town of Puerto Cayo, Ecuador. The beach-front land on which Cabalonga was established was inherited by one of the two proprietors, Diego Losada-Vasquez. Together, he and his business partner Maria-Elena Alvaredo-Villon built a quaint bamboo and palm structure housing the business office, kitchen and bar, utilities, and two covered open-air dining areas. Accommodations include several tents of various sizes, outfitted with electrical outlets, comfortable bedding, and ubiquitous hammocks, as well as a simple bamboo hut to house guests. The accommodations fill a small, and perhaps somewhat difficult to market-to niche, described variably as eco-lodging, five-star camping, or simply low-cost hostel. The company neither makes nor loses money for its entrepreneurs, but does provide a weekend getaway for its owners, financially maintained by its patrons. However, these weekend getaways have actually become hectic cross-country commutes, with every waking, and most sleeping-hours occupied with attending to guests' every need. While the enterprise is financially stable, Diego and Maria-Elena would prefer it was also a less time-intensive investment.

LEARNING OBJECTIVES

Working through the case will allow students to:

- Learn how to assess revenue streams and asset utilization.
- Learn how to assess options for growth and moving a business from start up to self-sustaining, in an environment of greatly attenuated resources.
- To demonstrate the fundamentals of positioning a start up to seize upon emerging trends in the tourism industry.
- To learn how to assess non-market strategies in emerging industries.

This case works well in a variety of strategic management, international management, entrepreneurship and emerging markets courses, at both the undergraduate and graduate levels of instruction. The simplicity of the company and its products makes this an ideal case for use in strategy capstone courses. At more advanced levels of instruction, the case can be used to analyze non-market strategy (i.e. working with government to promote an industry) and changing macroeconomic conditions. The slower pace of economic development and liberalization of Ecuador, being a very small country, makes it a great 'laboratory' for understanding the opportunities and challenges faced by domestic companies in developing economies, and to formulate strategic options for addressing them. Like many developing economies, Ecuador hopes

to capitalize on its natural beauty and rich culture by attracting tourists to a destination that is often overlooked by travellers.

POSITION IN COURSE

This case is ideal for strategy capstone courses at the graduate and undergraduate level of instruction. Enough information is provided to conduct analyses of the company's strengths and weaknesses, its brand positioning relative to direct competitors, and opportunities and threats emanating from the macroeconomic environment. It also allows more advanced classes to connect the evolution of an emerging market economy with business characteristics and requisite shifts in strategy. The case is designed not only to provide a setting to practice fundamental business strategy and marketing skills, but also to think of creative approaches to addressing opportunities and threats in domestic and international markets.

RELEVANT READINGS

This case works well with nearly any strategy or international business textbook such as:

- Dess, G.; McNamara, G. & Eisner, A. (2016), *Strategic Management: Text and Cases*, 8th edition (New York: McGraw-Hill).
- Navas-López, J.E. & Guerras-Martín, L.A. (2013), *Fundamentals of Strategic Management*, 1st edition (Madrid: Civitas).
- Christopher A. Bartlett & Paul W. Beamish (2018), *Transnational Management: Text and Cases*, (Cambridge: Cambridge University Press).

Additional readings on entrepreneurship in emerging economies an eco-tourism:

- Castaño, M.-S., Méndez, M.-T., & Galindo, M.-Á. (2015). The effect of social, cultural, and economic factors on entrepreneurship. Journal of Business Research, 68(7), 1496-1500.
- Lai, P.-H., & Shafer, S. (2005). Marketing ecotourism through the internet: An evaluation of selected ecolodges in Latin America and the Caribbean. Journal of Ecotourism, 4(3), 143-160.

ASSIGNMENT QUESTIONS

1. What are the possible avenues to achieve sustainable revenue growth?
2. How can Cabalonga increase its bookings and resource utilization?
3. How can the owners reduce their personal time commitment to Cabalonga?
4. How should Cabalonga S.A. position itself to take advantage of tourism trends in Ecuador?

TEACHING PLAN (90-MINUTE CLASS)

The assignment questions are intended to help the students prepare for the in-class session. The instructor can teach the case in one 90-minute session, using the following teaching plan to cover the discussion topics:

- (10 minutes) Instructor should provide a synopsis of the case, discuss the emerging phenomenon of ecotourism, and outline the plan for the analysis. The questions to be answers can be based on the assignment questions, and students can participate in analyses done on the board.

- (15 minutes) Conduct a financial analysis of the company and its product offerings (assignment question #1).

- (30 minutes) Based on the previous discussion, form a set of options to increase revenue streams (assignment question #2). The most logical approaches are to target more lucrative customer segments through marketing initiatives, or to alter the product offering to focus on the highest margin activities. Of course, students will realize that these two analyses are interrelated, in that choosing the customer will essentially make the choice of product a given. During this discussion, the potential of ecotourism in Ecuador should be explored for potential new product offerings aimed at capitalizing on this trend and the marketing efforts of the government (assignment question #4).

- (30 minutes) Making Cabalonga more self-sufficient, in terms of both cash flow and management (assignment question #3), is essentially the implementation of options focusing on specific product-markets students have already discussed at this point. The remaining questions now are a) how to match the product offerings to the skill set of the current staff and systems, and b) what additional resources should be obtained, if feasible, to make the operation run more smoothly.

- (5 minutes) Wrap-up. The instructor can now summarize the discussions, including any conclusions drawn. We have found it useful to emphasize both the opportunities and threats of business in emerging economies. The abundant natural beauty and relatively low cost of travel and accommodations in Ecuador creates a big opportunity. That said, travellers are still going to encounter difficulties communicating if not fluent in Spanish, and are likely to be hesitant about traveling to an area that is not known as a tourist destination. Hence, marketing for Cabalonga must be directed to meeting the needs and concerns of foreign travellers, and perhaps should be most specifically targeted to eco-travellers, given that these are likely to be a more adventurous group.

ANALYSIS

1. What are the possible avenues to achieve stable revenue growth?

Cabalonga has three primary revenue generating activities, which it combines into various forms of 'packages'. These are accommodations (tents and cabin with bedding, electricity, wi-fi internet access and private/shared bathroom facilities), dining, and various adventure tours, such as guided hiking and horseback riding, scuba diving, snorkeling, and so forth. The question that students really need to answer before generating and evaluating alternatives is "where does Cabalonga create the most value?" Answering this question naturally leads to an examination of margins. We suggest doing a quick conversion of the data in Exhibit 1 in the case to percentages of revenue in order to get a rough idea of where to start. This reveals the following:

Revenue	93,869	100%
Direct Costs	40,960	43.6
Gross Margin	52,909	56.4
Overhead		
Employee salaries	28,001	29.8
Managers' salaries	4,800	5.1
Occasional help	3,000	3.2
Utilities & supplies	5,412	5.8
Auditing	3,000	3.2
Maintenance	1,200	1.3
Advertising	3,600	3.8
Total Expenses	49,017	52.2
Earnings	3,893	4.1

The gross margin is quite attractive at 56%. On the other hand, overall earnings is a somewhat dismal 4.1%, although that is after the owners take their meager 5.1% from total sales. The primary portion of overhead, unsurprisingly, is employee salaries which make up nearly 30% of the total revenue. That said, the total yearly salary expense of $28K for two fulltime and 3 part-time employees is roughly in line with Ecuador's government mandated minimum wages. The company does not have much capacity to hire more full time workers, but does pay for occasional help from other community members, amounting to a total of $3,000, or 3.2% of revenues annually. What should be made obvious to students is that Diego and Maria-Elena are actually running a very tightly controlled budget in order to maximize the distribution of the proceeds to the community. They not only hire locally, but also source food locally and provide additional customers for tour operators. Items like auditing, utilities and maintenance are low and

probably not negotiable, and most will agree that marketing budget is quite modest. In many ways, the business appears to be closer to a small charity than a cash cow, but this has earned them recognition as an Eco Leader.

Overall the business appears to be sustainable as is, with positive margins and little threat of unexpected expenses given the simplicity of the operations. Cabalonga's reputation has spread by word of mouth and through social media, with sales growing faster than the tourism industry in Ecuador in general, suggesting that they are enjoying a period of early growth, with ample spare capacity. Of course that is not taking into account the gargantuan time and energy commitment of the owners, who take extremely little of the proceeds for themselves! To increase the profitability of the venture, we must first look for methods to increase revenues. The first step in the analysis is to study the income statements for Cabalonga to determine where the best margins are. By examining these scenarios, we can find the scenario with the highest profit margin, and begin to capitalize on that by gearing the business towards those services.

Revenue on meals is set to 100% of the cost of raw ingredients (Exhibit 2), however most meals 'sold' are actually included in the package costs. Exhibit 3 provides information on the packages, what they include, and the costs for tours, transportation and other supplies needed to provide activities. To these costs, the food and allocation of the overhead costs must be taken into account. From Exhibit 4, we calculate the total number of visitors to be 1,404 for 2017 leading to an allocation of the overhead costs of $28.40 per stay. When average meal costs are taken into account, the margins per stay are shown in Exhibit TN-1. What emerges is that many of the packages appear to be money losers, although they still contribute to paying the fixed overhead costs. Nonetheless, it seems that given the wide variance in margins for each of the packages, either the pricing scheme is not effective or the company is simply too diversified and should scale back to more profitable options. Students should be cautioned however, that any reduction in revenue greatly threatens the bottom line, since the overhead costs are mostly fixed.

Clearly revenue growth and/or simplification will be needed if the owners are to relinquish their control over day to day operations. This leads to the next question of what Cabalonga can do to increase resource utilization, in order to grow revenues without growing assets.

2. How can Cabalonga increase its bookings and resource utilization?

The analyses performed in the previous step lead us to conclude that either prices need to be adjusted, or the company should focus on only those packages which are most profitable. The company has spare capacity most of the time, so increasing assets is probably not an important initial goal. To decide where to focus, students must take into account the demand level for each of the packages (see Exhibit 4 in the case). The forecast for 2018 is based on the previous year's sales which show that the most popular packages are 'Beach' and 'Relax' which coincidentally are the cheapest and amongst the lowest margins (see Exhibit TN-1). Amongst the tours, snorkeling and the boat trip to Frailes Island are by far the most popular, although whale watching is also popular.

It won't take long for students examining TN-1 to realize that packages that include two nights of lodging are the most profitable, but also tend to be less popular than one night lodgings with tours. What this suggests is that there is a fairly sharp division between customers who stay for lodging and those that are interested in tours. Given the small size of Ecuador, the coast is accessible within a day's drive for most residents. Hence, it is quite possible that many of the customers are only using lodging for one night in order to partake of a tour and then get a night of rest before heading home. Indeed, this fits the description of the average middle-class or young single Ecuadorean weekend traveller.

Other options are to try and expand the restaurant sales, which would be worthwhile since the location is on the Spondylus route and many travellers will pass by on their way to their final destination. However, the staff who prepare meals need some idea of how many guests they are going to have in an evening so that they can obtain the right amount of ingredients, most of which require refrigeration, and have adequate time to prepare the meals. At a 50% margin, with no additional costs, it will be very worthwhile to attract a few additional diners each lunch and dinner, which can be done with relatively inexpensive roadside advertising. Perhaps a few of these travelers could be convinced to spend the night to partake in a karaoke session and have a couple beverages, which are also high margin sales. A complimentary cocktail for diners at the appropriate time may be all that is needed in some cases.

By examining Exhibit TN-1, we can see that the most profitable tours are the Romantic, Trekking 2N, Horseback Riding 2N, and Scuba Diving A. There are multiple packages that take a loss, however, the costliest are: Horseback Riding 1N, Relax and both the shared tent and the share room. Cabalonga can either try to fight against the tendency of its customers to prefer shorter stays of one night, or charge more for the tours which seem to be what they value most. However, convincing customers to stay two nights may be possible if packages are combined. That is, have two tours on two days, in order to convince travellers to stay and explore. To do this, Cabalonga should consider simplifying its website (Cabalonga.com) which at present provides the potential with a dizzying array of options which run the risk of producing information overload. They may consider creating a more interactive website which allows customers to build and price their own vacation packages. Eventually the owners may even consider a system to push this information to tour providers so that order fulfillment can be handled more seamlessly, thus requiring less hands-on involvement of the owners. From the current website, it is apparent that Diego has ample technical skills, so this next step in the evolution to a more dynamic website should be achievable within a 6 month time frame. The website change will take a large amount of time upfront and very little after it's completed, the Search Engine Optimization (SEO) will take a constant time commitment to make sure Cabalonga stays up on Google's rankings. Outsourcing this process to a website management firm can cost anywhere from $119-449USD/month[9], on the lower end of the spectrum, basic website updates, designs, security, and SEO is covered. Cabalonga may not

[9] Webpage FX, "Website Maintenance," Webpage FX, 2018, accessed May 29, 2018, https://www.webpagefx.com/websitemaintenance.htm.

need the extensive services that are offered by many website management firms. On top of this there are the current tasks of responding to emails and other digital comments.

Nonetheless, as the case states, prices seem to have little-to-no impact on demand, and so we can probably increase all prices across the board by 20% without turning away many potential customers. By examining this in Exhibit TN-2 and Exhibit TN-3, we can see that this price change increases year end profit from ~$3,900 to ~$22,600, without adding any new resources.

3. How can the owners reduce their personal time commitment to Cabalonga?

Diego and Ma-Elena's time commitments to Cabalonga can be split into three main activities: 1) Managing offsite through social media, electronic documents and messaging, 2) hospitality and 3) traveling to and from the lodge. Item 3 seems to be a rather large *transaction cost* involved with performing the hospitality duties (item 2) and so both should be targeted for reduction.

The simple answer is to increase training to have an employee take on more of the day-to-day management of Cabalonga. However, this will be difficult to do with local employees due to a lack of management education. The full time staff appears to be very committed to the operations, and will likely be able to take on more advanced management duties. Furthermore, a more advanced order fulfillment system as described in the answer to analysis question 2 could automate many of the more complex scheduling and pricing tasks.

To lessen the personal time commitment, Marie-Elena and Diego will eventually need to find qualified help, and spend a great deal of time training them. At minimum, the person would need to be able to speak and read English fluently to help with guests from the United States and elsewhere, as well as manage the personnel, scheduling, replenishment, and so forth. The biggest issue would be finding the right individual to manage Cabalonga, especially when the owners are not at Cabalonga full time, to recognize a qualified person with little to no interaction between them and the customers. They should look to the Universities of Ecuador for young graduates looking for an entrepreneurial challenge. The starting wage of approximately $15K is within Cabalonga's grasp with the 20% cost increase. In addition, the manager could earn a commission for increasing sales, which should also be achievable with someone stationed at the facility full time (see Exhibit TN-4).

4. How should Cabalonga S.A. position itself to take advantage of tourism trends in Ecuador?

From the preceding analyses, it is clear that acting as a tour intermediary is essential for boosting Cabalonga's revenues and profitability. In 2013, Ecuador tourist arrivals came in at 1,364,000 people, from 2014 to 2016 this changed to 1,557,000, 1,544,000 and 1,418,000 respectively. At the same time in the total receipts (USD) from tourism in Ecuador was 1.251 Billion, peaking at 1.557 Billion in 2015 and dropping to 1.449 Billion in 2016. International tourist arrivals is forecasted to reach 2,811,000 by 2027.

The earthquake in 2016 clearly took its toll on the industry, but tourism in Ecuador was certainly experiencing healthy growth prior to this, and Cabalonga's main business attracting mostly Ecuadorean tourists was not greatly affected. Looking to the future the, Cabalonga should prepare to accept more foreign eco-travellers, who have deeper pockets and greater need of the hospitality and the tour arranging services that Cabalonga offers to its guests.

Each year, the split between foreign and domestic tourism increases (see Exhibit TN-5). In 2016 62.60% of tourism spending was from foreign travellers, this increased to 64.80% in 2017, it is projected to be 68.06% for 2018[10]. Long range forecasts are expected to be 4.5% increase per annum between 2017 and 2027, topping out at 2.5% GDP in 2027.[11] In 2017, the USA and Columbia contributed the largest share of tourists to Ecuador. USA: 244,600 tourists, Columbia: 330,671 tourists, total global: 1,608,473 tourists[12] . With this increase in international visitors to Ecuador, Cabalonga should begin to shift it's positioning in their advertising to attract more foreign customers. This can in part be accomplished by created an English version of the Cabalonga's website. Cabalonga may consider the practice of charging higher rates on the English language website, a common practice in developing countries, where the spending power of the local consumer is greatly reduced from that of the international traveller. The prices currently charged are, by American standards, unnecessarily low.

[10] World Travel & Tourism Council, *Economic Impact 2015-2017 Ecuador*, 1;6;7;9, March 2017, accessed May 19, 2018, https://www.wttc.org/-/media/files/reports/economic-impact-research/archived/countries-2017-old/ecuador2017.pdf.

[11] World Travel & Tourism Council, *Economic Impact 2017 Ecuador*, 1;6;7;9, March 2017, accessed May 19, 2018, https://www.wttc.org/-/media/files/reports/economic-impact-research/archived/countries-2017-old/ecuador2017.pdf.

[12] Ecuador Potencia Turistica, "Migratory Balance of Ecuador," Ecuador Potencia Turistica, 2018, accessed May 16, 2018, http://servicios.turismo.gob.ec/index.php/portfolio/turismo-cifras/19-inteligencia-de-mercados/entradas-y-salidas-internacionales/3.

EXHIBIT TN-1: Margins for Cabalonga Packages (From Cabalonga Internal Documents and Website)

Package	Price	Cost	Meal Cost	Accommodation Cost	Margin
Beach	$ 34.82	$ 10.00	$ 11.13	$ 28.40	$ (14.71)
Romantic	$ 116.07	$ 34.00	$ 11.91	$ 28.40	$ 41.77
Relax	$ 15.00	$ 2.50	$ 1.46	$ 28.40	$ (17.36)
Snorkel	$ 74.82	$ 27.25	$ 11.13	$ 28.40	$ 8.04
Los Frailes Beach	$ 69.82	$ 26.55	$ 11.13	$ 28.40	$ 3.74
Whale Watching 1N	$ 79.82	$ 33.14	$ 11.13	$ 28.40	$ 7.15
Whale Watching 2N	$ 111.07	$ 43.14	$ 19.84	$ 28.40	$ 19.69
White Water Aqua Blanca	$ 60.82	$ 35.00	$ 11.13	$ 28.40	$ (13.71)
Isla de la Plata 1N	$ 95.82	$ 59.50	$ 7.77	$ 28.40	$ 0.15
Isla de la Plata 2N	$ 127.07	$ 69.50	$ 19.84	$ 28.40	$ 9.33
Trekking 2N	$ 103.25	$ 38.50	$ 18.74	$ 28.40	$ 17.61
Trekking 1N	$ 69.82	$ 33.50	$ 10.58	$ 28.40	$ (2.66)
Aquatic Adventure 2N	$ 141.07	$ 80.00	$ 18.74	$ 28.40	$ 13.93
Aquatic Adventure 1N	$ 109.82	$ 73.75	$ 13.93	$ 28.40	$ (6.26)
Pacoche Forest	$ 69.82	$ 40.00	$ 10.58	$ 28.40	$ (9.15)
Horseback Riding 1N	$ 81.79	$ 66.25	$ 10.58	$ 28.40	$ (23.44)
Horseback Riding 2N	$ 130.00	$ 62.50	$ 18.74	$ 28.40	$ 20.36
Bicycle	$ 55.82	$ 17.50	$ 11.13	$ 28.40	$ (1.21)
Scuba Diving A	$ 129.82	$ 75.00	$ 10.58	$ 28.40	$ 15.85
Scuba Diving B	$ 199.82	$ 155.00	$ 13.93	$ 28.40	$ 2.49
Shared Room	$ 10.00	$ 2.50	N/A	$ 28.40	$ (20.90)
Shared Tent	$ 8.48	$ 2.50	N/A	$ 28.40	$ (22.42)
Totals	$ 1,894.66	$ 987.59	$ 253.97	$ 624.78	$ 28.32
Average					$ 1.29

EXHIBIT TN-2: Margins for Cabalonga Packages with 20% price increase (From Cabalonga Internal Documents and Website)

Package	Price	Cost	Meal Cost	Accommodation Cost	Margin
Beach	$ 41.79	$ 10.00	$ 11.13	$ 28.40	$ (7.74)
Romantic	$ 139.29	$ 34.00	$ 11.91	$ 28.40	$ 64.98
Relax	$ 18.00	$ 2.50	$ 1.46	$ 28.40	$ (14.36)
Snorkel	$ 89.79	$ 27.25	$ 11.13	$ 28.40	$ 23.01
Los Frailes Beach	$ 83.78	$ 26.55	$ 11.13	$ 28.40	$ 17.71
Whale Watching 1N	$ 95.79	$ 33.14	$ 11.13	$ 28.40	$ 23.12
Whale Watching 2N	$ 133.29	$ 43.14	$ 19.84	$ 28.40	$ 41.90
White Water Aqua Blanca	$ 72.99	$ 35.00	$ 11.13	$ 28.40	$ (1.54)
Isla de la Plata 1N	$ 114.99	$ 59.50	$ 7.77	$ 28.40	$ 19.31
Isla de la Plata 2N	$ 152.49	$ 69.50	$ 19.84	$ 28.40	$ 34.74
Trekking 2N	$ 123.90	$ 38.50	$ 18.74	$ 28.40	$ 38.26
Trekking 1N	$ 83.78	$ 33.50	$ 10.58	$ 28.40	$ 11.31
Aquatic Adventure 2N	$ 169.29	$ 80.00	$ 18.74	$ 28.40	$ 42.15
Aquatic Adventure 1N	$ 131.79	$ 73.75	$ 13.93	$ 28.40	$ 15.71
Pacoche Forest	$ 83.79	$ 40.00	$ 10.58	$ 28.40	$ 4.81
Horseback Riding 1N	$ 98.14	$ 66.25	$ 10.58	$ 28.40	$ (7.08)
Horseback Riding 2N	$ 156.00	$ 62.50	$ 18.74	$ 28.40	$ 46.36
Bicycle	$ 66.99	$ 17.50	$ 11.13	$ 28.40	$ 9.96
Scuba Diving A	$ 155.79	$ 75.00	$ 10.58	$ 28.40	$ 41.81
Scuba Diving B	$ 239.79	$ 155.00	$ 13.93	$ 28.40	$ 42.46
Shared Room	$ 12.00	$ 2.50	N/A	$ 28.40	$ (18.90)
Shared Tent	$ 10.18	$ 2.50	N/A	$ 28.40	$ (20.72)
Totals	$ 2,273.59	$ 987.59	$ 253.97		$ 407.26
Average					$ 18.51

EXHIBIT TN-3: Cabalonga 2018 Financial Forecast with 20% increase in prices (From Cabalonga Internal Documents)

	Annually	Monthly	Annually with 20% increase
Sales	**93,869.20**	**7,822.43**	**112,643.04**
Costs	40,959.96	3,413.33	40,959.96
Margin	**52,909.24**	**4,409.10**	**71,683.08**
Salaries	28,004.54	2,333.71	28,004.54
basic services	2,412.00	201.00	2,412.00
Cleaning Suppliers	3,000.00	250.00	3,000.00
Accountant	3,000.00	250.00	3,000.00
Maintenance	1,200.00	100.00	1,200.00
Advertising	3,600.00	300.00	3,600.00
Managers	4,800.00	400.00	4,800.00
Help (?)	3,000.00	250.00	3,000.00
Total Expenses	**49,016.54**	**4,084.71**	**49,016.54**
Operational Utilities	**3,892.70**	**324.39**	**22,666.54**

EXHIBIT TN-4: Commissions Cost for 2018 Demand Forecast Cabalonga Packages (From Cabalonga Internal Documents)

Tour Packages	Price	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Commission	Commission Cost
Snorkel	$ 74.82	32	32	32	32	32					32	32	32	26	$ 7.48
Los Frailes Beach	$ 69.82	16	16	16	16	16	16	16	16	16	16	16	16	20	$ 6.98
Whale Watching 1N	$ 79.82						24	24	24	24				10	$ 7.98
Whale Watching 2N	$111.07						4	4	4	4				2	$ 11.11
White Water Aqua Blanca	$ 60.82	2	2	2	2	2	2	2	2	2	2	2	2	3	$ 6.08
Isla de la Plata 1N	$ 95.82	4	4	4	4	4	4	4	4	4	4	4	4	5	$ 9.58
Isla de la Plata 2N	$127.07	4	4	4	4	4	4	4	4	4	4	4	4	5	$ 12.71
Trekking 2N	$103.25			2	2	2								1	$ 10.33
Trekking 1N	$ 69.82			2	2	2								1	$ 6.98
Aquatic Adventure 2N	$141.07	4	4	4	4	4								2	$ 14.11
Aquatic Adventure 1N	$109.82	4	4	4	4	4								2	$ 10.98
Pacoche Forest	$ 69.82										2	2	2	1	$ 6.98
Horsebacking Riding 1N	$ 81.79										2	2	2	1	$ 8.18
Horsebacking Riding 2N	$130.00										2	2	2	1	$ 13.00
Bicycle	$ 55.82										2	2	2	1	$ 5.58
Scuba Diving A	$129.82	2	2	2	2	2	2	2	2	2	2	2	2	3	$ 12.98
Scuba Diving B	$199.82	2	2	2	2	2	2	2	2	2	2	2	2	3	$ 19.98
														87	$ 71.03

EXHIBIT TN-5: Ecuador Foreign/Domestic Tourism Spending Split (From WTTC Ecuador Tourism Forecast 2018)

Year	# Visitors	Domestic Spending	Foreign Spending
2014		58.50%	41.50%
2015	1,544,463	38.50%	61.50%
2016	1,418,159	37.40%	62.60%
2017	1,608,473	35.20%	64.80%
2018*		31.94%	68.06%
*Author's forecast			

Source: World Travel & Tourism Council, *Economic Impact 2015-2017 Ecuador*, 1;6;7;9, March 2017, accessed May 19, 2018, https://www.wttc.org/-/media/files/reports/economic-impact-research/archived/countries-2017-old/ecuador2017.pdf.

DECISION SCIENCES INSTITUTE

Causes of Mortality by Ethnicity and Gender in the USA: An advanced Comparative Analysis

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ABSTRACT

The mortality rate in the United States is different for the ethnicities and genders, in such a way that the mortality rates were analyzed and found some important differences that suggest the opportunity of using the unique characteristics of the ethnic and gender groups to reduce mortality on the others. This study focuses on projecting the national mortality data for the future identifying areas of research opportunities by ethnicity groups and gender.

KEYWORDS: regression, mortality, ethnicities, sensitivity analysis and health

INTRODUCTION

The United States is a country that has an amalgam of cultures, ethnicities, races, languages and religions that shape the country as a place for migrants looking for the land of opportunity. The country population of around 325 million people in 2017, and it continues growing by organic growth as well as migration. The composition of the population can be seen in figure 1 that clearly shows that most of the population is in the white persons' category.

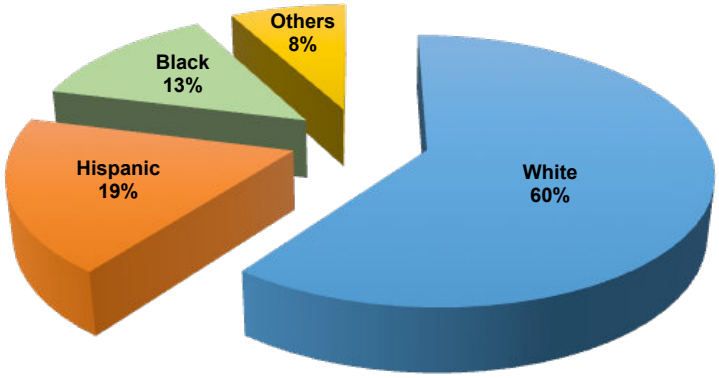

Figure 1: Races and Ethnicities' Composition of the USA Population

An important finding while analyzing the demographics, is that we expected a comparative difference between genders, but this is not true because there are 2.67 million more black women than men, that is 11% more in comparison to males, while in the case of white women,

they are 3% more than men. In the case of Hispanics genders are almost perfectly balanced according to the Census numbers.

Table 1: USA Population by Race and Gender

Male		Group	Female	
29.67%	95,842,609	White	98,885,235	30.61%
9.31%	30,058,779	Hispanic	30,094,010	9.32%
6.17%	19,922,595	Black	22,599,391	7.00%
3.78%	12,212,462	Others	13,381,513	4.14%

The mortality line from 2006 to 2015 shows a R-square of 0.905 with a slope or growth of 28,683 per year at national level, while the population growth is significantly higher with 2,380,488 per year (Census, 2017). This figure shows that there is an aging population in the country as the number of births and migrants is well over the deaths. The cities are growing, and people are living longer, but this study is going to go beyond the surface and into the details of the cause of deaths by ethnicity and gender.

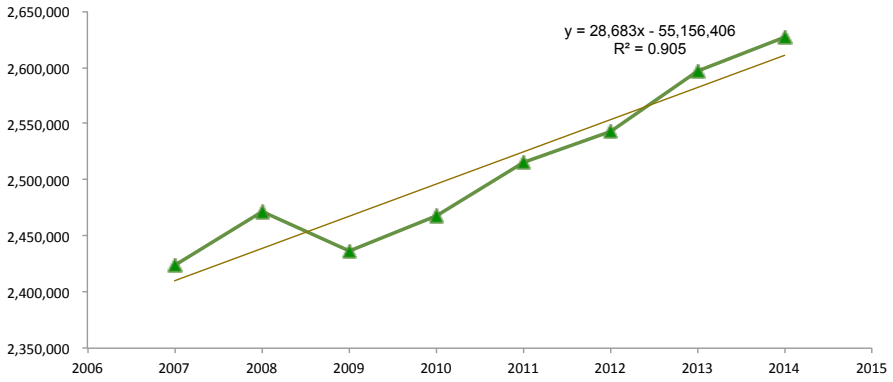

Figure 2: Mortality Numbers in the USA

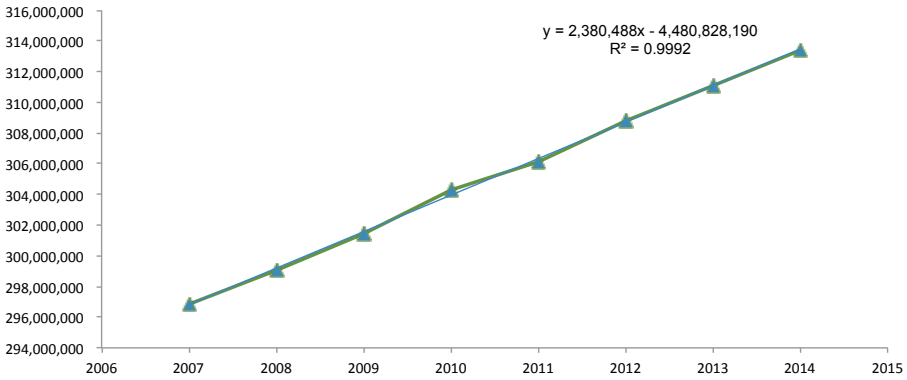

Figure 3: Population growth as Estimated by the Census Office

VIOLENT DEATHS ANALYSIS

We can separate deaths in the United States into two major groups: diseases and violent deaths. The study is based on the available information at the Centers for Disease Control and Prevention (CDC). We are looking at the period between 2007 and 2014 because the County information is not available for comparison, so we will go as far as all three levels of information are available.

The first point to address is the importance of the violent deaths in the country. The percentage of homicides, suicides and accidents is only 7.2% of all deaths, but the behavior of these deaths follows the polynomial non-linear regression with a R-square of 0.937, which is showing an alarming growth of rate on the last four years after a positive trend of reduction. For this particular study, we are only going to separate these statistics by gender and group to have a better idea of where the trend is going.

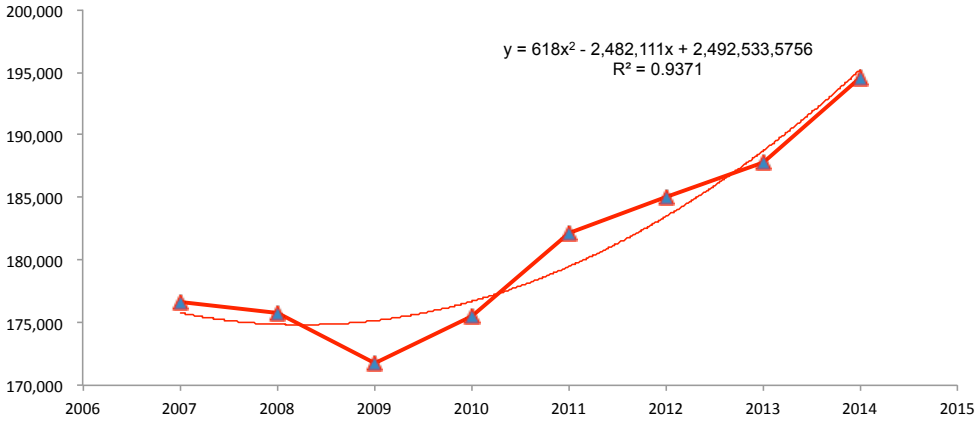

Figure 4: Total Violent Deaths in the USA

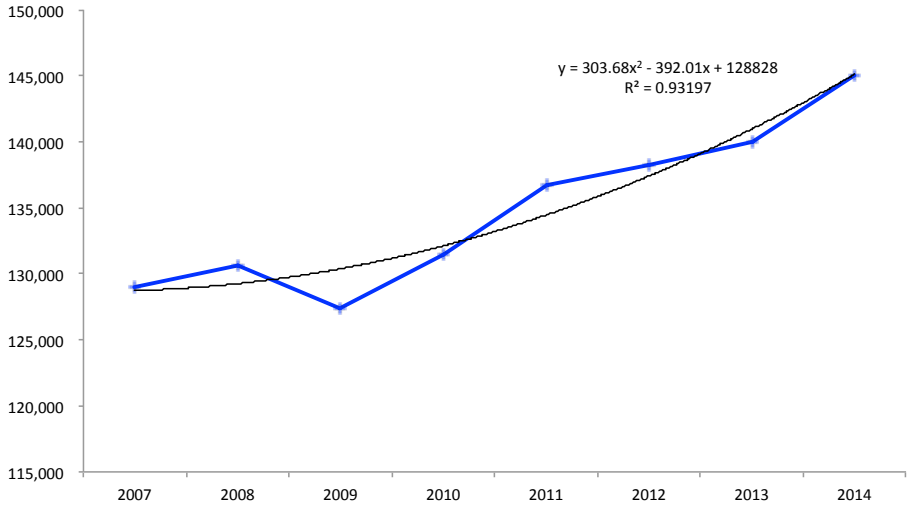

Figure 5: Violent Deaths for White Persons in the USA

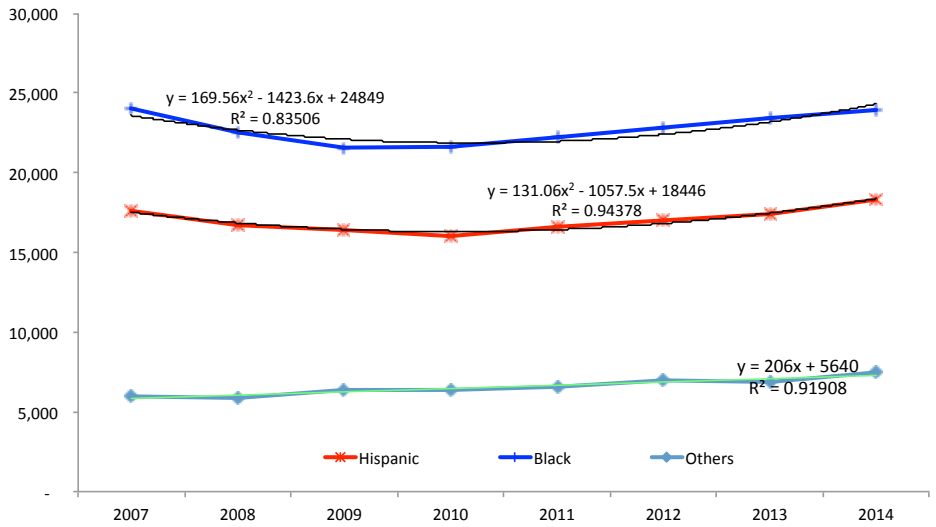

Figure 6: Violent Deaths for Minorities in the USA

The white population definitively drives the curve slope of violent deaths because of its number and proportion. Looking at table 2, we can see that the proportion of violent deaths is almost the same for Hispanics and the others' group, while the black and white groups are higher, being the white people the highest.

Table 2: Proportion of Violent Deaths for Groups to the Group's Population

Group	2007	2008	2009	2010	2011	2012	2013	2014
White	0.066%	0.066%	0.065%	0.067%	0.069%	0.071%	0.072%	0.074%
Hispanic	0.039%	0.036%	0.035%	0.033%	0.033%	0.033%	0.033%	0.034%
Black	0.064%	0.060%	0.057%	0.056%	0.057%	0.058%	0.058%	0.059%
Others	0.033%	0.032%	0.034%	0.033%	0.033%	0.032%	0.031%	0.032%

Table 3: Proportion of Violent Deaths by Gender and Group to the Specific Population

Males	2007	2008	2009	2010	2011	2012	2013	2014
White	0.089%	0.090%	0.087%	0.089%	0.092%	0.094%	0.095%	0.098%
Hispanic	0.060%	0.055%	0.052%	0.049%	0.049%	0.049%	0.049%	0.050%
Black	0.104%	0.097%	0.091%	0.090%	0.091%	0.093%	0.093%	0.094%
Others	0.045%	0.044%	0.047%	0.046%	0.047%	0.045%	0.043%	0.045%
Females	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
White	0.043%	0.044%	0.043%	0.045%	0.047%	0.048%	0.049%	0.051%
Hispanic	0.017%	0.016%	0.016%	0.016%	0.017%	0.016%	0.016%	0.017%
Black	0.029%	0.027%	0.027%	0.026%	0.027%	0.026%	0.027%	0.028%
Others	0.021%	0.020%	0.022%	0.021%	0.021%	0.020%	0.019%	0.021%

Table 3 shows the critically of gender while analyzing accidental deaths because females in all groups have a much lower proportion of violent deaths than men. A point to address at this point is that black male violent deaths were going down until 2010, when they started climbing again. It is noteworthy that white and black males have a similar proportion of violent deaths.

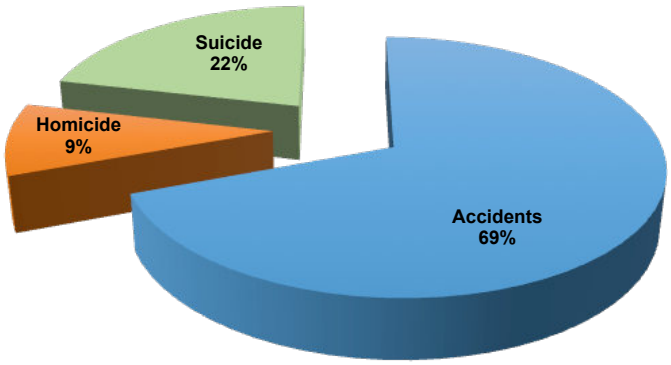

Figure 7: Violent Deaths by Categories in the USA

More than two-thirds of the violent deaths in the country are accidents, while suicides are the second largest contributor with 22% of all violent deaths.

Table 3: Causes of Violent Death by group and Gender in the USA

	White		Black		Hispanic		Others	
Violent Death Cause	Male	Female	Male	Female	Male	Female	Male	Female
Accidents (unintentional injuries)	0.062%	0.038%	0.047%	0.020%	0.033%	0.012%	0.029%	0.015%
Assault (homicide)	0.004%	0.002%	0.038%	0.005%	0.010%	0.002%	0.005%	0.002%
Intentional self-harm (suicide)	0.026%	0.007%	0.010%	0.002%	0.009%	0.002%	0.012%	0.004%

In table 3 we can easily see that the major contributors for accidental deaths are the males, and there is another important fact about the black males being the ones with the largest proportion of homicide deaths. Another subject recommended for further investigation is the higher than normal proportion of suicides from white persons.

DISEASES DEATHS ANALYSIS

The CDC identifies several causes of death due to illnesses, and for this study, we will focus on the major illnesses based on the national mortality data published by the CDC.

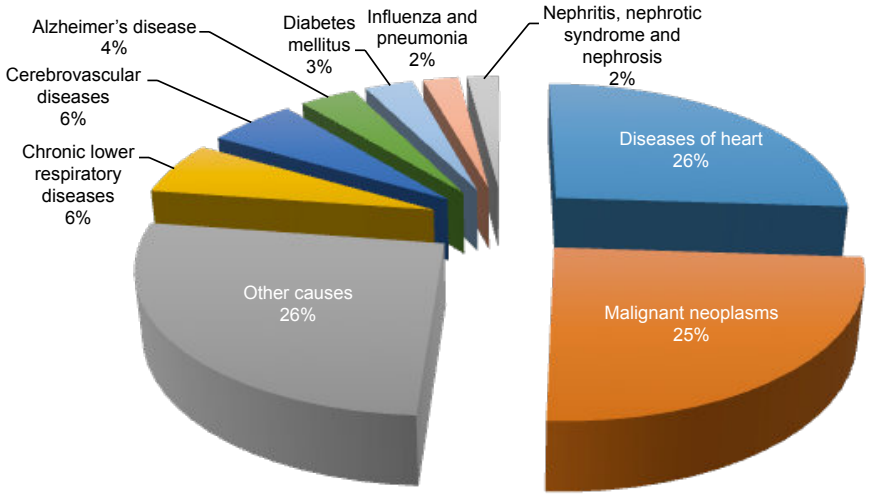

Figure 8: Top Diseases in the USA

The figure shows that Disease of the Heart and Cancers are the top two causes of death by illness in the United States as they add to over 50% of the deaths. The next contributors are much smaller because the following one on the list is the respiratory disease with only 8% of the deaths. Having identified the main causes of death, we now proceed to analyze by gender and then by ethnic group to identify possible trends or differences on the proportions.

Table 4: Causes of Mortality by Gender

Male		Group	Female	
0.209%	312,868	Diseases of heart	293,599	0.189%
0.201%	301,584	Malignant neoplasms	274,242	0.176%
0.166%	248,348	Other causes	300,553	0.193%
0.045%	66,733	Chronic lower respiratory diseases	74,165	0.048%
0.036%	53,276	Cerebrovascular diseases	77,721	0.050%
0.017%	25,139	Alzheimer's disease	58,172	0.037%
0.025%	37,404	Diabetes mellitus	35,039	0.023%
0.017%	25,149	Influenza and pneumonia	28,534	0.018%
0.016%	23,532	Nephritis, nephrotic syndrome and nephrosis	24,039	0.015%
0.011%	16,776	Septicemia	19,461	0.013%
0.014%	21,492	Chronic liver disease and cirrhosis	11,609	0.007%

The table shows that Cerebrovascular and Alzheimer's diseases have a larger percentage in women than in men. The difference is more noticeable in the Alzheimer's disease because the number of deaths is more than twice as much. Aronson et al. (1990) stated that women were over 3 times more likely to develop dementia than men despite controlling for baseline demographic, psychosocial, and medical history variables.

Table 5: Proportions of Death by Group and Gender

	White		Black		Hispanic		Others	
Diseases Causing Death	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Diseases of heart	0.261%	0.239%	0.195%	0.165%	0.067%	0.058%	0.092%	0.068%
Malignant neoplasms	0.251%	0.219%	0.185%	0.154%	0.066%	0.062%	0.095%	0.083%
Other causes	0.199%	0.241%	0.173%	0.169%	0.070%	0.070%	0.076%	0.076%
Chronic lower respiratory diseases	0.061%	0.067%	0.025%	0.021%	0.009%	0.009%	0.015%	0.011%
Cerebrovascular diseases	0.042%	0.062%	0.039%	0.043%	0.014%	0.017%	0.021%	0.024%
Alzheimer's disease	0.023%	0.051%	0.008%	0.019%	0.005%	0.010%	0.005%	0.010%
Diabetes mellitus	0.027%	0.024%	0.032%	0.032%	0.014%	0.014%	0.016%	0.014%
Influenza and pneumonia	0.021%	0.023%	0.014%	0.013%	0.007%	0.007%	0.011%	0.010%
Nephritis, nephrotic syndrome and r	0.018%	0.017%	0.021%	0.022%	0.006%	0.006%	0.007%	0.007%
Septicemia	0.013%	0.015%	0.015%	0.016%	0.004%	0.005%	0.005%	0.005%
Chronic liver disease and cirrhosis	0.016%	0.009%	0.010%	0.005%	0.013%	0.006%	0.008%	0.005%

Looking at the two diseases that were showing higher incidence of women than men, we see now that the Alzheimer disease causing death is showing the same behavior for all groups, because the proportion is more than twice as much as the men. Cerebrovascular diseases seem to be only found for white women because in all other cases the difference between males and females is very close. World studies suggest that CVD are going down in the world for both sexes but the statistics for white women in the USA are still high (Levi et al., 2002).

COMPARING THE RESULTS OF THE USA WITH TEXAS

The population in Texas has a different composition because the white population is still a majority, but closely followed by the Hispanics. If the proportions that we have seen in a national level as impacted by ethnicity, then the numbers should present a different behavior due to the demographics of the state. The idea of Hispanic migrants having better access to health care than the poor native Hispanics could have an improvement effect on the statistics (Gresenz et al., 2009).

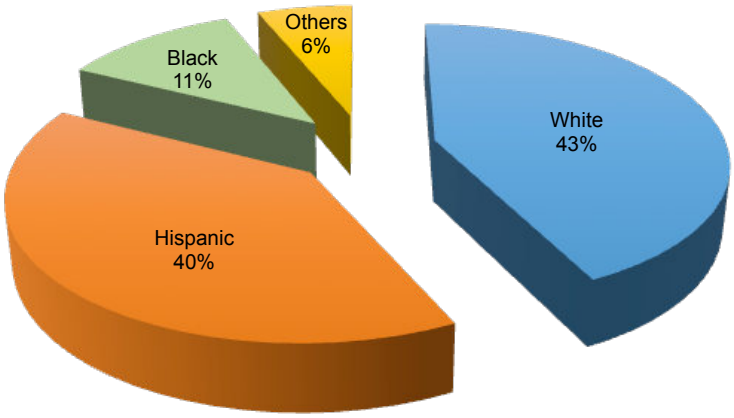

Figure 9: Races and Ethnicities' Composition of the Texas Population

In Texas, all ethnic groups have a close balance between males and females, as their differences on quantities are insignificant

Table 6: Texas Population by Race and Gender

Male		Group	Female	
21.18%	5,753,306	White	5,871,575	21.62%
19.95%	5,417,985	Hispanic	5,322,471	19.60%
5.54%	1,506,024	Black	1,608,163	5.92%
3.03%	821,995	Others	860,423	3.17%

The mortality line from 2006 to 2015 shows a R-square of 0.925 with a slope or growth of 3,204 per year at the state level, while the population growth is significantly higher with 449,629 per year (Census, 2017). These figures show that there is an incredible growth on population with a small mortality rate that is causing a larger than expected demographic growth.

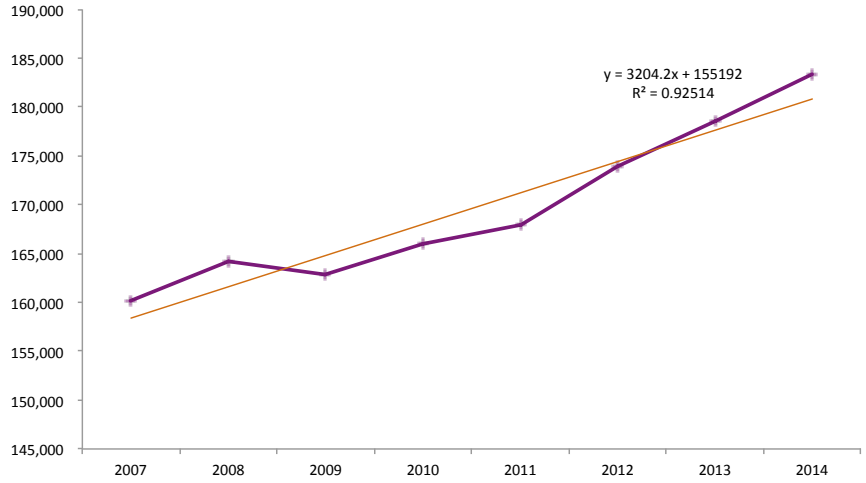

Figure 10: Mortality Numbers in Texas

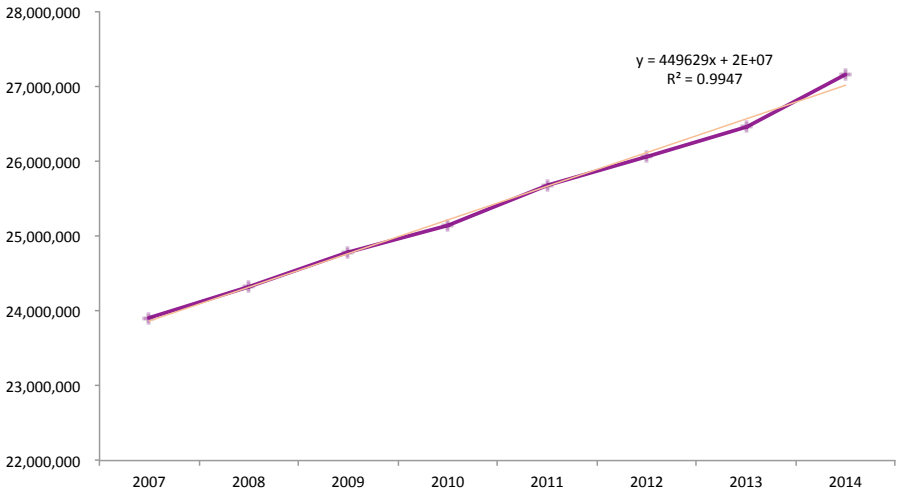

Figure 11: Population growth as Estimated by the Census Office

VIOLENT DEATHS IN TEXAS

The percentage of violent deaths in Texas is only 8% of all deaths, but the behavior of these deaths follows the polynomial of the third order non-linear regression with a R-square of 0.928, which is showing a stable period and the same alarming growth of rate on the last four years as seen in the national chart.

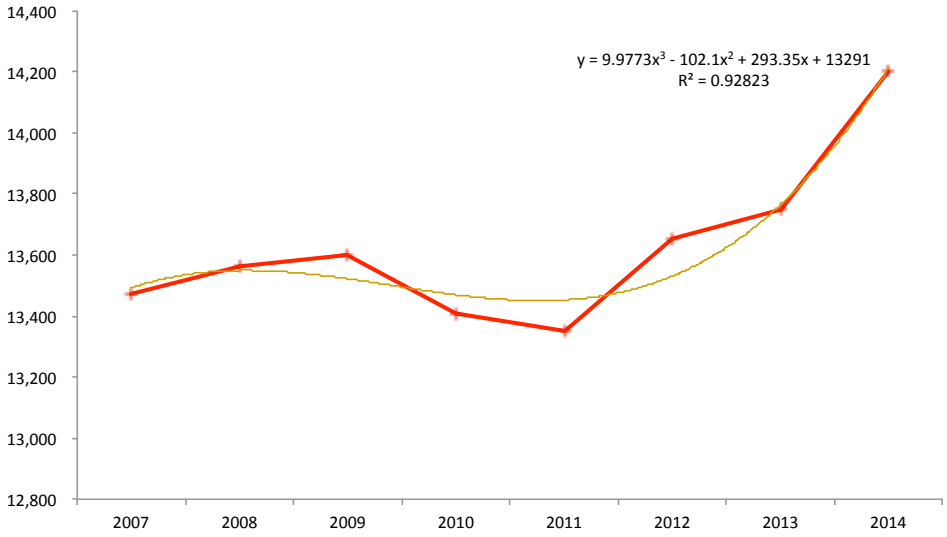

Figure 12: Total Violent Deaths in Texas

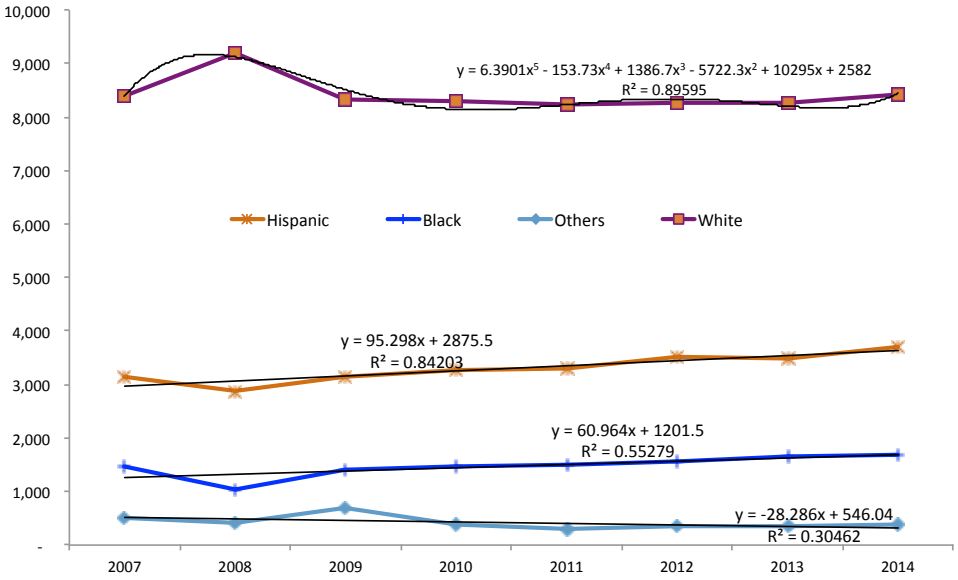

Figure 13: Violent Deaths for All Groups in Texas

Although the white and Hispanic populations are almost the same, the number of deaths of Hispanics is much lower than for white persons, and on regards to the national numbers, the number of violent deaths of Hispanics is comparable to the national proportion.

Table 7: Proportion of Violent Deaths by Gender and Group to the Specific Population

Males	2007	2008	2009	2010	2011	2012	2013	2014
White	0.099%	0.111%	0.097%	0.095%	0.097%	0.097%	0.097%	0.098%
Hispanic	0.052%	0.046%	0.049%	0.051%	0.050%	0.052%	0.050%	0.050%
Black	0.081%	0.054%	0.075%	0.072%	0.075%	0.080%	0.084%	0.083%
Others	0.071%	0.054%	0.091%	0.050%	0.030%	0.032%	0.029%	0.032%
Females	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
White	0.049%	0.053%	0.050%	0.050%	0.048%	0.047%	0.048%	0.048%
Hispanic	0.018%	0.017%	0.017%	0.018%	0.017%	0.018%	0.017%	0.018%
Black	0.026%	0.020%	0.026%	0.026%	0.029%	0.026%	0.027%	0.028%
Others	0.029%	0.028%	0.036%	0.018%	0.011%	0.014%	0.014%	0.014%

Table 7 shows the critically of gender while analyzing accidental deaths because females in all groups have a much lower proportion of violent deaths than men. A point to address at this point is that black male violent deaths have been at the same level for the past eight years.

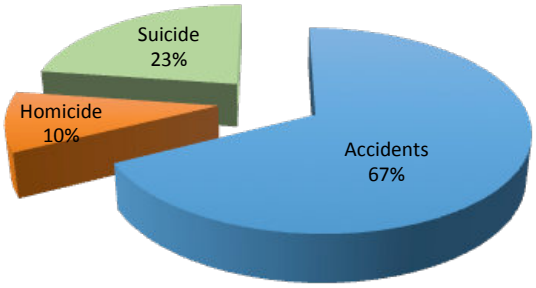

Figure 14: Violent Deaths by Categories in Texas

The same as in the national figures, more than two-thirds of the violent deaths in the state are accidents, while suicides are the second largest contributor with 23% of all violent deaths.

Table 8: Causes of Violent Death by group and Gender in the USA

	White		Hispanic		Black		Others	
Violent Deaths	Male	Female	Male	Female	Male	Female	Male	Female
Accidents	0.064%	0.039%	0.034%	0.014%	0.043%	0.020%	0.028%	0.013%
Homicide	0.005%	0.002%	0.008%	0.002%	0.024%	0.005%	0.008%	0.002%
Suicide	0.029%	0.008%	0.008%	0.002%	0.009%	0.002%	0.009%	0.004%

In table 8 we can easily see that the major contributors for accidental deaths are the males, and there is also the same factor of homicides being the cause of more black males.

DISEASES DEATHS ANALYSIS IN TEXAS

Following the analysis that we did for the diseases as reported by the CDC, we find that the top illnesses are very much the same as for the national level.

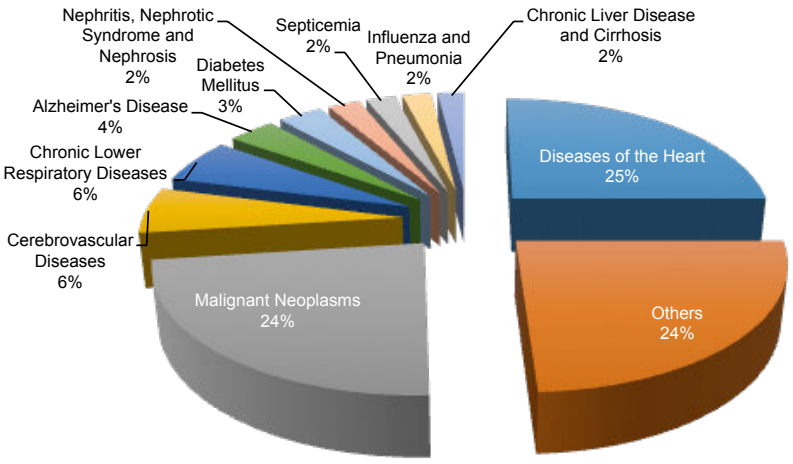

Figure 15: Top Diseases in Texas

The figure shows that Disease of the Heart and Cancers are the top two causes of death by illness in the United States as they add to over 50% of the deaths. The next contributors are much smaller because the following one on the list is the respiratory disease with only 8% of the deaths. Having identified the main causes of death, we now proceed to analyze by gender and then by ethnic group in order to identify possible trends or differences on the proportions.

Table 9: Causes of Mortality by Gender

Males		Diseases causing Death	Females	
0.164%	20,771	Diseases of the Heart	18,258	0.143%
0.137%	17,420	Others	20,508	0.161%
0.156%	19,716	Malignant Neoplasms	17,164	0.134%
0.031%	3,936	Cerebrovascular Diseases	5,406	0.042%
0.035%	4,418	Chronic Lower Respiratory Diseases	4,650	0.036%
0.013%	1,654	Alzheimer's Disease	3,714	0.029%
0.020%	2,586	Diabetes Mellitus	2,496	0.020%
0.014%	1,792	Nephritis, Nephrotic Syndrome and Nephrosis	1,837	0.014%
0.012%	1,581	Septicemia	1,805	0.014%
0.012%	1,535	Influenza and Pneumonia	1,712	0.013%
0.016%	1,996	Chronic Liver Disease and Cirrhosis	1,034	0.008%

The table shows that Cerebrovascular and Alzheimer's diseases have also a larger percentage in women than in men. The difference is more noticeable in the Alzheimer's disease because the number of deaths is more than twice as much.

Table 10: Proportions of Death by Group and Gender

Diseases Causing Death	White		Hispanic		Black		Others	
	Male	Female	Male	Female	Male	Female	Male	Female
Diseases of the Heart	0.250%	0.219%	0.075%	0.062%	0.172%	0.150%	0.069%	0.049%
Others	0.195%	0.238%	0.077%	0.081%	0.153%	0.162%	0.061%	0.059%
Malignant Neoplasms	0.235%	0.198%	0.072%	0.065%	0.165%	0.143%	0.075%	0.065%
Cerebrovascular Diseases	0.043%	0.063%	0.017%	0.019%	0.038%	0.047%	0.016%	0.018%
Chronic Lower Respiratory Diseases	0.064%	0.069%	0.009%	0.007%	0.023%	0.018%	0.009%	0.007%
Alzheimer's Disease	0.023%	0.050%	0.005%	0.010%	0.007%	0.018%	0.002%	0.006%
Diabetes Mellitus	0.024%	0.020%	0.017%	0.018%	0.026%	0.030%	0.009%	0.008%
Nephritis, Nephrotic Syndrome and Nephrosis	0.018%	0.017%	0.009%	0.010%	0.020%	0.022%	0.007%	0.006%
Septicemia	0.016%	0.018%	0.008%	0.009%	0.016%	0.019%	0.006%	0.006%
Influenza and Pneumonia	0.018%	0.020%	0.007%	0.007%	0.011%	0.011%	0.005%	0.005%
Chronic Liver Disease and Cirrhosis	0.018%	0.010%	0.016%	0.008%	0.009%	0.005%	0.005%	0.003%

Some interesting findings on the table 10 are that Hispanic men and women have higher diabetes and lower respiratory issues than white people; white and black women have an alarming rate of Alzheimer disease compared to the other minority groups; and diseases of the heart are predominantly higher for white people in proportion to the other ethnic groups.

CONCLUSION

In this paper, we started the conversation about the ethnicities' differences on the number of deaths by causes. It is our intent that future medical research can answer the above mentioned questions so that developing a health atlas, we can identify the unique cultural and habit practices of people for nourishment, exercise and how do they take care of themselves, so that those practices can be presented to the other groups as a way of reducing the ratios of death by those causes.

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World Bank Open Data https://data.worldbank.org/

DECISION SCIENCES INSTITUTE
Common Omissions and Mistakes in Six Sigma Case Studies

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ABSTRACT

DMAIC (Define, Measure, Analyse, Improve and Control) problem solving methodology is central to Six Sigma programmes. Hundreds of Six Sigma case studies are being reported in many journals. However, very little in terms evaluating the methodology and its application is published in the literature. Many of the published Six Sigma case studies have several common omissions and mistakes in the application of DMAIC methodology. This research investigated these common pitfalls through an analysis of eight case studies published in different peer reviewed journals. The findings of this research are presented in this paper.

KEYWORDS: Six Sigma, DMAIC, Quality Management, Problem Solving

INTRODUCTION

Six Sigma quality improvement programme is currently widely used throughout the world in many organisation: services and manufacturing, private and public sector (Davis, 2018). DMAIC (Define, Measure, Analyse, Improve and Control) problem solving methodology is central to Six Sigma programmes. Hundreds of Six Sigma case studies are being reported in many journals (including professional and peer reviewed journals) and business management magazines. Almost all of these case studies report process improvements / savings through the application of this methodology.

Six Sigma started at Motorola, but was promoted by Jack Welch at General Electric. It is indeed making a difference to organisations that adopt the programme in a systematic and rigorous way. DMAIC methodology is a standard and rigorous method which consists of several prescriptive steps: Define, Measure, Analyse, Improve and Control. Within each step / phase, there are several sub-steps. Literature consists of numerous problem solving tools (the seven problem solving tools, control charts, design of experiments, etc.) that are applicable to each of the DMAIC steps. While the broader methodology is prescriptive, the selection of tools and the way they are used depends on the quality / process improvement problem that is being solved and the skill and knowledge of the problem solving team. Effective solution to the quality / process improvement problem requires good understanding of the methodology and knowledge of the problems solving tools. Obviously following the methodology correctly and using appropriate data collection and problem solving tools help to achieve desired results in shorter period.

However, in the experience of the author, many of the published six sigma case studies have several common omissions and mistakes in applying DMAIC methodology: some do not follow the methodology correctly; some use wrong problem solving tools; some fail to use relevant tools.

The consequence of these omissions and mistakes in following DMAIC methodology, data collection and the application of the problem solving tools are: failing to identify real root causes,

identifying wrong causes, missed opportunity to further improve / save, delays in solving the quality / process improvement problem and even Six Sigma project failure.
This research aims to study the common omissions and issues in the application of DMAIC methodology. Specifically this research aims to investigate the following**:**

- What DMAIC steps are problematic for the investigator and why?
- What problem solving tools often not used but should have been used? What tools commonly incorrectly used? What could be the potential reasons for this?
- Do these mistakes occur for certain type of quality / process improvement problems? For certain industries? Why?

It is hoped that through the findings of this research organisations and analysts will learn to avoid these pitfalls / mistakes when adopting DMAIC methodology for problem solving and process improvement.

LITERATURE REVIEW

DMAIC stands for Define, Measure, Analyse, Improve and Control. The purposes of the five DMAIC phases are:

Define : to define the problem
Measure : to identify performance measure(s) and establish a current baseline.
Analysis : to identify root causes of the problem
Improve : to implement solutions that address the root causes
Control : to evaluate the solutions and standardize the improved process for sustainable improvement

These five phases are sequentially applied when working on a six sigma quality / process improvement project. Although prescribed to be sequential, in practice these phases overlap. For example, some analysis is often done during measure phase and vice versa. The strength of DMAIC framework is that it guides the analyst to frame the problem and leads to a solution – a solution that is likely to be robust. Six Sigma literature provides several tools that are applicable to each of the DMAIC phases. These are shown in Table 1.
Six Sigma is generally used in two ways:

- As a Strategic approach to productivity and process improvements: Organisations that adapt Six Sigma as a strategy to achieve process and quality improvements throughout the company. These organisations implement tens or hundreds of six sigma projects all of which require DMAIC methodology. Motorola and General Electric are examples of such organisations which have taken this approach. De Maast & Lokkerbol (2012) call this as “project-by-project” approach.
- As a problem solving approach: Ad hoc application of DMAIC methodology for a one-off quality / process improvement problem. The DMAIC framework helps to guide the analyst from starting the problem to solving the problem.

Either way, DMAIC is the recommended approach to problem solving. DMAIC evolved from its predecessor “the seven-step problem solving methodology” which is a prescribed problem solving methodology for TQM (1990s to date) and Quality Circles (1980s) programmes.
Six Sigma projects use more sophisticated statistical tools than is the case with TQM / Quality Circle programmes (Pulakanam & Voges, 2010). The most common tools used with the seven-step problem solving method are: The seven tools of quality (flowchart, cause and effect diagram, etc.), DOE, etc. DMAIC methodology is considered as a far more rigorous approach along with recommendation of far more advanced and simple statistical tools. There are several reasons for this.

Table 1: DMAIC Methodology Steps and most commonly used tools (Ref. Gitlow & Levine, 2005 & De Maast and Lokkerbol, 2012)

DMAIC Steps	DMAIC Tools
Define: problem selection and benefit analysis D1. Make a business case for the project D2. Identify and map relevant processes D3. Identify stakeholders D4. Determine and prioritise customer needs and requirements	**Define Phase Tools** • Process mapping: SIPOC diagram; detailed flow chart (Swim Lane chart); Deployment chart; Workflow diagram (spaghetti chart) • Abstraction Tree (KJ or Affinity) Diagram • Critical-to-quality tree (CTQ) tree • Kano model • Quality function deployment • Stakeholder analysis
Measure: Translation of the problem into a measurable form and measurement of the current situation; refined definition of objectives M1. Select one or more CTQs M2. Determine operational definitions for CTQs and requirements M3. Validate measurement systems of the CTQs M4. Assess the current process capability M5. Define objectives	**Measure Phase Tools** • Histogram • Check sheet & Location plot • Run charts • Control charts • Process capability analysis • Measurement system analysis • Failure modes and Effects analysis • Customer segmentation • Data measurement scales • Basic statistics (Data exploration; graphing data; sample size; ..) • Data stratification
Analyse: identification of influence factors and causes that determine the CTQs' behavior A1. Identify potential influence factors (Xs) A2. Select the vital few influence factors	**Analysis Phase Tools** • Data stratification • Cause and Effect diagram • Scatter diagram and Regression analysis • Pareto chart • Histogram • Runs charts, Control charts • Five Whys • Control charts • ANOVA • Y to X tree diagram • Root cause analysis
Improve: design and implementation of adjustments to the process to improve the performance of the CTQs I1. Quantify relationships between Xs and CTQs I2. Design actions to modify the process or settings of influence factors in such a way that the CTQs are optimized I3. Conduct pilot test of improvement actions	**Improve Phase Tools** • Design of Experiments • Brainstorming • Risk assessment • Control charts • Lean Tools: SMED, Poka Yoke, etc.
Control: empirical verification of the project's results and adjustment of the process management and control system in order that improvements are sustainable C1. Determine the new process capability C2. Implement control plans	**Control Phase tools** • Control charts • Performance dashboards • Poka Yoke (Mistake proofing) • Auditing

Employee participation in TQM and Quality Circle programmes is voluntary. Rarely the project team members work full-time on a project. In most situations, employees are expected to work on quality/ process improvement projects, not a quality engineer or a specialist. TQM / Quality Circles training programmes tend to be short (a few days) and the training is often limited to simple tools such as the seven tools of quality. Advanced tools such as DOE are covered, but these are beyond the capabilities of the shop-floor employees. Use of software is relatively less in TQM / Quality circle programmes as the software programmes in 1980s and 1990s were not that advanced and employees tend be less savvy at using computers or specialist software. In TQM / Quality Circle programmes, there are no specific expectations in terms of the level of improvements to be achieved from a project.

In contrast, six sigma projects are expected to be led by trained Black belts who often work full time on the projects (Harry, 1998). The Black belt training typically is of four weeks duration and the completion of a project that requires the application of DMAIC methodology. The training programmes include advanced statistical techniques and the use of software such as MINITAB. MINITAB and other similar software have become more sophisticated so much so that it is almost impossible to apply DMAIC methodology without such software. Availability of such software obviously encourages the analysts to apply these tools. Each six sigma project may last several months and is expected to save at least $150,000 (Harry, 1998). Many more problem solving tools applicable to different phases of DMAIC methodology are now recommended. These include ANOVA, probability plots, etc. Along with sophistication, it has become complex too, as opposed to the seven-step problem solving approach. For this reason, dedicated resources are needed to work on six sigma projects.

Looking at the number of case studies published in journals and professional magazines, it appears to be popular as a problem solving tool. It is widely used in several industries, including in health, Information Technology organisations even when it is not used as a part of a six sigma programme. A CEO of a local SME likes the approach so much so that he has employed a six sigma coordinator and was putting through some of their employees through A DMAIC training programme that was offered in US.

Nevertheless DMAIC has some weaknesses along with its strengths. De Maast et al. (2012), using scientific problem solving theories, provide an evaluation of DMAIC as a problem solving methodology. They identified several strengths and weaknesses:

- It helps as a problem structure device.
- it is a powerful methodology with advanced statistical techniques, for ‘fact finding and empirical verification’
- it has tools for undertaking testing of hypotheses
- a single authoritative account of DMAIC methodology does not exist
- it is a too generic technique. (In order it to be effective it needs to be specific to industry with specific tools and templates).
- it is not suitable for ill-structured problems.
- It is not suitable for situations with fuzzy objectives.
- it has weaknesses in the areas of problem diagnosis and finding remedies.
- it is not suitable for smaller scope projects

De Koning and de Mast (2006) argue that “ …the descriptions of the steps that these phases are comprised of and the tools that are prescribed for them diverge.” They also comment that definitions of concepts such as CTQ are not precise. Cursory examination of some of the case applications confirms these assertions. Similarly Mandal (2012) argue that “…the manner in which the process improvement is achieved in many DMAIC studies is far from satisfactory.”

In summary, DMAIC methodology is an useful problem solving methodology which is widely used. However, far too frequently the methodology is poorly applied. This research, therefore, aims to evaluate the issues and the causes for unsatisfactory application of the method.

RESEARCH METHODOLOGY

The following methodology was used to undertake this research:

1. Review available DMAIC methodologies and select the one that is robust / widely used.
2. Select peer reviewed journals to select DMAIC application case studies
3. Select a sample Six Sigma case studies that used DMAIC methodology.
4. Deconstruct and analyse the case studies by examining to what extent the standard DMAIC steps have been used correctly.
5. Summarise the findings

The above steps are elaborated further below:

DMAIC methodology and Steps: While there is no disagreement in the sequential application of the five DMAIC phases, there are considerable inconsistencies in the steps and their interpretation within each of these phases. De Koning and de Mast (2006) reviewed the recommended DMAIC steps from 20 sources and came up with their recommendations for DMAIC steps. Gitlow and Levine (2005) provided DMAIC phase steps and demonstrated how to apply these steps with an elaborate but fictitious example that cover all the recommended steps. There is lot more consistency between de Koning and de Mast (2006) and Gitlow and Levine (2005). We used these two references to come up with a set of standard DMAIC steps (Table 1) that we have used to evaluate the case studies.

It is important to clarify that the focus of our research is on the application of the DMAIC methodology. We are less concerned in the order these steps have been implemented in the case studies although we will be making observations on this as well. For example, CTQ is recommended in Define phase and in other cases in Measure phase. For the purpose of this research we will be focusing on whether CTQ was defined or not and not in which phase this was done.

Journal selection: In selecting case studies our initial goal was to include as many different journals as possible.

The journal selection was limited to rank order operations and quality management (including Six Sigma quality) journals listed in Australian Business Deans Council (ABDC) Master Journal list (http://www.abdc.edu.au/master-journal-list.php). Unfortunately, the top raked journals in this list did not have any six sigma case studies. Most of the journals selected were C rank journals. We then decided to select eight case studies form these selected journals. These case studies provided enough data to comment on the underlying issues. The sample is a convenient sample. We have not used any scientific approach to selecting journals or to determine the sample size as our focus at this stage is to assess the nature and extent of the problem rather proving any hypotheses. The selected case studies are shown in Table 2.

Table 2: Case study articles

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FINDINGS

The findings of our case analysis are presented below and a summary of the findings are given in Table 3.

Define Phase

Define phase defines the problem. It consists of:

1. Problem statement and issues and project objectives
2. An explanation of why the project worth considering
3. Process map and SIPOC diagram
4. Identifying customers and their needs VOC Analysis

All cases described the problem and project objectives fairly well. The differences in the level of details are due to the differences in the authors' writing skills and abilities and the requirements of the journal publishers.

Most cases provided an explanation of why the project is worth considering. Cost savings have been the most common reason provided. Just one case argued that the improvement project helps with meeting customer needs.

According to Six Sigma literature, the Six Sigma project goals ideally should be SMART (Specific, Measurable, Achievable, Relevant, Time limited) and the improvements need to be breakthrough improvements (See for example, Gitlow and Levine, 2005). According Harry (1998) an average Black Belt project will save a company $175,000. This makes sense if the project involves some of the team members (like Black Belts) working full time on the project. Besides six sigma training is not cheap! At the same time, it is to be noted that the DMAIC

methodology itself is applicable to almost all projects – weather it is a trivial project or a project that has the potential for savings hundreds of thousands of dollars.
Most cases describe the business cases for implementing a six sigma project only in general qualitative terms and do not provide in quantitative measures. In some cases they have provided the benefits at the end of the case in Control phase. The analysis of the cases does not provide any indication that breakthrough achievements have been made. However, they do demonstrate that the application of DMAIC methodology (rigorously or not) leads to some improvements if not breakthrough improvements.
Almost all cases provided a flowchart of the process and a SIPOC diagram. SIPOC is an appealing diagram, but it is not clear how it was used in the case. SIPOC diagram "helps to define a complex project that may not be well scoped, and is typically employed at the Measure phase of the Six Sigma DMAIC methodology" (iSixsigma). From this point of view, it is worth drawing a SIPOC diagram. However, there is less consistency in the way it is drawn. It may be worthwhile to provide a guide to draw SIPOC diagram to fully utilize its potential?
Six Sigma methodology recommends VOC (Voice of Customer) analysis. According to Gitlow and Levine (2005) this includes, customer segmentation, active and passive data collection and even Kano analysis (Gitlow and Levine, 2005). However, just only one case briefly did customer segmentation, but not followed through in the case analysis. None of the cases undertook Kano analysis. One reason for not undertaking Kano analysis is that most cases considered just one CTQ which is a "must be" otherwise they would not have considered.

Measure: The goal of the measurement phase is to clearly state a performance measure and establish a current baseline. It consists of:

1. Selecting and defining CTQs
2. Validating measurement system of the CTQs
3. Assessing baseline process capability
4. Defining project goals

The CTQs identified, the tools used along with the researcher's comments are provided in Table 4.

Table 3. A summary of case analysis

Phase	Step	What is practiced	Comments
Define	D1. Business case D2. Process mapping D3. Identify stakeholders D4. Determine and prioritise customer needs and requirements	Most cases describe the business case for implementing a six sigma project in qualitative terms, but do not use quantitative measures. Cases that did contain a description of the current process were well defined. Only one of the cases failed to provide any description of the current process.	Why most do not report benefits in measurable terms? Is it difficult to do this for some projects? For what type of projects would that be? Or do they find this an unnecessary step which is not essential to make improvements? Hence is this step necessary? It may be that problem can be solved without a quantitative measure! De we need SIPOC? How is this used?
Measure	M1. Select CTQ M2. Define CTQ M3.validate measurement system M4. Assess current process capability M5. Define objectives	Very few identified CTQ; Only a small number of cases identified what constituted a defect, In some cases the CTQ was poorly defined (For example: “not having too much operating noise”) In many cases there was no description of what is being measured. Most cases skipped validating the CTQ measurement system entirely. Cases with well-defined CTQs are usually the cases that also follow through with well-described baseline measurements. Five out of the eight cases included baseline measurements: A range of measures are used to measure current capacities: Histograms and C_p/C_{pk} and process sigma levels Many cases fail to provide a project goal, or if they do, the goals are often not SMART (I.e., the goal is simply improving X instead of improving X characteristic by a certain percentage within a specified time period).	Is CTQ difficult to define? Poor definition of CTQ is an indicator of poor application of DMAIC which further lead poor improvement results? Is this step difficult? Is it necessary? How critical is this step? Why is this step not done? Dependency on software? Why some case studies have not provided any baseline measurements? Can improvements be achieved without completing this step? What baseline measurements are best? Why have a goal? Isn’t it artificial? Can the problem not be solved without having a goal?

Analyse	A1. Identify potential Xs A2. Select the vital few Xs	Most cases poorly identified / described what the Xs. This has further contributed to the difficulty of measuring Xs. Cases with a very short analyse section were usually preceded by poorly defined define and measure sections.	Why? Perhaps Analysis (i.e. identifying potential influence factors) starts from almost 'Define' phase and continues till Control phase. That is identifying influence factors happens right from the start of the project as there is heightened awareness of the problem. As the saying goes "a problem clearly stated is a problem half solved."
Improve	I1. Quantify relationships between Xs and CTQs I2. Design actions to modify the process or settings of influence factors in such a way that the CTQs are optimized I3. Conduct pilot test of improvement actions	Improve phase was very short for all cases. Cases with a detailed analyse phase didn't necessarily need a detailed improve phase as the information could be viewed as repeating itself. Only two cases adequately described the Xs, with only a single case actually describing the different levels of each X available. Four out of the eight cases didn't describe how the Xs were discovered, nor how the optimal settings were chosen. Many cases only describe a single tool used to arrive at the optimal settings for each X.	How Xs were discovered and chosen seems to be an issue. No specific tools have been described to finding the solution.
Control	C1. Determine the new process capability C2. Implement control plans	Overall most cases presented a good description of the control phase. The cases with the best control phases were consistent with those cases with an effective Analyse/Improve Phase. However, with some categories information needs to be assumed by reading into the case. Some cases did not present any information regarding the level of process improvements.	Again Maast may have provided a good explanation why control phase was general well done

Table 4. Measure Phase: Case study CTQs and tools used to measure baseline capability

	CTQ	Analysis and tools used for baseline capability	Comments
Case 1	Processing time	Histogram	SPC charts would be useful
Case 2	Thickness of Toffee	X-MR chart; Histogram; C_p / C_{pk}	X-MR charts are OK; but Xbar & R charts are more appropriate
Case 3	The ratio of first call resolution	p-chart	
Case 4	Patient Waiting time	Histogram; % not meeting target	SPC charts would be useful
Case 5	Operating noise of car seats (distance between right and left seat frames)	Histogram; C_p	SPC charts would be useful
Case 6	Quantity dispatched; Quantity delayed	Process sigma	SPC charts would be useful
Case 7	Medicine buying time	X-MR chart; C_p	OK; Histogram would be useful too
Case 8	Defective casting / crack propagation in parts (casting density)	Xbar charts; C_p / C_{pk}	Correct type of charts but indicates potential error is the use of the charts

Very few clearly identified and defined CTQs. In many cases it is not clear what is being measured. Because of this it is not clear how the CTQ is measured. For example, how one measures the thickness of a soft toffee? If CTQ is not well defined, then it is difficult to determine what constitutes a "defect". Given accurately defining CTQ is critical to problem solving, it is important to understand why analysts avoid defining or incorrectly define CTQ.
Only two out of the eight cases validated the measurement system. Why?
Five out of the eight cases included baseline performance measurements. Cases with well-defined CTQs are usually the cases that also follow through with well-described baseline measurements. A range of measures were used to measure current capacities: Cp / Cpk and process sigma levels.
Many cases fail to provide a project goal, or if they did, the goals were often not SMART. That is, the goal stated was simply improving X instead of improving X by a certain percentage within a specified time period.
The tools used and type of analysis carried out to measure baseline capability are shown in Table 4. Most cases used histograms (for measurable CTQs) and process capability indices. Some used control charts. Control charts are applicable for almost all of the eight cases, but only three out of the eight cases used control charts! Why? Histograms are useful to understand the process mean and variability, but are inadequate as a tool for process improvement. Linderman et al. (2003) argues that having project goals helps to alter the behavior of organized members and their perceptions about how much change is possible. Eckes (2001) suggests a rule of thumb of reducing the problem of 50% within 120 to 60 day period! In our research only three out of the eight cases set a measurable project goal. Did this help? Did it hinder for the other cases by not setting any project goals? It is not clear.

Analyse Phase: The goal of the Analyse phase is to identify root causes (the Xs). The steps involved are:

1. Identify potential Xs
2. Select vital few Xs.

The following are the finding of the analysis of the Analyse phase:
Three of the eight cases involve reducing time – time to resolve customer enquiry; time taken by the patients to buy medicine and patient waiting time. All these cases rightly identified the component times that adds to the total time (i.e. $Y = Y_1 + Y_2 + \ldots + Y_n$). They then identified the few process steps that significantly contribute to the overall time and attempted to improve these few process steps.
In three cases the original Y (i.e. the CTQ) is different from the final Y that was studied (Table 5). In these cases the original Y is the language of the customer ("too much noise" or "defective casting"). In these three cases the analysts rightly studied the technical causes of the original Y (distance between right and left seat frame, or density of the casting).

Table 5. Analyse phase: Original Y vs root cause Y

Initial Y	**The final Y**
Thickness of sweets	Bubbles in the sweet, which contributes to the thickness of sweets
Car seat operating noise is one of the major contributing factor	Variation in distance between right and left seat frames contributes to car seat operating noise.
Defective casting / crack propagation	Casting density

Most case studies failed to explain how the root causes (well defined or not) were identified and how they have been screened. That is, it is not clear what tools were used to identify the root causes and to select the vital few. Also, many of these cases poorly described the root causes (the Xs) that are being measured.
Brainstorming exercise and Cause and Effect diagrams are the most commonly used methods to identify potential Xs. In one case control chart analysis helped to identify the potential Xs. In our opinion, if the analysts used control charts to assess baseline process capability, they would have found the control charts helpful to identify some of the root causes.
In many cases it is not clear how Xs were shortlisted. Commonly reducing the pool of Xs was done in consultation with team members. Other methods used were: trial and error experiments, multi-voting techniques and FMEA.
In most cases that we studied, the Xs were often inadequate process steps: inadequate maintenance, addition of new step, etc.
Cases with a very short analyse section were usually preceded by poorly defined 'define' and 'measure' phases. The cases that did have detailed Analyse phase with relevant information were usually those that had well defined Define and Measure phases.

Improvement Phase: The goal of the Improve phase is to implement solutions that address the root causes. The improvement steps are:

1. Study relationships between Xs and Y
2. Identify improvement solutions / determine optimal Xs
3. Conduct pilot tests

The following are the findings of the analysis of Improvement phase:

Is X related to Y? This is answered by collecting data. But, establishing relationship (an equation) is difficult in most cases. This was possible when DOE type of experiment was done. Half of the cases didn't describe how the Xs were discovered, and how the optimal settings were chosen. Most cases described just one single tool to arrive at the optimal settings for each X.
In most cases improvements were identified through process flowcharting, "walking" the process and observing the process in action.
Improvements are typically process streamlining (adding / improving a process step), improved maintenance including a measurement system, etc. Such improvements in process steps helped to reduce variation in Y. Many used lean tools: 5S and VSM to make improvements.
Identifying optimal Xs (like optimal production temperature) require trial and error experimentation or design of experiments.
Pilot studies are not undertaken by all case studies. Such studies perhaps are not necessary when improvements are obvious. One case undertook confirmation capability study to assess the true improvements. When one needs a pilot study?
Improve phase was very short for all cases. Cases with a detailed analyse phase didn't necessarily need a detailed improve phase as the information could be viewed as repeating itself.

Control Phase: The goal of the Control phase is to empirically evaluate the solutions, assess if the project goals have been met and standardize the improved process for sustainable improvement. The specific steps are:

1. Determining new process capability
2. Implementing control plans

The key findings of the analysis of this phase are:
Overall most cases presented a good description of the control phase. The cases with the best control phases were consistent with those cases with an effective Analyse and Improve Phases

SUMMARY AND CONCLUSIONS

Six Sigma is a worldwide phenomenon with only a fraction of the actual applications being reported in journals. However, very little in terms evaluating the methodology and its application is published in the literature. In this sense the findings of this research would be most useful to industry. It will add to the Six Sigma literature.
The analysis of the eight cases indicated that the use of DMAIC methodology as a problem solving methodology has been beneficial for organisations, although the improvements are not breakthrough improvements as is promoted by the Six Sigma promoters.
The DMAIC methodology was decidedly poorly applied by the analysts. More research needs to be done to investigate how extensive these findings are. The author thinks that lack of expertise and experience of the analysts may be the main reason for the unsatisfactory application of DMAIC methodology although this need to be further investigated.
There are several limitations in this research, the primary being the sample design: small sample size and the use of convenient sample. Also, the findings are based on what is presented in the case studies. The authors of the case studies most likely have done lot more than what is presented in the case studies. These limitations make it difficult to generalize the research findings. Future research will need to consider these limitations.

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DECISION SCIENCES INSTITUTE
Community Based Care Coordination: An Elder-Care Learning Community Platform

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ABSTRACT

Community based care coordination is an important strategy for reducing preventable hospital readmissions among the elderly. The purpose of this paper is to discuss the design, development and implementation of an elder care learning community platform aimed at coordinating care and communication between patients, patients' families and caregivers and health care providers. This paper highlights the importance of utilizing design thinking as a strategy for solving complex medical and public health problems and demonstrates how the balanced scorecard model can be used as a foundation for this learning community.

KEYWORDS: Care coordination, elder-care, design thinking, balanced scorecard

INTRODUCTION

According to the Centers for Medicare & Medicaid Services (CMS), national healthcare spending is projected to increase at an average rate of 5.5 percent between 2017 and 2026 and is estimated to reach $5.7 trillion by 2021. The health share of the GDP is estimated to increase from 17.9 percent in 2016 to 19.7 percent by 2026 (CMS, 2018). Reducing preventable hospital readmissions is one strategy that has taken national priority for payers, providers and policymakers to improve quality and health care spending. In 2012, the CMS began to reduce the Medicare payments for certain hospitals that had excessive 30-day readmissions for patients with conditions such as heart attacks, heart failure, pneumonia, chronic obstructive pulmonary disease (COPD), hip or knew replacement and coronary artery graft (CABG) surgery through its Hospital Readmission Reduction Program. In order to lower the rate of readmission, many hospitals have focused on improving the coordination of care and communication between providers and patients and their caregivers, improving discharge planning and education in addition to the use of electronic medical records to improve continuity of care (AHRQ, 2018). In 2013, the national readmission rate fell to 17.5 percent after holding steady at 19-19.5 percent for many years (AHA, 2018) however, the majority of these readmissions are of elderly patients. Hospital readmission among the elderly is a multifaceted and complex issue;

strategies for reducing hospital readmission in elderly patients include comprehensive, multidisciplinary approaches such as patient needs assessment, medication reconciliation, timey outpatient appointments and patient education (Kripalani, Theobald, Anctil & Vasilevskis, 2014).

Care of the elderly is a multi-faceted and multi-organizational service. Some common challenges that are often discussed when dealing with care for the elderly are related to the access, quality, and cost of care. Further, the therapeutic, policy, technological, financial, ethical, and moral issues involved require continuous learning by all the care providers, specifically to help them navigate the interactions between these issues. As such, there is an important need to coordinate and synthesize the fragmented efforts of the many providers and organizations who serve this population. It takes a community of learners to care for a community of the elderly. Florida has the highest proportion of the population age 65 and older (19.4 percent in 2015). Within Florida, some counties have more than 50% of the population age 65 and older as of 2015 (i.e. Sumter, FL.). Meeting the current challenges of elder-care in Florida will provide effective guidelines for managing the challenge at a national level.

The purpose of this paper is to discuss the design and development of a sustainable online learning community for elder-care service providers in Palm Beach County, Florida, to facilitate knowledge sharing, communication, collaboration and coordination of care among providers. This paper contributes to the literature by applying the balanced scorecard design for the online learning community platform as the underlying foundation for care coordination. This paper also provides practical contributions because by addressing the issues facing elder care in Florida, we provide guidelines for implementing similar platforms for elder-care at a national level. In this paper we will begin with a discussion of community-based care and the incorporation of the balanced scorecard framework into the learning community. Then we will provide an overview of the design and build process of the learning community, with a focus on design thinking and provide an overview of the system architecture and components. In the final section, we will discuss the implementation of the learning community and review community efforts along with key outcome measures that will be considered during the implementation phase. We conclude with a discussion of next steps and provide a brief agenda for future research.

LITERATURE REVIEW

Community based care and care coordination

As of 2015, there were 47.8 million adults age 65 and older in the US, which accounted for 14.9 percent of the total population. This population grew 1.6 million from 2014 and is projected to grow exponentially by 105.2 percent between 2015 and 2060 (US Census Bureau, 2018). While the population continues to age, health care providers are tasked with the need to serve more patients while also trying to reduce costs. The central goal of care coordination is to meet the needs of patients and to deliver high quality, high value care by bridging the gaps along the care pathway (AHRQ, 2018).The Agency for Healthcare Research and Quality (AHRQ) of the US Department of Health and Human Services defines care coordination (CC) as "*the deliberate organization of patient care activities between two or more participants (including the patient) involved in a patient's care to facilitate the appropriate delivery of health care services. Organizing care involves the marshalling of personnel and other resources needed to carry out all required patient care activities and is often managed by the exchange of information among participants responsible for different aspects of care."* (AHRQ, 2018).

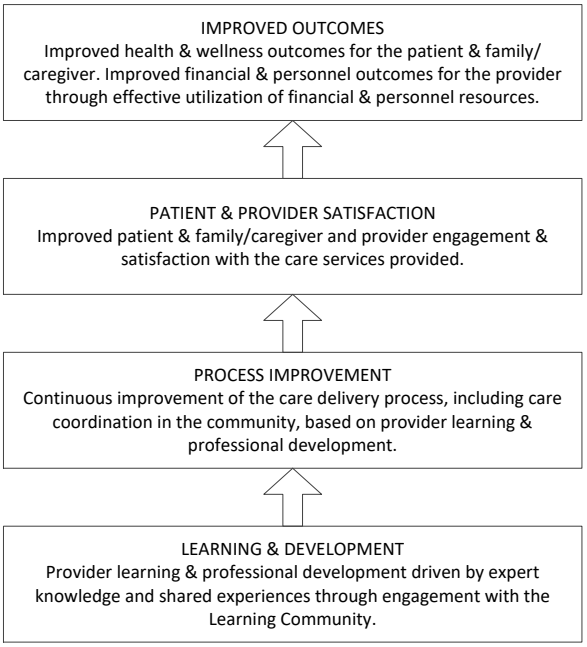
The typical care coordination system focuses on the patient, their health care providers, and their family/friends or designated caregiver while sometimes ignoring the auxiliary services such as social workers and community support that may be available after hospital discharge. Community based care coordination incorporates the services that are provided by non-clinical community organizations which help to supplement clinically oriented care coordination. This care coordination can be provided at different stages of a patient's disease progression or medical condition and has been classified into different stages based on the occurrence or impact of the disease or medical condition. These stages include: acute condition, chronic condition and wellness condition (Dehen et al., 2010). Care coordination can be understood from a system perspective which examines the tasks and processes which are required for coordination of care, a healthcare professional perspective which accounts for the various health care providers and a patient/family perspective which keeps the patient central to the care coordination system. When incorporated with the community perspective which integrates the health and social support networks, this model of care takes a holistic, patient centered approach which is aligned with the Institute of Healthcare Improvement's (2007) Triple Aim framework which emphasizes the need to improve the patient care experience, improve the health of the population and reduce per capita health care costs (Lewis, 2014).

Balanced scorecard

Leaders in healthcare have started to use the balanced scorecard model (Kaplan & Norton, 1990) as a framework for performance measurement and strategic planning in healthcare organizations and the health services sector (Voelker, Rakich & French, 2010). The principle behind the balanced scorecard is that top management should have a balanced set of measures that reveals the interdependency of the critical aspects of the organization. This balanced perspective is then used by top management when designing and implementing strategic decisions in the organization. The balanced scorecard has four perspectives from which they can choose measures and complements traditional financial indicators with measures of performance for customers, internal processes and innovation and learning activities (Kaplan & Norton, 1996). In healthcare the scorecard needs to reflect three categories of interdependent value: the business, employee and patient value and this balance is achieved by considering measures from the patient, internal, learning and financial perspectives (Castañeda-Méndez, Mangan & Lavery, 1998).

Figure 1 illustrates our proposed use of the balanced scorecard model for community-based care and care coordination. Through engagement with the learning community, providers and professionals are able to learn from expert knowledge and shared experiences to facilitate provider learning and professional development. This leads to continuous process improvement of the care delivery process which includes care coordination in the community. As processes are improved, there is subsequent improvement in the engagement between the patient and family/caregiver with the provider and increased satisfaction with the care services that are provided. This ultimately results in improved health and wellness outcomes for the patient and family/caregiver. These improved outcomes are realized through financial and personnel measures for the provider through effective utilization of financial and personnel resources.

Figure 1: Overall Balanced Score Card for the Learning Community



We focus primarily on the outputs and outcomes of the Learning & Development segment of the learning community balanced score card, as that is the primary focus of the proposed care coordination project. The project outputs will be measured in four participation categories: (1) membership; (2) online activity; (3) event activity and (4) engagement. *Membership* will be measured by the number of new members who join the learning community. *Online activity* will be measured by several measures: number of unique participants utilizing the online community, number of unique visits to the online resources/webinars, number of unique contributions or new resources to the online community, number of unique responses to posts by other participants and number of webinars developed. *Event activity* will be measured by the number of participant sponsored small events or site visits and the number of learning community members who participate in large or small events. Finally, *engagement* will be measured by the number of volunteers engaged in the day-to-day operation of the learning community and the tenure of the volunteers involved.

Project outcomes will be evaluated along several key dimensions: (1) network development; (2) technical satisfaction; (3) functional satisfaction; (4) knowledge growth; and (5) efficacy. *Network development* is defined as the growth of the professional network due to participation in the learning community (both quantitatively and in the variety of professional contacts). *Technical satisfaction* is defined as the learning community member satisfaction with system use (e.g. access, ease of use). *Functional satisfaction* is defined as the learning community member satisfaction with learning outcomes. *Knowledge growth* is defined as new topics learned and new resources identified. *Efficacy* will be defined as the improved patient outcomes as a result of learning community participation, contribution to success of others in the learning community and active collaboration in a collective approach to care delivery based on case-based evidence.

Design and build

Design thinking is a human-centered approach to innovation that integrates the needs of people, the possibilities of technology, and the requirements for organizational success. Design is driven by the idea that different perspectives should be analyzed, considered and synthesized to offer solutions to indeterminate problems and has the potential to envision alternative futures for health care (Valentine et al., 2017). Design thinking for social innovation is a collaborative approach that involves everyone rather than just the designer to collectively come together to analyze their usefulness and connections to a given question and collaborate both internally with colleagues and externally with partners (Valentine et al., 2017). This innovative approach to health care encourages the embrace of creative mechanisms of knowledge integration to deliver solutions to complex problems rather than relying solely on a linear approach to problem solving such as the traditional evidence-based practice (EBP) paradigm (Valentine et al., 2017). One such method has been Experience-based co-design (EBCD) which is a participatory co-design method used to improve healthcare practices that integrates the experiences of staff, patients and caregivers to improve health care process. Donetto, Tsianakas and Robert (2014) reviewed a variety of clinical projects however the empirical publications have been limited to support the recommendations developed from design thinking in health care and there has been little formal or systematic evaluation of EBCD projects.

As discussed previously, the primary objective of this online community platform is to facilitate learning and improve the coordination of care for the elderly in the county. This overall model was accomplished by adopting a design thinking approach and through a collaborative process involving appropriate community partners that included clinical, medical, para-medical, social and auxiliary services providers. The direct involvement of elder care service providers in the county, is shown on Figure 2. The elements involved in the design thinking approach included large gatherings in the form of regional conference sand local professional meetings; small gatherings through workshops, classroom trainings, site visits and volunteers in the community; and virtual gatherings through a web presence, social media, a newsletter, webinars and conference calls.

The resulting design was the basis for the development of an online learning community platform that facilitates elder-care coordination in the county. The overall learning system architecture is shown in Figure 3. The key system components include local conversations, announcing events, presenting and sharing webinars on topics of interest to the community of providers, a newsletter to keep the community of providers informed, and established outcomes-oriented tools that community providers can use to improve their services. Specific sub-topics of conversation that were relevant to elder-care in Palm Beach County were identified through the design study.

Figure 2: Elements of the Designed Thinking approach to the learning community

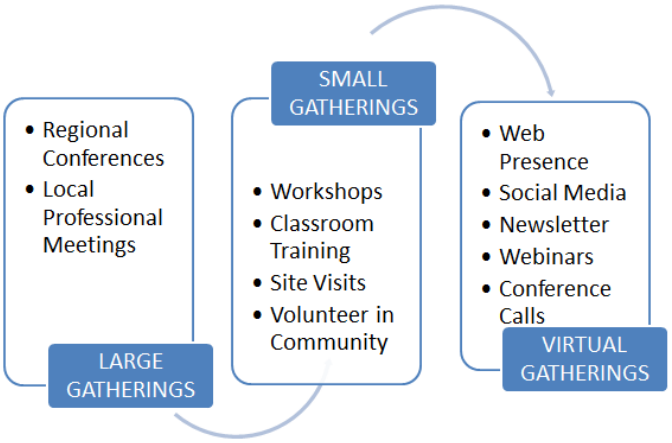


Figure 3: Learning Community System Architecture

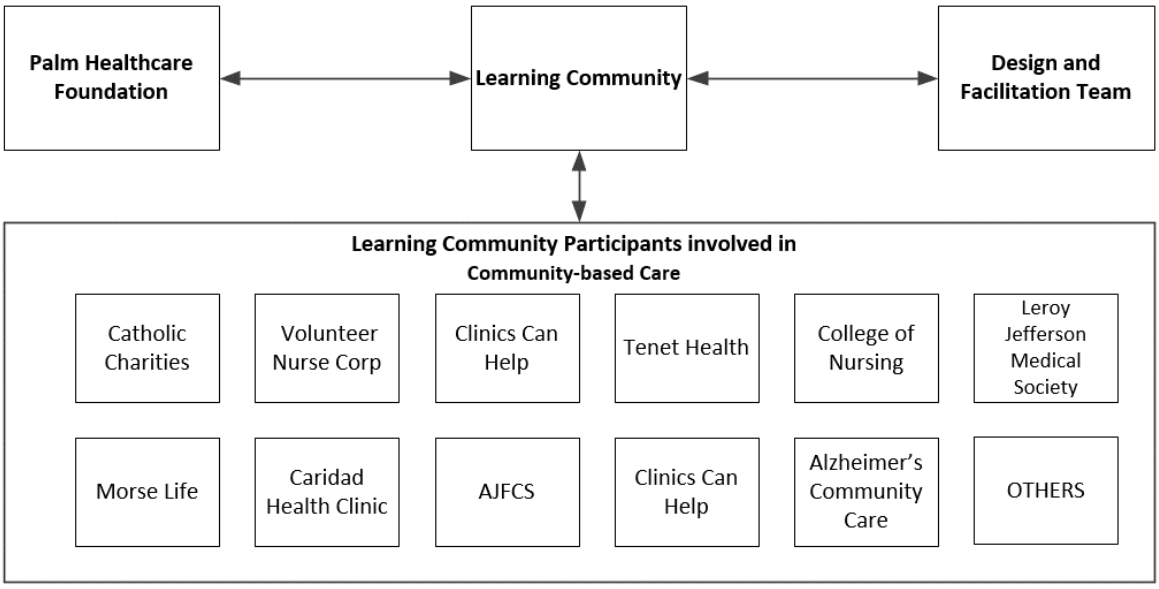
Implementation and community efforts

The Elder-Care Learning Community platform is a system managed by a community of clinical, medical, para-medical, social and auxiliary services providers and the primary purpose of this community platform is to facilitate learning to improve the coordination of care for the elderly in the county, thus implementation involved community efforts. This would be accomplished by developing and implementing a learning community that has both in-person and on-line components. Initial management of the learning community was co-developed with community members to establish a sustainable learning community to support their learning and service efforts. Key system components include: Local Conversations, Events, Webinars, Newsletters, and Tools. At the time of this article, implementation of all components, excluding Tools, are completed. The project structure is shown below in Figure 4. The learning community is supported by the Palm Healthcare Foundation and the authors facilitated the design and implementation of the platform. Some of the participants involved in the community-based care

included: Catholic charities, Morse Life, Volunteer Nurse Corp, Caridad Health Clinic, Clinics Can Help, Alpert Jewish Family and Children's Service (AJFCS), Tenet Help, College of Nursing, Alzheimer's Community Care, Leroy Jefferson Medical Society.

The platform facilitates virtual gatherings, based on which the Learning Community can continue to mature. The system also facilitates the large and small gatherings, which inherently have to be delivered by the Learning Community members themselves. Through these efforts, authors will help the Learning Community reach a level of operational sustainability. The execution of these real and virtual gatherings, and the continued and increasing participation of Learning Community members, will signify the value it provides to elder care service providers through operational, tactical, and strategic information and knowledge that will help care delivery in a rapidly changing healthcare environment.

Figure 4: Project Structure



DISCUSSION AND CONCLUSION

This paper highlights the importance of utilizing design thinking as a strategy for solving complex medical and public health problems and demonstrates how this approach was used to develop a learning community to improve coordination of care for elderly patients in the county. Design thinking has been used and implemented in a variety of healthcare organizations in the last decade around the world, however this field is still in its infancy.

Technically, the system is designed based on the MVC (Model View Controller) architecture on a LAMP Stack using Zend Framework. The Model manages fundamental behaviors and data of the system, the View provides User-Interface element of the application and renders the data from model into a suitable user interface form. The Controller interfaces between user inputs, models and views by making a call to model and view and performing an action. The system is divided into separate modules for all necessary components to implement the various eco-system related activities through components that included discussion groups, newsletters,

webinars, events, tools and permissions. These components are being developed to facilitate learning across members of the learning community. This system was designed with a Role Based Access Control mechanism, where each user is assigned a role and that role is allowed to access various modules. The roles implemented in this application are Super Admin, Admin, Group Coordinator, Newsletters Coordinator, Webinars Coordinator, Events Coordinator, Tools Category Coordinator and Members. These roles were designed so that a small team of volunteers could eventually manage this system with little assistance, thereby driving the adoption and sustainability of the effort.

At this stage, a cloud-based platform has been developed and tested. The main aim of this online community platform is to facilitate learning to improve the coordination of care for the elderly in the county. The key system components include local conversations, announcing events, presenting and sharing webinars on topics of interest to the community of providers, a newsletter to keep the community of providers informed, and established outcomes-oriented tools that community providers can use to improve their services. Specific sub-topics of conversation that were relevant to elder-care in Palm Beach County were identified through the design study. These detailed conversations related to typical cases are being uploaded into the system to provide initial community relevant information before a soft launch of the system later in 2018. In addition, the authors are working with a broader healthcare coalition in the county that will eventually pilot the platform of specific projects involving specific areas of readmission risk for the elderly.

Future work specific to this study is to collaborate with the core team of community volunteers and work to reduce avoidable hospital readmissions among the elderly. The system developed in this study will be the platform on which such efforts will be developed.

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DECISION SCIENCES INSTITUTE

Comparing Two "Free" Software Platforms for Assisting in Teaching an Introductory Business Statistics Course

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ABSTRACT

AACSB (2016) mandated that analytics be integrated into the undergraduate business curriculum. Given that concrete statistical knowledge is necessary to comprehend and learn the discipline of analytics, this paper focuses on selecting data analysis tools that enhance the learning of introductory business statistics in the modern world of big data.

KEYWORDS: Business Statistics, Data Analysis Tools, Excel, R, and R-Deducer

INTRODUCTION

In 2016, AACSB Standard 9 has mandated that analytics be integrated into the undergraduate curriculum. Since a 120-credit curriculum is currently typical across programs, there has been talk at some institutions of subsuming the business statistics course as part of an analytics course. However, there is ample research indicating data-driven decision-making (DDD) is typically superior to intuitive decision making (Brynjolfsson & McElheran, 2016; McElheran & Brynjolfsson, 2016) and that a statistical foundation is necessary to understand advanced analytics concepts (e.g., Logistic Regression). Thus, we contend that strengthening the introductory statistics course will help students to be better prepared for future undergraduate and graduate analytics courses. We believe that students ready to take an analytics course must have a solid foundation in fundamental descriptive methods, a basic understanding of risk and inference, and an introduction to predictive modeling. Therefore, in this study, we re-engineer an introductory business statistics course and explore two data analysis tools to assist in delivering the course content to our students. We choose *Excel*, which is freely available as part of Microsoft Office 365 to all students providing their school e-mail address, and *R-Deducer, which is also freely available to all users*.

LITERATURE REVIEW

In a re-engineering of a modern-day core-required introductory business statistics course, three key pedagogical issues must be addressed:

1. What should be taught? – 2. Why it should be taught? – 3. How it should be taught?

The first and second questions above are reflected in course learning goals while the last question focuses on mode of course delivery. One of the primary goals of instructors is to design an appealing course so that students can be motivated and engaged to learn more about topics. The challenge, however, faced by educators in all disciplines throughout our colleges

and universities is how to achieve this when dealing with current Generation Z student audiences (Bernstein, 2015) who, although clearly more technologically capable than all predecessor student groupings, are often less quantitatively prepared and have seemingly less interest in textbook reading.

With respect to business statistics, Berenson *et al.* (2018) opined that offering discipline-specific introductory business statistics courses (e.g., statistics for marketing) would increase motivation for learning because the course topics and applications would be in career interest to that student audience. Although this appears to be true, the broader question needs to address the teaching of a more traditional statistics course, particularly if it becomes prerequisite to a required course in business analytics. The six key recommendations of the GAISE (Guidelines for Assessment and Instruction in Statistics Education) College Report (Carver *et al*. (2016)) sponsored by the American Statistical Association displayed in Table 1 must be considered when re-engineering a statics course.

Table 1: Six Recommendations of GAISE College Report to Enhance Pedagogical Delivery

***What* to Teach:**
1 – Teach Statistical Thinking
2 – Focus on Conceptual Understanding
***How* to Teach:**
3 – Integrate Real Data with a Context and a Purpose
4 – Foster Active Learning
5 – Use Technology to Explore Concepts and Analyze Data
6 – Use Assessments to Improve and Evaluate Student Learning

The report emphasizes the pedagogical importance of topic and application relevancy in an increasingly data-centered world. In the learning paradigm to be discussed here, not only must topic and applications be relevant, student audience must perceive them as so. With respect to what to teach, the GAISE College Report's focus is on students' understanding that the subject of statistics is a problem-solving process essential for decision making (Recommendation 1) and on students' realizing that many questions require explorations of multidimensional relationships (Recommendation 2). With respect to how to teach, the GAISE College Report's focus on the use of real data with a context and purpose (Recommendation 3) lends itself to classroom projects employing structured data sets that can be used to demonstrate the integration of topics covered throughout the course (Gould, 2010). Active learning (Recommendation 4) can be promoted individually, or in teams, if students can carefully study their data sets and develop the questions they want to address. Assessments for improving and evaluating student learning (Recommendation 6) could be based on written project reports and oral presentations as well as in exam questions that require the students to articulate their key findings. To re-engineer the business statistics course based on our interpretation of the GAISE College Report guidelines, we contend that all the above recommendations relate to its focus on Recommendation 5 – the use of technology to explore concepts and analyze data (Chance *et al.,* 2007). Therefore, the selection of the appropriate data analysis software for such a course will be essential.

THEORETICAL DEVELOPMENT

Any re-engineered introductory business statistics course must first satisfy broader B-school curriculum goals and serve as a prerequisite to learning in the functional areas disciplines. Given the new Standard 9 AASCB (2016) mandate, a redesigned statistics course should also explore the potential for a more seamless transition to a follow-up course or courses in business analytics. An undergraduate business statistics course should provide students opportunities to extract knowledge from data and unveil meaningful association among the variables. After successfully finishing an introductory business statistics course, students should be able to analyze datasets with multiple variables without explicit instructions.

Starting the course with a "prerequisite preparation" that covers basic algebra and fundamental mathematical concepts for business (i.e., indices, ratios, and percentage changes) will help align students with varied mathematical backgrounds and quantitative skillsets. The course then begins with an overview of statistics and stresses the importance of statistical applications in business and business analytics. A paradigm for problem-solving (Levine & Stephan, 2011) that aims at developing statistical thinking and reasoning is then presented and key terms that will be used throughout the course are explained. Learning statistics is in many ways like learning a language. There is an evolving vocabulary that students must develop and continue to use throughout the course. Moreover, in a project-oriented course as proposed here, the structured data set becomes the integrated, unifying course theme, enabling students to expand their knowledge and their overall comprehension as the course topics flow from description to inference to modeling. The selected computational software tools are, of course, integrated into all topics. We opine that such an approach should enhance student learning because they will have the opportunity to develop the parts of a study into a whole project. Business statistics should never be taught as a set of disjoint topics.

Table 2 (on the following page) presents a list of methods covered in a re-engineered project-oriented business statistics course. To compare the *Excel* and *R-Deducer*, we used these tools and conducted analyses for the methods given in Table 2.

Assessing *Microsoft Excel* and *R-Deducer* in Terms of Cost, Platform Capability, and Availability

In general, before deciding to select what data analysis tool to use, three initial issues must be addressed:

1. What will be the cost of the tool?
2. Will it have the capability to equally support both Windows and Mac student users?
3. What is the likelihood of its availability to users in the workplace after graduation?

Addressing the First of Three Initial Issues – Cost

With respect to cost, *Microsoft Excel* (Microsoft, 2013) and *R-Deducer* (Fellows, 2012; Doi *et al*., 2016), are free to students. Thus, the cost will not play a role in our decision-making process.

Addressing the Second of Three Initial Issues - Capacity to Support Varying Platforms

R-Deducer seamlessly supports both Windows and Mac student users. On the other hand, Mac student users are often frustrated in their attempts to obtain some of the charts in *Microsoft Excel*. Currently, *Excel* requires differing instructional sets for the two user groups. At our

institution, for example, where roughly half the students have either PCs or Macs, this would add an unnecessary layer of faculty instruction for teaching the two user groups. In sum, a decision on this issue would be driven by the institutional requirement for the use of *Excel* in all its business courses. If there is no such requirement, as would overwhelmingly be the case, careful consideration must be given for any decision to utilize *Excel* as the appropriate course software tool unless a campus site provides the virtual machines that would enable Mac owners to use their computers as if they were PCs.

Addressing the Last of Three Initial Issues - Likelihood of Workplace Availability

Microsoft Excel and *R-Deducer* provide free access and will readily be available to graduates once they are in the workplace. The only issue with *R-Deducer* could be that employees will not be able to install *R-Deducer* if they do not have administrative privileges on their work computers. Those employees will need to get permission from their employers to install *R-Deducer*.

Table 2: Recommended Topics in Introductory Business Statistics Course

Topics	**Methods**
● Data Presentation for Categorical Variables and Numerical Variables	● Categorical Variables: Summary Table with Bar, Pie, and Pareto Charts for One Categorical Variable; Contingency Table with Side-by-Side Bar Chart for Two Categorical Variables ● Numerical Variables: Ordered Array, Frequency and Percentage Distribution with Histogram
● Numerical Data Characterization	● Summary Statistics, Five-Number-Summary, and Boxplot
● Probability Theory and Distributions	● Applications via Contingency Table ● Normal Distributions: Obtaining Probabilities and *Z*-Scores; Assessing Normality Using a Normal Probability Plot ● Sampling Distributions: Interactive Demonstrations of Central Limit Theorem
● Confidence Interval Estimation and Hypothesis Testing	● Confidence Interval Estimate for a Population Mean and for a Population Proportion ● Hypothesis Test for a Population Mean and for a Population Proportion ● *t*-Test for Differences in Two Population Means; *Z*-Test for Differences in Two Population Proportions
● Simple Linear Regression Modeling	● Obtaining a Scatter Plot, Building a Simple Linear Regression Model, Interpreting the Output, Assessing the Assumptions, Developing a t-Test for the Population Slope or Confidence Interval Estimate for the Population Slope, Making a Prediction

Assessing *Microsoft Excel* and *R-Deducer* in Support of Data Analysis

Once the three initial issues have been pondered, the selection of an appropriate computational software tool for assisting in data analysis should be based primarily on:

- Support of specific course topics being covered
- Correctness of printouts
- Simplicity of access and installation
- Simplicity in data import and data entry
- User friendliness in tool/dialog box design interaction
- Simplicity in exporting printouts to Word files and PowerPoint files

And the selection of an appropriate tool for visual demonstrations aimed at enhancing student learning should be based primarily on its interactive capabilities and through interactive explorations (e.g., "sensitivity analyses that depict how changes in data values affect both numerical results and its graphical display. If not sufficiently provided by statistical software packages, either spreadsheets or web applets can be employed to achieve this purpose.

Using two different datasets (one dealing with a university case study and the other dealing with a retirement funds case study), we were able to assess Excel and R-Deducer by writing instructions and obtaining printouts for the course topics displayed in Table 2.

Assessing Support of Specific Course Topics Covered

When Microsoft *Excel* is used naked without any templates, it falls short in supporting all the course content given in Table 2. For example, *Excel* used along with Analysis ToolPak does not support boxplot diagrams, and its histogram tool is flawed. Additionally, the use of *Excel* without any add-ins burdens students with too many worksheet preparation tasks (such as the manual entry of data and calculation formulas) in addition to numerous editing tasks that distract learning from course content. *Microsoft Excel*, when combined with a properly prepared set of template solutions such as those developed in Levine, Stephan, & Szabat (2017) along with *Excel*'s own Analysis ToolPak add-in program, supports all the course topic methods. However, if instructors want to explore some advanced analytics methods (e.g., VIF scores, logistic regression) in their introductory to business statistics course, *Excel* will not be a good choice as it does not have these capabilities. *R-Deducer* cover all highlighted course topics and many other advanced topics (e.g., clustering, classification, PCA); thus, it becomes a great choice for a program that contains multiple analytics courses in addition to the introductory business statistics course.

Assessing Correctness in Printouts

Using the two datasets, we observe the following: Microsoft Excel incorrectly displays fitted regression lines to a scatter plot in a simple linear regression analysis. The sample regression equation incorrectly uses the symbol *Y*, instead of $\hat{Y}$. This easy-to-fix error has unfortunately not been corrected in the *Excel Template* set proposed by Quintela del-Río & Francisco-Fernández (2017). Additionally, *Microsoft Excel* uses the word *Multiple R* to represent the value of the coefficient of correlation. Should the slope of the fitted line be *negative*, the value for *Multiple R* will, nevertheless, be displayed as *positive*, which would cause confusion to the student user. *Microsoft Excel*'s histogram representing a continuous numerical variable is improperly

displayed with disjoint vertical bars. The word bins, representing the class interval grouping into which the individual numerical data values are assigned, are shown centered on the vertical bars where midpoints should be displayed. This visual presentation causes immediate confusion to students because the bin column which must be entered for developing both the frequency distribution table and the histogram represents the upper boundary of each class interval grouping, not its midpoint. Editing instructions needed to adjust these *Microsoft Excel*-caused errors are time-consuming and unnecessarily detract from the teaching of statistics. On the other hand, *R-Deducer* does not always use the Greek letters to denote the population parameters. For example, the population proportion is denoted using the Latin letter p instead of the Greek letter ∏. Moreover, we observe that the printouts of *R-Deducer*, although correct, can be overwhelming for undergraduate students because it tends to provide more information than needed in an undergraduate statistics course. For example, a linear regression result will generate the Cook's distance plot as well as the partial regression plots, which are not used in an introductory business statistics course.

Assessing Simplicity of Access and Installation

Students can easily access and download a set of *Excel Templates* using textbooks or webpages (such ASQ, 2018). It is also easy for students to access Microsoft Excel and its Analysis ToolPak. Moreover, Installing *R* is easy; however, downloading the *Deducer* package can be sometimes tedious since the package requires several Java dependencies. Once the *R-Deducer* is configured, accessing it again throughout the semester is seamless and does not require any additional work.

Assessing Simplicity in Data Import and Data Entry

Employing the two datasets, data import and data entry are easy to do using Excel and R-Deducer. However, to be able to upload data into *R-Deducer,* users need to save the *Excel* data files as comma-separated values (csv) files, which requires extra instructions and will slow down the pace of the course.

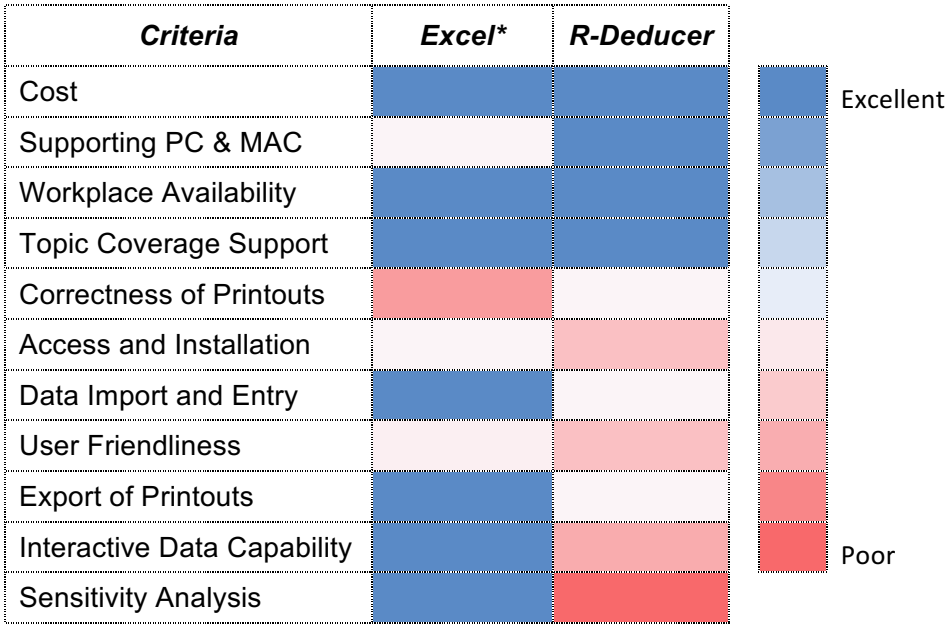
Assessing User Friendliness in Tool/Dialog Box Design Interaction

Our assessment using the two datasets shows that R-Deducer provides a User Interface (UI) where users can easily navigate. However, this interface lacks visual cues, such as icons and pictures; thus, it might take some time for students to locate the commands. On the other hand, students are more familiar with the *Microsoft Office* UI because many students are exposed to *Excel* during high school or in freshmen year in various business schools. Thus, it can take more time for students to learn how to navigate through the *R-Deducer* UI as compared to *Excel*.

Assessing Simplicity in Exporting Printouts to Word and PowerPoint Files

Based on our assessments with the two datasets, we observe that exporting the printouts to Word and PowerPoint files using *Excel* is easy. On the other hand, *R-Deducer* does not allow copy and paste; thus, users must first select images, take screenshots (such as Snipping Tool in PC or Preview in Mac) and then export them to Word or PowerPoint files.

Figure 1: "Quasi" Heat map for a comparison of *Excel* and *R-Deducer*: subjective "report card" grades



* Excel includes its Analysis ToolPak and Templates that can be downloaded online

Assessing Interactive Capabilities

As articulated in the GAISE Report (Carver *et al*. (2016)), in addition to supporting data analysis, it would be useful if the selected computational software tool could also provide appropriate visual demonstrations and enable data exploration to promote conceptual understanding and enhance statistical thinking. Thus, *Microsoft Excel* is strongly recommended for the PivotTable demonstration of data exploration through drill down. R-Deducer, on the other hand, does not offer such capabilities.

Assessing Interactive Explorations (i.e., "Sensitivity Analyses")

Student learning and understanding of concepts can also be enhanced through a computer software tool's capability of demonstrating sensitivity analyses that depict how changes in data values affect both numerical results and its graphical display. Although *R-Deducer* and *Microsoft Excel* are insufficient for such purposes, a properly prepared set of *Excel Templates* are excellent for these sensitivity analyses. Printouts from the *Excel* enable the student user to alter the statistics in the various confidence interval estimates and hypotheses tests and observe how such changes impact on the findings. Besides, the *Excel* enable the student user to alter the parameters and selected values of a random variable when studying different probability distributions.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In this paper, a comparison of *Excel* and *R-Deducer* intended for use in the introductory business statistics course has been presented and a paradigm for a re-engineered, project-oriented course has been developed. The reason why we analyzed these two software tools is

that they are free for students. Thus, they can be alternatives to paid computational tools (e.g., *Minitab, JMP*) if budget is a concern. Our main conclusions, derived from experimentation with the two tools using two datasets, are summarized as follows:

- Although Microsoft *Excel* is widely used in the workplace and one of the most common tools used in various B-School courses, its pedagogical limitations severely dampen its value for use in an introductory business statistics course. The errors in the printouts of key topics in descriptive statistics and simple linear regression and the omissions in its development of confidence interval estimates are cases in point. And writing formulas in *Excel* to conduct statistical analysis will slow down the pace of the course and puts extra pressure on faculty struggling to finish the course material by the end of the semester.
- If instructors want to use *Excel* as the primary tool, they should use *Excel Templates to facilitate the course instruction.*
- *R-Deducer* is a professional open-source statistical software package. It enables students to spend more time interpreting the results and understanding the concepts rather than formulating the analysis. However, learning to navigate through this software will take some time for our students. Thus, instructors preferring to employ R-Deducer should start using it as early as possible in the semester.
- If the curriculum includes more courses on analytics, we do believe that early exposure to R through R-Deducer will help students in these courses because *R* is one of the primary computational tools in the business analytics field.

The ultimate course goal is the learning of statistics. To this end, we recommend the following if budget is a concern, and the institutions/departments/instructors want to choose a free data analysis tool:

- To support data analysis, particularly in a re-engineered project-oriented business statistics course, *R-Deducer* be selected for use as the computational software tool
- To promote conceptual understanding and enhance statistical thinking, the selected computational software tool be supplemented by interactive applets for visual demonstrations and by *Microsoft Excel* for PivotTable demonstration of data exploration through drill down.

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Competitive Advantage and a New Paradigm Shift: A Game-Theoretical Model

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ABSTRACT

A game-theoretical model is designed to study the competition between a company that continuously exploits its established competitive advantage, and an agile company that anticipates and adapts to market changes. We show how the former loses its competition to the latter, when the former could raise the entry barrier to protect its market share, and when such effort would be useless. Practically, we provide guidelines for when firms that are incumbent in the market should prepare to ride a paradigm change, and what firms should constantly look out for the next breakthroughs in order to introduce their next competitive advantages.

KEYWORDS: entry barrier, hybrid product, technology, market invasion

INTRODUCTION

In the present world of business, for a company to remain ahead of the fierce competition, it has to be super vigilant in its pursuit of the next trend or transient advantage (Chan & Chan, 2010). So a natural question arises: How do companies that do not stay alert with market trend lose their shirts in the competition with companies that do? Speaking differently, how can a company really tell whether or not it is losing its market competition?

To address this question, this work treats each market and organization as systems (Lin, 1987; 1999; Senge, 1990; Morgan, 2006), consisting of component parts; and organizations must be adaptable to continuous market and technological changes (Johnson, 1998). Specifically, this paper designs 2×2 and 3×2 games to model the direct competition between two companies named X and Y, where the former honors the once-championed philosophy of sustainable advantages and the latter is of the modern type of transient advantages. Then, the following main results are shown: (1) If Company Y is expected that its expansion will generate profits, which are more than the cost for Company X to take defense, then Company X would move first and take defense against Company Y although the consequence is uncertain; and (2) If there is a much greater market than that occupied by Company X for Y to expand into, then Company Y will definitively introduce its hybrid product.

By considering a customer as the third player who interacts with the two companies, our 3×2 game modeling leads to the following results: (1) If Y's revenue is greater than its cost and its revenue from outside the market base of Company X is smaller than its cost, and Company X does not take any defense to protect itself, then the probability for the customer to purchase X's product is inversely proportional to Y's activities of producing its hybrid product; and when the revenue Y earns from the market of X is equal to its fixed cost of producing its hybrid product minus the revenue generated from beyond the customer base of X, then the probability for the customer to purchase Y's hybrid product is equal to 1. (2) If Y's revenue is greater than its cost and its revenue from outside the market of X is smaller than its cost, and X does take defense to protect itself, then the higher the difference between the cost for Y to produce its hybrid product and the revenue generated beyond the customer base of X, the lower the probability for X's customer to purchase Y's hybrid. (3) If the profits of Y's expansion come mainly from X's market share, then X can successfully delay the deterioration of its territory as long as less than 2/3 of its maximum expected revenue is taken by Y.

There are vast literatures on market entry (Zachary, et al., 2015) and R & D races to develop new products (Jindal, et al., 2016), our focus here is on the interaction between firms that practice the philosophy of sustainable competitive advantages and those that ride the wave of transient advantages. At the same time, there is a large literature of game-theoretical studies of duopoly competition (Puu, 1991; Zhang, et al., 2009; Dubiel-teleszyński, 2011; Fan, et al., 2012; Ma & Xie, 2016; Zhu, et al., 2014; Zhang & Ma, 2016; Pecora & Sodini, 2018). However, for practical purposes, none of these prior models actually fits our needs. So we have no choice but develop a different and straightforward game-theoretical model based on a few very realistic and intuitive assumptions. And instead of optimizing the representative customer's utility function, we maximize companies' profits, which is most likely the practice of relevant companies when they try to decide their courses of action.

Beyond addressing the question posed at the beginning of this section, this paper also attempts to show that other than inductive reasoning, deductive reasoning should be employed to produce scientifically sound theories and conclusions. And, this work also shows the need to enrich the literature of duopoly competition through developing new models that are beyond those established under unrealistic conditions – such as linear price and quantity interactions, linear demand and cost functions, etc. – and processes – such as optimizing customers' utilities.

The rest of the paper is organized as follows. The next section models the competition between Companies X and Y, where X is old-fashioned while Y modern. The following section analyzes the competition between X and Y while the role of consumers is considered. Then the details of the old-fashioned company is analyzed. And the last section concludes this work.

COMPETITION BETWEEN TWO PLAYERS

Assume that companies X and Y operate under two different business models such that X is a successful, old fashioned company that enjoys its time-honored sustainable competitive advantage and that Y also enjoys its traditional success with its unique product(s), its leadership adopts the philosophy of transient competitive advantages. For the sake of convenience, assume that both X and Y each produce only one product. That is, Y is market- and technology-driven (Day, 1994) and fully ready to embrace next fleeting advantage (Kaharuddin, et al., 2017). So, Y considers whether or not to produce a new product that improves the functionality, user friendliness, and the features of the two products produced respectively by X and Y. If it decides "yes, it will produce the imagined hybrid product," then the production of Y's old product will be terminated, and its loyal customers will move on to enjoy the hybrid (better) product at the same price as that of the retired product. And, a portion of X' customers will switch to buy this new

product, which would be considered cheaper and better than the product of X due to the enhanced functionality, user friendliness, and combined features.

Summarizing what are assumed, we have the two-player game in Table 1, where S_X stands for the total sales revenue of Company X without Company Y's invasion of X's territory, S_Y the sales revenue of Company Y generated from the market share of Company X by producing the imagined hybrid product, *C* the cost of Company X for it to take actions, such as raising the barrier of entry, in order to deter the invasion of Company Y, R_0 (respectively, R_1) the cost of Company Y, including risk and opportunity costs, for designing and producing the hybrid product without (respectively, with) Company X taking defensive actions.

TABLE 1. The payoffs of the 2 × 2 game of pure strategies

		Company Y	
		Design/produce	Don't design/produce
Company X	Take defense	$S_X - C - S_Y, S_Y - R_1$	$S_X - C$, 0
	Don't take defense	$S_X - S_Y, S_Y - R_0$	S_X, 0

What is assumed stands for a 'camera' snapshot of the interaction between X and Y. That is, if time is considered, X could still be monitoring what Y is doing and expanding its advantages by investing in resources and capabilities that strengthen its current market position and open up new opportunities. It could still be systematically using these strategic resources and capabilities to respond to the pressures of Y. For example, the rivalry between Montgomery Ward and Sears had been in such a game situation at almost any chosen moment of time since the late 1800s. Montgomery Ward monitored and analyzed what Sears introduced and was planning on doing, while developed itself in a totally different direction (Sobel, 1999).

By the philosophy of transient competitive advantages, it is meant that the leadership of Y, as well as its culture and value system, is more in sync with the technological changes and desires of consumers than X so that Y knows how to excite consumers. In real life, when a company decides to produce a hybrid product, there are many different ways to do it. If a company is in sync with the technological changes and desires of consumers, its product will more likely excite the market than the products of other companies. This end is very well demonstrated by the case of Montgomery Ward and Sears.

A point of notice regarding this game model is that X really stands for the aggregate of all incumbent firms of the marketplace that is in a state of mutual forbearance (Bernheim & Whinston, 1990; Li & Greenwood, 2004; Yu & Cannella, 2012; Fuentelsaz & Gómez, 2006; Haveman & Nonnemaker, 2000). And Y represents the aggregate of all firms that always think about introducing newer and better products.

A second point of notice is that if the additional profits of Y come from the loss of X's market, then X has an incentive to spend an amount equal to this potential loss to create entry barriers; so in equilibrium X would always spend an amount equal to S_Y to eliminate any incentive for Y to introduce a new hybrid product. However, in practice S_Y cannot be known at the time the model is developed and changes over time. And, although S_Y might turn out to be very close to zero, Forrest, Amatucci and Markman (2017) show that Y still has to introduce its new product to just maintain its current customer base. That is, the amount X spends on building entry barriers is not a function in S_Y. In fact, Forrest, Buttermore and Wajda (2017) show that S_Y (less cost) could potentially be greater than S_X (less cost).

All the assumptions imply: (1) For both X and Y, each unit of produced product is sold. (2) When the sales revenue S_Y is > 0, the sales revenue of X is $S_X - S_Y$. That is, S_Y stands for the portion of sales revenue Y takes away from X, assuming that is the total increased sale of Y. (3) When X takes defense to deter Y from invading its territory, the total cost for Y to produce its

hybrid product goes higher so that $R_1 > R_0$. For the rest of this paper, assume that all players establish their best responses by playing the Nash equilibrium through pure self-analyses.

In the following, this game is analyzed in cases.

Case 1: The increased sales revenue S_Y of Y is less than the sum R_0 of the cost of producing the hybrid product and the risk and opportunity cost. So, Y does not produce the hybrid product. And, X does not take any action to deter Y from entering its territory. In this case, (don't take defense, don't design/product) is the Nash equilibrium, although in real life such a situation does not really exist. It is because at least some of the features of X's product can be combined with those of Y's product without breaking the budget by adopting appropriate technologies.

Case 2: $R_0 < S_Y < R_1$ and $S_Y < C$. (Don't take defense, Design/produce) is the Nash equilibrium. That is, if X takes defense against the potential entry of Y into its territory, X has to spend more than its loss in terms of revenue. Due to the high costs, X does not take defense; and Y will enter the territory of X.

Next, if $R_0 < S_Y < R_1$ and $S_Y > C$, then X would decide which strategy to use to maximize its revenue, assuming this company chooses its strategy first. In this case, X is better by taking defense and by expelling Y from entering its market, because the strategy profile (Take defense, Don't design/produce) will give X the maximum revenue. In the subgame for X to take defense, (Take defense, Don't design/produce) is the Nash equilibrium.

TABLE 2. A 2×2 game of mixed strategies

		Company Y	
		Design/produce	Don't design/produce
Company X	Take defense (p)	$S_X - C - S_Y, S_Y - R_1$	$S_X - C$, 0
	Don't take defense $(1-p)$	$S_X - S_Y, S_Y - R_0$	S_X, 0

To make the decision making process more dynamic, instead of using pure strategies, assume that X assigns probability *p* for the event for it to take defense. At the time when the model is established, Y does not really know whether or not X will take defense. So, the payoff matrix is given in Table 2. This game leads to:

Proposition 1. Assume all other conditions are held constant. If Y's revenue from X's territory is greater than its costs when X does not take defense, while less than the costs when X does take defense, and greater than the defense costs of X, then the probability for X to take defense and the sales revenue of Y generated from the market of X by producing its hybrid product are directionally proportional to each other.

Proposition 2. Assume all other conditions are held constant. If Y's revenue from X's territory is greater than its costs when X does not take defense, while less than the costs when X does take defense, and greater than the defense costs of X, then the probability for X to take defense and the cost for Y to produce its hybrid product with X taking defense are inversely proportional to each other.

Next, we consider the case that when deciding on producing its hybrid product, other than the possibility of taking a portion of X's revenue, Y also knows that its new product will appeal to customers beyond the customer bases of X and Y. To study how the incumbent firms in this new market would raise entry barriers to keep new comers from entering, assume that the market the imagined hybrid product will enter competitively is occupied by *m* incumbent firms, *m* = 1, 2, … They provide customers with substitutable products; and these firms enjoy

the backing of their respective loyal customers who only purchase the product of their firms if the price is no more than their reservation value 1. Assume that these firms raise the entry barriers for Y by competing over the price switchers who make purchase decisions based on whose price is lowest only. To prevent Y from entering, assume that these incumbent firms are well aware of their pricing strategies, and that these firms have established their best responses by playing the Nash equilibrium through pure self-analyses. Then, we have the following.

Proposition 3. In the Nash equilibrium, the following two statements are equivalent:

1) B can profitably enter the pre-described market; and
2) The size of the market segment of switchers is greater than zero.

The proof of this result is outlined in Appendix.

What the proof of this result says is that it is impossible for the incumbent firms to stop Y from entering because to counter the pricing strategy of the incumbents Y randomizes its price between the unit cost and the reservation price the incumbents charge their loyal consumers. And, this proof indicates that Y could potentially take all the switchers. That in turn means that if this segment of the market is larger than any of the royal-customer bases of the incumbents, then Y could make more profits than any of the incumbents.

Summarizing what is discussed, it follows that Y expands its market share by taking a portion of X's customers and a portion of the greater market of the hybrid product. So, it is practically possible that the additional revenue Y generates from its hybrid product is more than S_Y, the sales revenue of Y from X's market. Let S_Y- be the revenue Y generates from the market beyond X's market. Then, we naturally have the following case.

Case 3: $S_Y + S_Y- \geq \max\{R_1, C\}$. That is, Y's expanded sales revenue from producing its hybrid product is at least the larger of Y's cost (R_1) of producing the hybrid product and X's cost (C) of taking defense. If, additionally, $S_Y > C$, then X takes defense and the Nash equilibrium is (Take defense, design/produce). If also $S_Y + S_Y- = R_1$, then the Nash equilibrium is (Take defense, don't design/produce). On the contrary, if $S_Y + S_Y- > R_1$ and $S_Y > C$, then (Don't take defense, Design/produce) is the pure strategy Nash equilibrium with payoffs ($S_X - S_Y$, $S_Y - R_0$), Table 1. In other words, X's market share is gradually taken by Y's hybrid product while X cannot do anything about it.

In short, we have the following result:

Proposition 4. Assume that X exploits its sustainable competitive advantages, while Y looks forward to adopting transient competitive advantages (McGrath, 2013), as described above. Then

1. If Y is expected from expansion to generate more profits than the cost for X to take defense, then X would move first and take defense against Y;
2. If Y's decision of whether or not to produce its hybrid product is based on the existence of an expanding market beyond that of X, then Y will introduce its hybrid product.

Result 2 above follows from Proposition 3 and Theorem 5 in (Forrest, Buttermore & Wajda, 2017).

COMPETITION AMONG THREE PLAYERS

The fortune and fate of X and Y are really determined by the consumers. So, let us now include a fictitious customer in the interplay of the X and Y's competition. Assume that X first offers a

product in the market, Y then provides its improved hybrid product, while the customer decide on whether to purchase or not to purchase and which product to buy. Because Y practices the philosophy of transient competitive advantages, it observes X's initiatives and then acts accordingly. On the contrary, X identifies and invests in its determined set of resources and capabilities, believing that they will help the company maintain its current market position and respond to competitive pressures of the market. At this junction, Montgomery Ward was a good example of X described here. So, assume that although the customer is from X's market, she would try the new product by Y if such a product is available. That is, Y closely monitors and follows X, while the customer follows both companies and would try out the new product. So, X needs to increase the consumer confidence on its product and to decide on whether or not to take defense against Y's possible invasion. So we have the following game model:

X chooses whether to take defense (with cost *C*) or not (with cost 0). Y elects between produce its hybrid product (with fixed cost *D*) and not (with cost 0). If X takes defense to deter Y's following, assume that Y will spend additional αC to produce its hybrid product, where $0 < \alpha < 1$. That is because to follow up with X's defense, Y has to push its organization's knowledge envelope outward to incorporate unknown technologies in its production of the hybrid product (Harrigan & DiGuardo, 2016). Ultimately the customer decides whether to purchase or no. If she purchases X's product, her utility is $(-u)$, because after purchasing the product she feels being exploited by a product that is not as innovative as what the market is expected to provide. Such situations of negative utility occur in real life quite frequently and almost surely when the market is controlled by a monopolist. If she purchases Y's hybrid product, her utility is u, because Y's hybrid innovatively reflects the features of both X's product and the old product of Y and more. When the customer decides to purchase, if there is no hybrid product available in the market, X earns revenue S_X. In this case, although the customer does not feel good from the purchase, she does not really have a choice. However, if there is hybrid product in the market, then Y grabs revenue S_Y from X by selling its hybrid to the customer. So, $S_X \geq S_Y$. When the customer decides not to purchase, the revenues of X and Y will both be 0.

TABLE 3. Payoffs of the customer and Y when X takes defense

		Company Y	
		Design/produce (*p*)	Don't design/produce (1 – *p*)
Customer	Buy (τ)	u, $[(S_Y + S_{Y^-}) - D - \alpha C]$	$-u$, 0
	Don't buy $(1-\tau)$	0, $[(S_{Y^-}) - D - \alpha C]$	0, 0

TABLE 4. Payoffs of the customer and Y when X does not take any defense

		Company Y	
		Design/produce (*q*)	Don't design/produce (1 – *q*)
Customer	Buy (ε)	u, $[(S_Y + S_{Y^-}) - D]$	$-u$, 0
	Don't buy $(1-\varepsilon)$	0, $[(S_{Y^-}) - D]$	0, 0

So, the payoffs of Y and the customer are respectively given in Table 3 for the case when X takes defense and in Table 4 for the case when X does not take any defense, where S_{Y^-} is the revenue Y generates from the market of the hybrid product beyond X's market and its expected revenue from its old product.

Proposition 5. If Y's additional revenue from beyond its original territory is less than its cost of producing its hybrid product, then the pure strategy Nash equilibrium is reached when X does

not take defense, Y does not produce its hybrid product, and the customer does not make purchase.

Proposition 6. If Y's additional revenue from beyond its original territory is greater than its cost of producing its hybrid product, then the pure strategy Nash equilibrium is reached when X does not take defense, Y produces its hybrid product, and the customer makes purchase. In this Nash equilibrium, X collects no revenue, Y makes profits, while the customer enjoys her utility u. And, if, moreover, Y's additional revenue from X's market territory is greater than the cost for X to take defense, then when X moves first, the Nash equilibrium is (Take defense, design/produce).

Proposition 6 implies that when Y's additional revenue from its hybrid product is more than the total cost of producing the hybrid product, then Y will move ahead with its production of the hybrid product. In this case, because any defense is useless, X does not even attempt to take any action. However, considering that X is a diehard believer and practitioner of the old school of sustainable competitive advantages, such as Montgomery Ward, it in really life would most likely not passively watch for its market to deteriorate without trying to do something. Because of this, we next consider mixed strategies assuming $S_Y + S_{Y^-} > D + \alpha C$. That is, Y's additional revenue from beyond its original territory is greater than the cost of producing its hybrid product. In this case, assume also $S_{Y^-} < D + \alpha C$ (that is, Y's revenue from outside X's market is less than Y's cost), because otherwise Y will definitely produce its hybrid product.

Because before making its decision, Y has to firstly sense, secondly seize and transform itself, and then acquire the critical capabilities for successful organizational adaptation (Day & Schoemaker, 2016), assume that if X takes defense, the probability for Y to produce its hybrid product is *p*. Let the probability for the customer to purchase be τ. And if X does not take any defense, let the probability for Y to produce its hybrid product be *q*, and the probability for the customer to purchase ε. By solving for mixed strategy Nash equilibrium, we have $p = q = 1/2$, and

$$\tau = \frac{D+\alpha C-S_{Y^-}}{S_Y} \quad (1)$$

$$\varepsilon = \frac{D-S_{Y^-}}{S_Y}. \quad (2)$$

Proposition 7. If Y's additional revenue from beyond its original territory is greater than its cost of producing its hybrid product and its additional revenue from outside X's market is smaller than the cost, and X does not take any defense to protect itself, then

1. The chance for the customer to purchase X's product is inversely proportional to Y's production of its hybrid product; and
2. When Y's revenue from X's market is equal to its fixed cost of producing its hybrid product minus the revenue generated from beyond X's customer base, then the chance for the customer to purchase Y's hybrid product is equal to 1.

Proposition 8. If Y's additional revenue from beyond its original territory is greater than its cost of producing its hybrid product and its additional revenue from outside X's market is smaller than the cost, and X does take defense to protect itself, then

1. The higher the difference between Y's cost of producing its hybrid product and the additional revenue from beyond X's customer base, the higher the chance for X's customer to purchase Y's hybrid; and
2. If, additionally, the α-value is fixed, then the more X spends on raising the barriers against Y's invasion, the lower the chance its customer will buy Y's hybrid.

This result means that X's defense actually works in terms of slowing down the deterioration of its customer base.

COSTS AND BENEFITS

When Y's additional revenue from beyond its original territory is greater than its cost of producing its hybrid product and its revenue from outside X's market is smaller than its cost (or $S_Y + S_{Y^-} > D + \alpha C$ and $S_{Y^-} < D + \alpha C$), it is shown above that to slow down the deterioration of X' customer base the most significant decision is to spend more on building a costly barrier for Y's invasion into X's territory and to increase the customer retention. As part of the most important investment, X could constantly make the features and functionalities of its product better. That would make it difficult for Y to follow. For the comparison of X's deterrence cost C and X's revenue, we have:

Proposition 9. If Y's additional revenue from beyond its original territory is greater than its cost of producing its hybrid product and its additional revenue from outside X's market is smaller than the cost, then

1. If X decides to defend its territory by raising entry barriers, then it can successfully delay the deterioration of its territory as long as less than $\left(\frac{1}{\alpha} + \frac{1}{2}\right)$ of its maximum expected revenue is taken by Y; and
2. If X decides not to take any defense against Y's possible invasion through producing its hybrid product, then X can produce positive revenues. However, this positive revenue decreases with increasing revenue Y generates from outside X's market.

Proposition 9 says that to continuously stay in business, X has no choice except also adopt the philosophy of transient competitive advantages, as pointed out by Dobni and Klassen (2015). And the proof of this result reveals that with improvement of technology and availability of information, the fixed cost D and the cost coefficient α for Y to produce its hybrid product gets lower with time, while the cost C for X to spend on entry barrier gets higher. So, X's expected revenue will be crashed by Y quickly unless X also starts to improve its product by producing hybrid products for the purpose of expanding its market share, as what Y tries to do throughout this presentation. However, Tushman and O'Reilly III (1996) show that this end is a real challenge for X's managers, just as the case of Montgomery Ward.

CONCLUSIONS

Failure to focus on multiple or transient competitive advantages may place a firm in an unenviable deficit with a commensurate serious loss in market share and/or dominance (McGrath, 2013). Accepting that any advantage will be short-lived is critical in a continuous learning and innovative company. Hence, there is a need to show why any company that plans on continuously exploiting its competitive advantages for the long term will disappear from the market place or soon become irrelevant. To this end, this paper employs a simple and

straightforward game model, instead of anecdotes data mining, to show analytically how unresponsively a company that plans on reaping in its profits by exploiting its sustainable competitive advantages is losing its future to those that adopt and practice transient competitive advantages.

To avoid the weaknesses, such as deriving unreliable conclusions from maximizing customers' utilities, developing results from particularly chosen utility functions, and creating beliefs from imposed unrealistic linearities, of the literature of duopoly competition (Singh & Vives, 1984; Zanchettin, 2006), this work establishes thought provoking and practically useful results on the basis of the mathematical formulation of the problem by providing the feasible solutions that incorporate the differences in actions between two companies. The most important conclusion this study produces *analytically* is that to avoid becoming history, any company has to adopt and practice the philosophy of transient competitive advantages.

All results established in this paper suffer from the weakness of missing time variable. In other words, conclusions of this work only describe momentary situations of the competition between Companies X and Y. So, as a theoretical interesting and practically significant research question for future works, one needs to investigate what would follow after X realizes what it needs to do at the next time moment in the competition with Y.

Comparing to the literature of competitive advantages, this study is the first that uses an analytical approach to address issues related to many overriding conclusions – drawn mostly on anecdotes, or data mining, or models developed on limiting or unrealistic conditions. That is why we are able to provide insights into the practically significant question: How do companies of the philosophy of sustainable competitive advantages actually lose their shirts in the competition with companies that ride the current wave of transient advantages? In the meantime, this work enriches the literature of duopoly competition by showing how some of the major weaknesses of the models established to study either Cournot competition or Bertrand competition can be avoided.

APPENDIX

Proof of Propositions 1 and 2. From Table 2, Y's indifference condition is

$$p(S_Y - R_1) + (1-p)(S_Y - R_0) = 0,$$

from leads to

$$p = \frac{S_Y - R_0}{R_1 - R_0},$$

where $R_1 > S_Y > R_0$ is assumed for the analysis here. And when $R_1 > 0$, R_0 will be a nonexistent value. In this case, we assume $R_0 = 0$.

Proof of Proposition 3. Let α stand for the portion of the market of the loyal customers of the *m* firms and $\beta = 1 - \alpha$ be the market segment of switchers, where $0 \le \alpha, \beta \le 1$. Assume that the constant marginal costs of the incumbent firms and Y are set to zero without loss of generality – so in the rest of this proof, revenues are the same as profits. And consider the aggregate of the incumbent firms as one firm, because these *m* firms are in a state of mutual forbearance (Bernheim & Whinston, 1990). So, the market share of this aggregate firm is α so that $\beta = 1 - \alpha$ represents the market size of switchers who base their purchase decisions on which price is lower.

The necessity condition is obvious. Let us now look at the sufficiency condition. Assume that the customer surplus satisfies $\beta = 1 - \alpha > 0$. Let α_0 be a real number satisfying $\beta = 1 - \alpha > \alpha_0 > 0$ and $\alpha = \ell\alpha_0$, where ℓ is a large natural number, indicating that the market has been largely taken by the incumbent firms.

Imagine that the aggregate firm is divided into ℓ many identical "firms", named *i*, *i* = 1, 2, …, ℓ, each of which provides customers with identical products and enjoys the market share $\alpha_0 = \alpha/\ell$ of loyal customers. These imaginary firms compete over the switchers with adjustable prices. Because these imaginary firms are really equal partitions of the same aggregate firm, they have the same constant marginal cost, which is set to zero without loss of generality, the managements of these firms are fully aware of the pricing strategies used by all the firms (because the firms are managed by the same administrative unit), and they establish their best, identical responses by playing the Nash equilibrium through their unified self-analyses.

These ℓ imaginary firms do not have any symmetric pure strategy Nash equilibrium. Because the reservation price of the loyal customers is set to be 1, all the prices (or pure strategies) are values in the interval $[0,1]$. (For the setup here, there is no need to consider asymmetric pure strategy Nash equilibrium, because all these imaginary firms take identical actions). In fact, for any symmetric pure strategy portfolio $(x_1, x_2, \dots, x_\ell)$, where $x_i = x_j$, for *i*, *j* = 1, 2, …, ℓ, a randomly chosen Firm *j* ($\in \{1, 2, \dots, \ell\}$) can slightly lower its price from x_j to x_j' to produce additional profits for all the firms as long as $x_j'\beta > (x_j - x_j')\alpha$, which is possible to do by adjusting x_j' sufficiently close to x_j. So, $(x_1, x_2, \dots, x_\ell)$ is not an Nash equilibrium. Even so, (Forrest, Buttermore, & Wajda, 2017) shows that these ℓ firms do have a symmetric mixed-strategy Nash equilibrium.

For the rest of this proof, it suffices to show that Y will be expected to profit by entering this market through uniformly randomizing its price strategy over the interval [0,1].

Let $F(P)$ be the price distribution of Firm *j*, one of the imaginary firms of the aggregate firm. The aggregate firm or equivalently each of the ℓ imaginary forms sets its price after taking into account the price of Y and those of all other imaginary firms. Hence, the profits for Firm *j* from its loyal customers is $\alpha_0 P$ and those from its share of the switchers is $(1-P)\beta P \prod_{i\neq j}^{\ell}[1 - F(P)] = \beta P(1-P)[1 - F(P)]^{\ell-1}$, where $(1-P)$ stands for the portion of the switchers not taken by Y, and $[1 - F(P)]$ the portion of the switchers not taken by one of the other imaginary and identical firms. Hence, the profits Π Firm *j* generates when the firm sells its product at price *P* are $\alpha_0 P + \beta P(1-P)[1 - F(P)]^{\ell-1}$ and the objective function of Firm *j* is

$$max_{F(P)} E(\Pi) = \int_{-\infty}^{+\infty} \{\alpha_0 P + \beta P(1-P)[1 - F(P)]^{\ell-1}\} dF(P)$$
$$= \int_{0}^{1} \{\alpha_0 P + \beta P(1-P)[1 - F(P)]^{\ell-1}\} dF(P)$$

where $E(\Pi)$ stands for Firm *j*'s expected profits for all possible prices, and the objective for Firm *j* is to maximize its expected profits by choosing its price distribution $F(P)$. The reason why the upper and lower limits of the integral are changed respectively from $+\infty$ and $-\infty$ to 1 and 0 is because when *P* < 0 or when *P* > 1, the profits are zero.

The equilibrium indifference condition of Firm *j* is

$$\alpha_0 \times P + \beta \times P(1-P)[1 - F(P)]^{\ell-1} = \alpha_0 \times 1 \quad (3)$$

So, for the ℓ imaginary firms, solving equation (3) leads to their symmetric equilibrium pricing strategy as follows:

$$F(P) = 1 - \left(\frac{\alpha_0}{\beta P}\right)^{\frac{1}{\ell-1}} \tag{4}$$

From $\beta > \alpha_0$, it follows that $\alpha_0/\beta < 1$. So, for any Price *P*, satisfying $1 \geq P \geq \alpha_0/\beta$, equation (4) is a well-defined probability distribution. This end implies that for the ℓ imaginary firms, or equivalently, the aggregate firm, the lowest allowed price is α_0/β.

From $lim_{P\to 1^-} F(P) = 1 - (\alpha_0/\beta)^{1/(\ell-1)} \neq F(1) = 1$, it follows that the cumulative price distribution function $F(P)$ has a jump discontinuity at the reservation value $P = 1$, where the amount of jump is $(\alpha_0/\beta)^{1/(\ell-1)}$. That is, $F(P)$ has a mass point of size $(\alpha_0/\beta)^{1/(\ell-1)}$ at the reservation price $P = 1$. So, the expected profits of Y are the following:

$$E(\Pi) = \int_0^{\alpha_0/\beta} \beta P dP + \int_{\alpha_0/\beta}^{+\infty} \beta P[1 - F(P)]^{\ell} dP \tag{5a}$$

$$= \int_0^{\alpha_0/\beta} \beta P dP + \int_{\alpha_0/\beta}^{1} \beta P[1 - F(P)]^{\ell} dP + \beta \left(\frac{\alpha_0}{\beta}\right)^{\ell/(\ell-1)} \tag{5b}$$

where the first term in the right-hand side of equation (5a) stands for the expected profits of Y when it charges the lowest price in the marketplace and captures the entire segment of the switchers, and the second term is Y's expected profits when it is in direct competition with the ℓ incumbent firms.

It can be readily seen from equation (5b) that the expected profits $E(\Pi)$ of Y is greater than zero. So, if the customer surplus satisfies $\beta = 1 - \alpha > 0$, Y can profitably enter the market to compete with the incumbent firms.

Proof of Propositions 5 and 6: This result follows from the payoffs of X that are corresponding to the scenarios that X either takes defensive actions or does not take any defensive actions (either Table 3 or Table 4). For details see Tables 5 and 6, respectively.

TABLE 5. The payoffs of X when it takes defensive actions

		Company Y	
		Design/produce (*p*)	Don't design/produce (1 – *p*)
Customer	Buy (τ)	$-C$	$S_X - C$
	Don't buy $(1 - \tau)$	$-C$	$-C$

TABLE 6. The payoffs of X when it does not take any defensive actions

		Company Y	
		Design/produce (*q*)	Don't design/produce (1 – *q*)
Customer	Buy (ε)	0	S_X
	Don't buy $(1 - \varepsilon)$	0	0

Proof of Propositions 7 and 8: To solve for the mixed strategy Nash equilibrium, we solve the following indifference equations:

$$pu + (1-p)(-u) = 0$$
$$qu + (1-q)(-u) = 0$$
$$\tau[(S_Y + S_Y\text{-}) - D - \alpha C] + (1-\tau)[(S_Y\text{-}) - D - \alpha C] = 0$$

and

$$\varepsilon[(S_Y + S_Y\text{-}) - D] + (1-\varepsilon)[(S_Y\text{-}) - D] = 0$$

So, we have $p = q = 1/2$ and equations (1) and (2). Now, Proposition 7 follows from equation (2), while Proposition 8 follows from equation (1).

Proof of Proposition 9: Let π_X represent the expected revenue of X. Then we have

$$\pi_{X,\text{defense}} = p\tau(S_X - C - S_Y) + p(1-\tau)(-C) + (1-p)\tau(S_X - C) + +(1-p)(1-\tau)(-C) \quad (6)$$

and

$$\pi_{X,\text{don't defend}} = q\varepsilon(S_X - S_Y) + (1-q)\varepsilon S_X. \quad (7)$$

So, by substituting the values of $p = q = 0.5$, τ and ε from equations (1) and (2) into equations (6) and (7), we have

$$\pi_{X,\text{defense}} = \frac{S_X(D + \alpha C - S_Y\text{-})}{S_Y} - \frac{1}{2}(D + \alpha C - S_Y\text{-}) - C \quad (8)$$

and

$$\pi_{X,\text{don't defend}} = \frac{1}{2}\frac{D - S_Y\text{-}}{S_Y}(2S_X - S_Y) \quad (9)$$

Because

$$\frac{\partial \pi_{X,\text{defense}}}{\partial C} = \frac{\alpha S_X}{S_Y} - \frac{\alpha}{2} - 1 = \alpha\left(\frac{S_X}{S_Y} - \frac{1}{2}\right) - 1 \quad (10)$$

and α is a constant between 0 and 1, it follows that when $S_X < \left(\frac{1}{\alpha} + \frac{1}{2}\right)S_Y$, we have $\frac{\partial \pi_{X,\text{defense}}}{\partial C} < 0$. That is, when $S_X < \left(\frac{1}{\alpha} + \frac{1}{2}\right)S_Y$, the expected revenue $\pi_{X,\text{defense}}$ of X becomes a decreasing function in variable C. In other words, as soon as the revenue Y generates from X's customer base is greater than X's revenue when X does not experience any challenge from Y divided by $\left(\frac{1}{\alpha} + \frac{1}{2}\right)$, then X can no longer exploit its sustainable competitive advantages by continuously raising its investment in raising the entry barrier in order to prevent B from invading its territory.

On the other hand, equation (9) indicates that when $S_Y\text{-} > D$, the expected revenue $\pi_{X,\text{don't defend}}$ of X will be a loss. In other words, if X decides not to defend itself against Y's

challenge and the expected revenue Y generates from the market except X's territory is greater than the fixed cost of designing and producing the hybrid product, then X's expected revenue will be a loss.

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DECISION SCIENCES INSTITUTE
Conceptual Framework for
Designing Robust and Resilient Supply Chains

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ABSTRACT

Owing to the cost reduction efforts (e.g. reducing inventory and node redundancy), supply chains have become increasingly vulnerable to disruptions. However, it is essential that firms should consider designing robust and resilient supply chains because the world has entered an increasingly volatile era where we observe many disruption risk factors (e.g., recent political atmosphere and natural disasters like Hurricane Maria). Thus, this paper explores the literature and develop a conceptual framework to make supply chains more strong and elastic so that they can survive potential risks they might face in the future.

KEYWORDS: Supply Chain Design, Analytics, Resiliency, Risk, Robustness

INTRODUCTION

Many firms have assumed that volatility caused my financial and political crisis, as well as other disruptions, is generally followed by a return to stability, and markets can recover quickly (Christopher & Holweg, 2011). However, the world has entered an increasingly turbulent atmosphere where this is not the case anymore. Disruptions (e.g., political, natural, financial) in this era have enormous economic impacts and may even lead to a total collapse of supply chain systems. It is interesting that many supply chain leaders and practitioners have focused so much on making supply chains leaner and reducing costs (e.g., removing excess capacity).

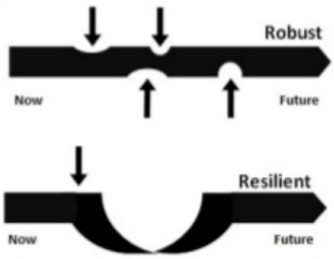
Table 1: Robust vs Resilient Supply Chains

Robust SC	**Resilient SC**
Strong and static	Elastic and dynamic
No excess inventory	Safety stocks and excess capacity
Velocity oriented	Acceleration oriented
Capable of steady output during moderate variability	Capable of responding and adapting to significant variations
Redundancy	Flexibility

However, this attitude, after the recent events (e.g., 2008 financial crisis, Hurricane Katrina, and current global political environment), has started to change, and companies have begun to understand that lean supply chains are more efficient in stable conditions but highly vulnerable in volatile environments (Blackhurst et al., 2005). Thus, business leaders seek methods to identify and manage disruptions in their complex supply chain systems by analyzing the tradeoffs between efficiency, robustness, and resilience (Tang, 2006).

A comparison between the robust and resilient supply chains is given in Table 1. Robust supply chains, when they face disruptions, can function near normalcy (Christopher & Peck, 2004). Resilient supply chains, after they experience disruptions, can quickly return to almost normal operations. The main difference between robust and resilient supply chains is that strategies that help supply chains function near normalcy in robust supply chains have already been defined before disruptions occur. On the other hand, recovery strategies in resilient supply chains are dynamic as they adapt to disturbances.

Figure 1: Resiliency versus robustness



Husdal (2006) states that resiliency is more important than robustness in industry, and his explanation of resiliency vs. robustness is given in Figure 1. A few essential strategies making supply chains robust and resilient are strategic inventory, excess capacity, node redundancy, and multi-sourcing (Pettit, 2008). Although firms might be attracted to the idea of making supply chains robust and resilient to all possible risks and disruptions, supply chains can become costly to operate if they must be robust to all potential threats. Similarly, supply chains can be inefficient if they need to mitigate all the predictable hazards (Johnson & Nagarur, 2012). Therefore, it is essential that field of analytics such as risk quantification, predictive modeling, and simulation must be used to both conceptually and quantitatively design resilient and robust supply chains. In this study, we will review the prominent literate regarding supply chain design and discuss the use of analytics. We will also propose a conceptual supply chain design framework for industry practitioners like ourselves.

THEORY AND LITERATURE

There are several research articles exploring supply chain design from three different perspectives, namely the design of the facility network, distribution system, and transportation system (Chopra & Meindl, 2007). The plan of the distribution network focuses on how and where inventory is stored throughout the supply chain. The transportation system design entails how these inventories are physically shipped throughout the supply chain network. The design of the supply chain network encompasses locating facilities, and then assigning capacities and allocating customers to them.

Quantifying Disruption Risks

Identifying supply chain risk factors is a highly strategic decision and affected by many factors. Deterministic models are not adequate to reflect the dynamism and stochasticity of these ever-changing uncertain factors. Chopra and Meindl (2007) classify these factors into several categories, such as political, technological, and infrastructure. Categorizing supply chain risks is the first step in network design under disruption. Ritchie and Brindley (2007) classify supply chain risks as either systematic or unsystematic. Systematic risks are inherent to a company's attributes and can be controlled (e.g., production yield). Unsystematic risks are impacted by the environment in which the company operates and cannot be controlled (e.g., natural disasters and political instability).

Another risk classification scheme adopted in the literature is endogenous versus exogenous risks (Trkman & McCormack, 2009). The endogenous risks can be controlled whereas the exogenous risks cannot be controlled. While the probability of any exogenous event (also known as an external or unsystematic event as discussed above) occurring may be very low, they often have the highest impacts on the supply chain (e.g., Hurricane Katrina). Therefore, exogenous events, also known as disruptions, must be mitigated to reduce their impact on the supply chain (Snyder & Shen, 2006). Pettit and Fiksel (2010) suggest that supply chain resilience can be assessed in terms of two dimensions: vulnerabilities (e.g., increased outsourcing and centralized distribution) and capabilities (e.g., flexibility in sourcing and capacity). Resilience is defined as the desired balance between vulnerabilities and capabilities.

Applications of Optimization for Designing Robust and Resilient Supply Chains

Sawik et al. (2014), under disruption risks, study single and multiple sourcing strategies, as well as their cost and service levels. In their model, suppliers located in different locations are faced with independent local, semi-global, and global disaster events. They account for potential disruption scenarios and formulate the problem as a mixed integer programming. Their algorithm reveals the outsourcing strategies as those that minimize expected worst-case cost or maximize expected worst-case customer service level. Snyder and Daskin (2005) use linear programming and stochastic modeling to identify location failures due to disruptions. The primary objective of this research is to build resilient and robust supply chains that can work when a facility (a node in a supply chain) fails. Snyder and Daskin (2005) measure the effectiveness of the proposed supply chain system utilizing the distance between the failed facility and the secondary facility that now must meet the customer demand.

Hishamuddin et al. (2013), in case of a transportation disruption, explore a recovery model for a two-stage production and inventory system. Their proposed solution utilizes a heuristic-based approach and can determine the optimal ordering and production quantities during a recovery window after a disruption. Shishebori et al. (2014) consider facility location and network design problems together with a constraint on the maximum allowable disruption cost. The combined facility location and network design problem is essential to public and private facilities; because taking reliability into account with this incorporation becomes an effective way to an effective way to hedge against disruptions in the system. Jabbarzadeh et al. (2014) propose a model that aims to determine the strategic location and tactical allocation decisions for a deterministic four-tier supply chain, then the researchers extend the model to incorporate robustness into the design.

Applications of Simulation for Designing Robust and Resilient Supply Chains

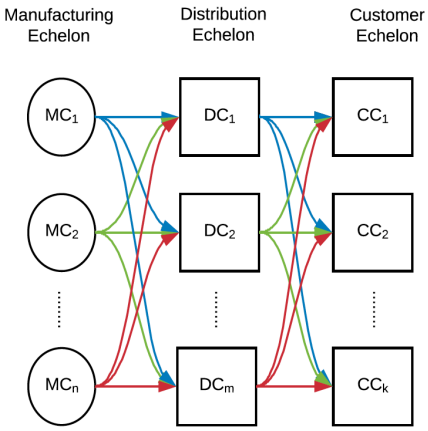
The discrete event, Monte Carlo, and agent-based simulation methods have been used to quantify risk and model the performance of robust and resilient supply chain systems. Strategic inventory at the manufacturing sites and having multiple suppliers of components are two crucial risk mitigation strategies, and Sirivunnabood and Kumara (2009) develop an agent-based simulation model to compare the effectiveness of these strategies. Their results delineated that disruptions with longer durations are best assuaged by multiple suppliers while disruptions with short durations are best mitigated with strategic inventory while. Deleris and Erhun (2005) build a simulation model with four stages. The first stage is to model the risk of specific disruption occurrences and severities with a Poisson process. The second part, which is called operations model, considers the interactions among the network and can be utilized to observe how risks perpetuate through the network. Then, a general semi-Markov process (GSMP) model is used to integrate the disruptions with operations models. In the last element, a Monte-Carlo simulation model is employed to obtain probability distributions of total losses.

Deleris and Erhun (2005) conduct research to measure network vulnerability through loss of volume. They first identify weaknesses by estimating their probability of occurrence and severity of disruptions, then analyze the consequences of these vulnerabilities on the supply chain through a network model. Afterward, they use a Monte-Carlo simulation to quantify the risk and develop mitigation strategies. Discrete event simulation is also used to assess disruption risks using user-defined probability distributions. For example, Schmitt and Singh (2009) propose a research method to determine current levels of disruption risk, test multiple mitigation strategies, and identify redundancies that can be removed without jeopardizing the performance of the supply chain. The disruption risks considered in this model include component shortages (operational), and political instability. Peng et al. (2014) propose a system dynamics model to analyze the behaviors of disrupted disaster relief supply chains. They define and test different replenishment solutions combined with three inventory planning strategies with lead time uncertainties.

CONCEPTUAL DESIGN

In this conceptual framework, we consider a multi-echelon supply chain given in Figure 2 (e.g., manufacturing, distribution, and customer echelons) where disruptions may occur at any stage.

Figure 2: Multi echelon supply chains

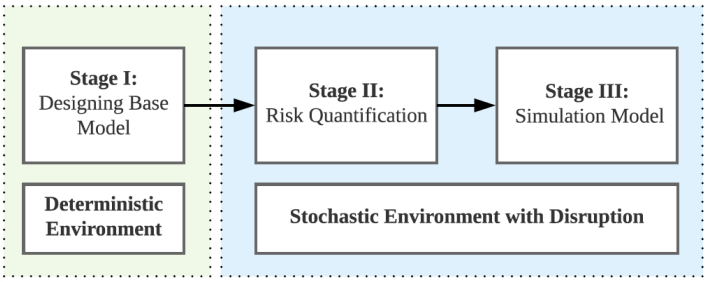


Our primary goal is to design robust (strong) and resilient (elastic) supply chain systems that can mitigate disruptions by adaptively changing the product flow among the centers at various echelons.

General Framework

Although there are multiple ways to design a resilient and robust supply chain (e.g. stochastic programming) systems, our proposed approach is to use deterministic programming and then introduce stochasticity through simulation to model the disruption risk. This approach is simple to frame and easy to solve. The first step to designing such a network is to build a base model using linear programming and then come up with alternative models by incorporating several mitigation strategies (e.g., node redundancy or strategic inventory). Afterward, the performance of these several design strategies can be tested employing discrete event and Monte Carlo simulation methods. We propose that the first stage is to identify a base model using mixed integer programming techniques. It is expected that the base model would require various types of information such as the locations of manufacturing, distribution, and customer echelons, and the transportation times among all these echelons. Then, the base model can determine the best product flow among echelons. However, establishing the base model is just half the equation because disruptions can disable various centers (e.g., manufacturing) located in different echelons. Thus, a mitigation strategy, which will determine the new product flow until the impact of disruption is faded away, is necessary. To be able to decide on the mitigation strategies, one first needs to model to disruptions using probability distributions.

Figure 3: General conceptual framework



Building the Base Model

Supply chain network design has been studied in both supply chain management and logistics fields. The problem entails selecting centers (i.e., node or sites) to install manufacturing plants, distributions warehouses, and assigning customers to customer centers (i.e., serving facilities). The network design problem also determines the optimum connectivity among the nodes at each echelon and identify the best product flow. We think that such a model, which we name it as the “base model” is necessary to determine the initial network design and create the product flow without considering disruptions. Such a base model can be built using mixed integer programming with an objective function of minimizing the total fixed and transportation costs utilizing the estimated demand across different locations where the business has a footprint. We also think that multi-objective optimization that also tries to maximize the customer satisfaction levels can be incorporated into the base model. The base model has one primary constraint, demand satisfaction for the centers located at different echelons. This problem can be sold either using tools like CPLEX or Lingo, as well as meta-heuristics techniques (e.g. genetic algorithms) that can be coded using programming languages such as Python and Matlab. The

output of the base model, which is product flow and the number of facilities in each echelon, can be used to test the mitigation strategies (e.g., excess capacity and inventory).

Quantifying Risks

We suggest that to be able to quantify risk, researchers must collect data regarding the past disruptions in every center located at each echelon. This previous data, then, can be used as an input to several prediction models that can predict rare events (e.g., Bayesian approached) or simulation models such as Monte Carlo. We propose, as implemented by Schmitt and Singh (2009), that researchers model disruptions at each node (e.g. manufacturing center) independently, and that the performance of any downstream nodes may be impacted by upstream disruptions. We propose that there will be different sources of uncertainty that constitute a disruption event (e.g., severity). We suggest that one can incorporate these uncertainties using Monte Carlo simulation. The first thing is to use the past data to decide the distribution of the disruptions and determine its parameters. Keep it in mind that the disruption probability distribution can be different for each node. We propose the following parameters with varying distributions of probability for any disruption:

- Severity
- Duration
- Time to Recovery

After one can determine the probability distributions for each of the above parameters for each disruption using either Monte Carlo simulation or Bayesian approaches, various mitigation strategies can be tested for the base and alternative supply chain designs.

Measuring Effectiveness of Designed Network

We propose that the best performance indicator of any supply chain design will be profits. Thus, we suggest that the data collected through the simulation model must be compared for each robust and resiliency strategies incorporated with the base model. For example, users can integrate postponement and strategic placement capacity at the same time, and compare the overall profits of these two mitigation strategies using ANOVA.

Table 2: Example Mitigation Strategies

Disruption Mitigation Strategy	Description
Postponement	Custom configurations of products should be delayed
Multi-sourcing	Critical components should be supplied using several suppliers
Strategic Inventory	Spare inventory should be placed at different echelons of a supply chain
Strategic Capacity	Spare capacity should be allocated at different echelons of a supply chain
Dynamic Pricing	Shift demand away from product that is disrupted

It is also imperative that users need to account for the cost of implementing mitigation methods. For instance, if the cost of using spare capacity more than using strategic inventory, then this cost must be included in the overall profit calculation. The best mitigation strategies can be selected as those that give the highest profits.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In this theoretical study, we have emphasized the importance of designing robust and resilient supply chains, especially in this volatile environment where stability is not always guaranteed after disruptions. In our literature review, we have identified the best mitigating strategies to make supply chains both strong and flexible using optimization, simulation, and risk quantification. These mitigation strategies include strategic inventory, excess capacity, and multi-sourcing. In our conceptual framework, we have proposed the following general steps:

1. Build a base model first without the consideration of disruptions
2. Model the probability distributions of disruptions and identify their parameters (e.g., Monte Carlo Simulation)
3. Select several disruption mitigation strategies that will make the network more robust and resilient
4. Use discrete event simulation to test the performance of the proposed network system with mitigation strategies, and employ statistical analysis (e.g., ANOVA) to compare and contrast the candidate supply chain networks

We believe that this literature review and conceptual framework can be employed to build a practical robust and resilient supply chains. As part of our future studies, we plan to use our conceptual design in an empirical study to create a supply chain network to determine the best strategies that will make the system robust and resilient.

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Concession Candidates Selection Model for Infrastructure projects Using Interval Number and Grey Relational Analysis: A Social-Cost-Based Perspective

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ABSTRACT

Social cost is a factor that has been widely considered in social and economic development activities. For any infrastructure projects that has a bearing on the general public, great attention should be paid to any potential social negative effects arising from the mishap thereof. This paper presents a set of social-cost-based attributes for bid evaluation of BOT infrastructure project concession candidates. In case of known weighted attributes, the bid evaluation committee can develop a model for bid evaluation of concession candidates based on interval numbers and grey relational analysis, if it faces uncertainties concerning the attributes themselves and the owner's preference for concession candidates. The ranking of concession candidates can be done by obtaining grey correlation for interval numbers through the distance between interval numbers. This social-cost-based model is set to contribute to less social costs by forcing a concession candidate to work out a more reasonable operational scheme. Meanwhile, uncertain information for decision making is offset by interval numbers, leading to more practical evaluation results.

KEYWORDS: Infrastructure project, concession candidate, bid evaluation, social cost

INTRODUCTION

As a form of project financing for infrastructure construction by way of absorbing foreign capital or social capital, BOT has been widely used. To select a desired BOT concession candidate in the infrastructure project is not only a most important decision the Owner has to make, but also one of the key factors concerning the success of a project (Wang et al. 2012).

In fact, the study on concession candidate selection is a derivative from the mainstream research on project contractor selection (CSn) (Holt 1998). Different in research object, they both in essence deal with typical multi-attribute decision problems involving multiple factors, indexes and levels. The solution to this kind of problems rests with two critical factors, namely,

selection criteria and selection approaches (including the approaches to determine index weight and solve the multi-attribute decision problems). With the enhancement of environmental awareness and sustainable development concept, the concept "social cost" early put forward by some researchers has been attracting the attentions of the public, academia, and government in a great way; especially in Western developed countries, social cost is a factor that has been widely considered in social and economic development activities(Gilchrist & Allouche 2005). For any BOT infrastructure project that has a bearing on the general public, its construction and operation is bound to imposing adverse impacts on ecological, economic and social and other aspects of the surrounding areas, which will evolve into the social cost (the common concern of the project's sponsor, investor and the public) in the end and give rise to social negative effects (Gilchrist & Allouche 2005). Therefore, incorporation of "social cost" into the criteria for bid evaluation of concession candidate is a new issue worthy of studying (Wang et al. 2008). Accordingly, there are still two problems to be solved: on the one hand, how to measure the China's "social cost" in criteria for bid evaluation of BOT project concession candidate, on the other hand, how to deal with the uncertain information. The researches on social cost in recent 20 years in western academia show that, measurement of social cost is complicated and not so accurate.

Social cost evaluation is very necessary for pushing the concession candidates to develop more reasonable project schemes and be more conscious of social benefits of project investment. Moreover, the smooth construction of the project can be assured due to pre-estimation and control of social costs (Wang et al. 2008). Given the above, this research presents a set of social-cost-based attributes for bid evaluation, based on analyses for concession candidate's capacity and quality, as well as evaluation indexes. In case of known weighted attributes, the bid evaluation committee can develop a model for bid evaluation of concession candidates based on interval numbers and grey relational analysis, if it faces uncertainties concerning the attributes themselves and the Owner's preference for concession candidates. The ranking of concession candidates can be done by obtaining grey correlation for interval numbers through the distance between interval numbers.

ESTABLISHMENT OF SOCIAL-COST-BASED ATTRIBUTES

Literature review

Selection of evaluation criteria has always been a hot issue among research topics. A research report titled Infrastructure Concessionary Design and Conferring issued by the World Bank in 1998 points out that: one of critical factors for a successful BOT project is the reasonably designed approach to confer a concession, but criteria selection can be based on two aspects, i.e., technology and financing (Michel et al. 2008). Seen from the time series of researches on criteria for bid evaluation of BOT project concession candidate, Dias, Marcus and Zhang Xueqing made outstanding achievements in this regard. Dias determined the importance of specific indexes by virtue of questionnaire surveys, and suggested evaluating the capacity of the concession candidate based on internationalization characteristics, production capacity, financing capability, team ability, technical competence, and contribution to the project's locality (Dias & Ioannou 1996). Based on a large number of empirical studies for the British Government and private sectors in 2004, Ahadzi believed that, organizational characteristics and advantages, project proposal and financial capacity should be the three main aspects to measure the abilities of concession candidates (Ahadzi & Bowles 2004). The current relevant researches in China basically cited or referred to the research results from Zhang Xueqing. He successively researched the current situation and defects with regard to the criteria and

approaches of Hong Kong Government for selecting the concession candidates during 2001-2005, and put forward detailed and well exercisable criteria for bid evaluation of BOT project concession candidate based on plenty of questionnaires in Hong Kong and the UK, which include financing standards, technical standards, health, safety and environmental standards, and management standards (4 dimensions, 92 elements) (Zhang et al. 2001 2002 2004 2005). Recently, although the social and economic environment has changed greatly, the criteria for bid evaluation of BOT project concession candidate have not yet, which still focused on financial, management, technical, health, safety and environmental project, with the only difference lying in the selection and adjustment of observational variables according to different types of project.
The researches on "social cost" as a consideration for "contractor" selection are numerous in many countries but rare in China. Allouche argues that, the social cost referred to the cost that could not be included into the direct and indirect construction cost according to the contract in the construction process of the project, which included 4 aspects, i.e., natural environment, human society, public property, and regional economy (Allouche et al. 2000). This macro definition covers all aspects to be considered in measurement of social cost, and many relevant specific researches are made within this scope. In conclusion, foreign scholars' researches on measurement of the engineering project's social cost mainly focused on following aspects (Gilchrist & Allouche 2005): (1) Output value loss. This cost estimation largely concentrated on the project's construction process' impacts on normal production or operation of surrounding enterprises and public institutions, which measured the corresponding value loss incurred at current market price by output loss. (2) Human capital. This aspect of researches focused on the human's production capability imposed by the project, which mostly measured the project's adverse impacts on human's health and income, involving currency loss arising from construction accidents, unemployment, as well as decline in income, physical and psychological health and environmental quality. (3) Replacement cost. It refers to the cost to replace the original facilities destroyed by construction of new projects, such as the replacement cost caused by destroying the structure of existing facilities, and increasing the service load of relevant roads due to road occupancy in the process of project construction. (4) Opportunity cost. Estimation of opportunity cost is mainly related to the behaviors violating the rights of citizens, such as loss in social public rights arising from forcible occupancy of cultivated land and illegal demolition and other reasons (the qualitative evaluation generally). (5) Road closure cost. It mainly measures the cost from the adverse impacts on pedestrians due to closure of road under construction, the cost from traffic delays, traffic control and management needs during the construction, as well as the cost lost due to decrease of commercial trading volume thereby. (6) Traffic delay cost. It refers to the value loss caused by traffic jams and decline in travel speed during the project's construction. The aforesaid analyses do not cover all evaluation and measurement of social cost, for example, the social cost value full-prediction model put forward by American Water Works Association (AWWA) also supported the social cost observation. Thus it can be seen that, the observation for social cost can be achieved, and relatively mature foreign research results shall be absorbed and followed.

Establishment of bid evaluation attributes

Based on the above analyses and in order to better link the researches with practices, this research, based on existing research results, classifies the attributes for bid evaluation of concession candidates into five categories: finance, management, technology, health, safety and environment as well as social cost, aiming to determine the observation elements suitable for China's actual situations through discussions with relevant researchers and personnel engaged in this field. Under the comprehensive, scientific and measurable principle, combined

with chrematistics of the BOT project, this research finally builds a bid evaluation attribute set covering 5 bid evaluation attributes and 29 observation elements. See Table 1 below for more details.

Table 1 Attributes for Bid Evaluation of BOT Project Concession Candidates

Bid evaluation attribute	Observation element
Financial position	6 observation elements: Working capital, net capital, project financing amount and financing plan, concessionary price and adjustment program, concessionary period, and the extent requiring government guarantee
Management capability	7 observation elements: Qualification, experience and performance of management organization, project management capability, organizational culture and structure, resource allocation capability, human resources allocation, communication and coordination capability, risk management capability
Technical capacity	7 observation elements: Qualifications, experience and performance of key design and construction personnel, capability of design units and subcontractors, information system, construction scheme and assurance capability, project transfer scheme, operation and maintenance scheme
Health, safety and environment capability	5 observation elements: Qualifications and experience of health, safety and environmental personnel, previous health and safety performance, previous environmental performance, safety and health management measure, environmental protection program
Social cost	5 observation elements: output value loss, human capital, replacement cost, opportunity cost, road closure cost, and traffic delay cost

In Table 1, there are good evaluation approaches for the observations of the first four bid evaluation attributes both in practice and academia. For example, the working capital can be measured by difference value between current assets to current liabilities to further reflect the evaluation object's capability to generate cash; the information system can be measured by information technology equipment rate (total informatization input/fixed-asset investment), so as to judge the informatization degree of the evaluation object; some qualitative indexed such as management capability, guarantee extent, qualification and experience may be determined by score by experts. However, the observation for social cost needs the incorporation of relevant foreign research results into China's actual situations. See details in Table 2.

Table 2 All Observation Elements of Social Cost and Evaluation Approaches

Observation element	Evaluation approach
Output value loss	Number of employer affected by the project × output per hour × production drawdown coefficient × project construction period
Human capital	To evaluate the currency loss arising from construction accidents, commercial loss, unemployment, as well as decline in health and environmental quality and others

Replacement cost	To fully evaluate all replacement expenses related to original facilities with physical accounting
Road closure cost	Road closure time in peak period × Unit cost of road closure in peak period + Road closure time in non-peak period × Unit cost of road closure in non-peak period
Traffic delay cost	Number of passenger per vehicle × Average delay time per vehicle × Average salary per hour × Salary percentage

Note: The production drawdown coefficient and salary percentage may be provided by certain industries.

ESTABLISHMENT OF MODEL FOR BID EVALUATION

In selection of BOT project concession candidates, the evaluation task is very hard (not easy to determine cost frontiers), since it is impossible for decision-makers to provide accurate figures corresponding to the evaluation attributes in Table 1, especially social cost. Therefore, the most effective approach shall be to combine expert's experience and existing research achievements (quantitative and qualitative assessment on observation elements) of bid evaluation committee and use uncertain numbers such as fuzzy number and interval number to conduct fuzzy evaluation for all bid evaluation attributes. In addition, the bid evaluation committee often conducts standard evaluation, but the complexity of objective conditions and the uncertainty of subjective thinking vary the demands of different Owners of projects, resulting in Owners' some subjective preference for concession candidates. That preference information can only be showed by a range instead of certain real number. For this reason, in case of known weighted attributes, the bid evaluation committee can solve the concession candidate selection problem based on multi-attribute decision of interval number and GAR, if it faces uncertainties concerning the attributes themselves and the Owner's preference for concession candidates. The most outstanding characteristic of this method is to be able to address uncertain information for decision making and solve the problem about multi-attribute decision of the Owner's preference for concession candidates.

Agreed symbols

The following symbols and variables shall be applied:

X —Alternative solution set, which is recorded as $X = (x_1, x_2, \ldots, x_m)$; m indicates the number of concession candidates.

U —Evaluation attribute set, which is recorded as $U = (u_1, u_2, \ldots, u_n)$; n indicates the number of evaluation attributes.

W —Pre-determined weighted attribute information set (all are real numbers), which is recorded as $W = (w_1, w_2, \ldots, w_n)$, of which $\sum_{j=1}^{n} w_j = 1, j = 1, 2, \ldots, n$.

a_{ij} —After evaluation of attribute u_j of concession candidate x_i, the bid evaluation committee can obtain the attribute values in interval number and record as $a_{ij} = [a_{ij}^L, a_{ij}^R]$ which shows the subjective preference of the bid evaluation committee for attribute u_j of concession candidate x_i.

θ_i —After the evaluation of concession candidate x_i, the Owner can obtain attribute values in interval number and record as $\theta_i = [\theta_i^L, \theta_i^R]$ $(i = 1, 2, \ldots, m)$ which shows the Owner's subjective preference for concession candidate x_i.

λ_{ij} —Grey relational coefficient, reflecting the level of similarity of objective and subjective preference of decision-maker under concession candidate x_i for attribute u_j.

λ_i —Grey relational degree, reflecting the overall level of similarity of objective and subjective preference of concession candidate x_i for all attributes.

Bid evaluation procedures

Based on above description, ranking concession candidates can be done through using multi-attribute decision and GRA of interval numbers, in accordance with the following specific procedures:

(1) The bid evaluation committee appraises all bid evaluation attributes of a concession candidate in the form of interval number (based on synthetic judgment after collection of observation elements data) and lists an interval decision matrix *A*. The known bid evaluation committee appraises attribute u_j of concession candidate x_i and then obtains attribute value $a_{ij}=[a_{ij}^L, a_{ij}^R]$ in interval number. Therefore, after evaluation of n bid evaluation attributes of m concession candidates, the bid evaluation committee will obtain an interval decision matrix *A*:

$$A=\begin{bmatrix} [a_{11}^L, a_{11}^R] & [a_{12}^L, a_{12}^R] & [a_{1n}^L, a_{1n}^R] \\ [a_{21}^L, a_{21}^R] & [a_{22}^L, a_{22}^R] & [a_{2n}^L, a_{2n}^R] \\ & & \\ [a_{m1}^L, a_{m1}^R] & [a_{m2}^L, a_{m2}^R] & [a_{mn}^L, a_{mn}^R] \end{bmatrix}$$

(2) We normalize the interval decision matrix. Normalizing decision matrix is in order to eliminate the influence of indicative dimension, order of magnitudes and type of attribute on decision results, that is, to normalize attribute values. The normalization methods of interval decision matrix mainly include sum method, vector normalization method and max-min method. This research adopts the vector normalization method to normalize above decision matrix (Goh et al. 1996).

The method of handling profit attribute is

$$B_{ij}^L=\frac{a_{ij}^L}{\sqrt{\sum_{i=1}^{m}(a_{ij}^R)^2}} \quad \& \quad B_{ij}^R=\frac{a_{ij}^R}{\sqrt{\sum_{i=1}^{m}(a_{ij}^L)^2}} \tag{1}$$

The method of handling cost attribute is

$$B_{ij}^L=\frac{\left(\frac{1}{a_{ij}^R}\right)}{\sqrt{\sum_{i=1}^{m}\left(\frac{1}{a_{ij}^L}\right)^2}} \quad \& \quad B_{ij}^R=\frac{\left(\frac{1}{a_{ij}^L}\right)}{\sqrt{\sum_{i=1}^{m}\left(\frac{1}{a_{ij}^R}\right)^2}} \tag{2}$$

The normalized interval decision matrix is recorded as: $A'=([B_{ij}^L, B_{ij}^R])_{m\times n}$.And the attribute value $[B_{ij}^L, B_{ij}^R]$ can be regarded as objective preference of bid evaluation committee for attribute u_j of the concession candidate x_i.

(3) We compute the distance d_{ij} between interval number $[\mathrm{B}_{ij}^{L}, B_{ij}^{R}]$ and interval number $[\theta_i^{L}, \theta_i^{R}]$. Because objective and subjective preference are both uncertain information handled in interval number (subjective preference $\theta_i = [\theta_i^{L}, \theta_i^{R}]$, and objective preference $A' = [\mathrm{B}_{ij}^{L}, B_{ij}^{R}]$), we introduce the formula of distance between interval numbers:

$$d_{ij} = \sqrt{(B_{ij}^{L} - \theta_i^{L})^2 + (B_{ij}^{R} - \theta_i^{R})^2},\ i = 1,\ 2,\ \ldots,\ m,\ j = 1,\ 2,\ \ldots,\ n. \tag{3}$$

With above formulation, we will obtain the distance matrix $d_{m\times n}$ of interval numbers.

(4) We compute the grey relational coefficient between each concession candidate's objective and subjective preference. Grey Relational Analysis (GRA) is put forward by Professor Deng Julong in 1985, with the fundamental principle that: when statistics are showed by curves, the more all curves are parallel, the closer their variation trends are, and the bigger their level of similarity is. For this purpose, the formula of grey relational coefficient λ_{ij} between objective and subjective preference of concession candidate x_i for attribute u_j is

$$\lambda_{ij} = \frac{\min\limits_{i}\min\limits_{j}|d_{ij}| + \rho\max\limits_{i}\max\limits_{j}|d_{ij}|}{|d_{ij}| + \rho\max\limits_{i}\max\limits_{j}|d_{ij}|} \tag{4}$$

In the formula, ρ is an identification coefficient, $\rho \in [0,\ 1]$, and 0.5 is adopted there. With above formula, we will obtain grey relational coefficient matrix $\lambda_{m\times n}$.

(5) We calculate the grey relational degree of objective and subjective preference for all concession candidates, and sort all concession candidates thereof.

$$\lambda_i = \sum_{j=1}^{n} \lambda_{ij} w_j,\ i = 1,\ 2,\ \ldots,\ m. \tag{5}$$

The bigger λ_i is, the closer objective and subjective preference of a decision-maker for concession candidate x_i are, and the better concession candidate x_i is; otherwise, the concession candidate x_i is worse.

ANALYSIS OF NUMERICAL EXAMPLE

Basic information

In a certain city, BOT project selects concession candidates through open tendering. After pre-qualification, five tenders are selected. According to content of bidding documents, the five bid evaluation attributes of evaluation and award of bid during the bid of the project are: Financial position, management capability, technical capacity, the healthy, safe and environmental capacity, and social cost. Known conditions of the numerical example:

(1) the weighted attributes of all bid evaluations have been determined by the bid evaluation committee and the Owner after negotiation and expressed as $W = (0.26,\ 0.23,\ 0.20,\ 0.14,\ 0.17)$ in certain real numbers.

(2) the Owner's subjective preference for all concession candidates are expressed as $\theta_1 = [0.3,\ 0.5],\ \theta_2 = [0.2,\ 0.6],\ \theta_3 = [0.1,\ 0.4],\ \theta_4 = [0.3,\ 0.7],\ \theta_5 = [0.4,\ 0.9]$ in the form of interval number.

At last, the bid evaluation committee appraises all bid evaluation attributes of concession candidates by reference to collected observation elements data. The results of evaluation are given in the form of interval number as showed in Table 3.

Table 3 The results of evaluation of concession candidates by the bid evaluation committee

Bid evaluation attribute / Concession candidates	Financial position	Management capability	Technical capacity	Healthy, safe and environmental capacity	Social cost
T1	[7.2, 8.5]	[8.0, 9.5]	[7.0, 8.5]	[0.5, 1.5]	[7.0, 9.2]
T2	[5.4, 7.0]	[5.5, 8.2]	[6.4, 7.5]	[2.5, 3.5]	[6.5, 8.0]
T3	[6.5, 8.0]	[7.5, 9.0]	[5.5, 7.0]	[2.0, 2.5]	[6.3, 7.5]
T4	[5.5, 9.0]	[4.5, 7.0]	[6.0, 9.2]	[1.5, 2.5]	[8.5, 9.0]
T5	[6.0, 7.5]	[7.0, 8.5]	[5.0, 7.5]	[1.0, 3.0]	[7.0, 7.5]

Computational process

Step 1 According to evaluation values of all bid evaluation attributes of concession candidates in the form of interval number from the bid evaluation committee, the interval decision matrix A is listed as

$$A=\begin{bmatrix} [7.2,\ 8.5] & [8.0,\ 9.5] & [7.0,\ 8.5] & [0.5,\ 1.5] & [7.0,\ 9.2] \\ [5.4,\ 7.0] & [5.5,\ 8.2] & [6.4,\ 7.5] & [2.5,\ 3.5] & [6.5,\ 8.0] \\ [6.5,\ 8.0] & [7.5,\ 9.0] & [5.5,\ 7.0] & [2.0,\ 2.5] & [6.3,\ 7.5] \\ [5.5,\ 9.0] & [4.5,\ 7.0] & [6.0,\ 9.2] & [1.5,\ 2.5] & [8.5,\ 9.0] \\ [6.0,\ 7.5] & [7.0,\ 8.5] & [5.0,\ 7.5] & [1.0,\ 3.0] & [7.0,\ 7.5] \end{bmatrix}$$

Step 2 The interval decision matrix is normalized according to formula (1) and (2).To simply computational process, we select all profit attributes here, handle them and obtain a normalized matrix A':

$$A'=\begin{bmatrix} [0.4009,\ 0.6175] & [0.4218,\ 0.6409] & [0.3923,\ 0.6314] & [0.0833,\ 0.4045] & [0.3784,\ 0.5793] \\ [0.3007,\ 0.5085] & [0.2900,\ 0.5532] & [0.3587,\ 0.5571] & [0.4617,\ 0.9439] & [0.3514,\ 0.5038] \\ [0.3619,\ 0.5811] & [0.3954,\ 0.6071] & [0.3082,\ 0.5201] & [0.3333,\ 0.6742] & [0.3406,\ 0.4723] \\ [0.3063,\ 0.6538] & [0.2373,\ 0.4722] & [0.3363,\ 0.6834] & [0.2500,\ 0.6742] & [0.4595,\ 0.5667] \\ [0.3341,\ 0.5448] & [[0.3691,\ 0.5734] & [0.2802,\ 0.5571] & [0.1667,\ 0.8090] & [0.3784,\ 0.4723] \end{bmatrix}$$

Step 3 After calculations in accordance with formula (3), we can obtain the distance d_{ij} between interval numbers of objective and subjective preference for all bid evaluation attributes of concession candidates, and work out the following distance matrix $d_{m\times n}$ of interval numbers thereof:

$$d = \begin{bmatrix} 0.1549 & 0.1863 & 0.1606 & 0.2369 & 0.1114 \\ 0.1360 & 0.1015 & 0.1643 & 0.4319 & 0.1794 \\ 0.3184 & 0.3608 & 0.2402 & 0.3600 & 0.2512 \\ 0.0781 & 0.2362 & 0.0400 & 0.0566 & 0.2078 \\ 0.3612 & 0.3282 & 0.3692 & 0.2504 & 0.4283 \end{bmatrix}$$

Step 4 After calculations in accordance with formula (4), we can obtain the grey relational coefficient λ_{ij} of objective and subjective preference for all bid evaluation attributes of concession candidates, and work out the following grey relational coefficient matrix $\lambda_{m\times n}$ thereof:

$$\lambda = \begin{bmatrix} 0.6092 & 0.6363 & 0.6798 & 0.5652 & 0.7819 \\ 0.7273 & 0.8063 & 0.6732 & 0.3951 & 0.6474 \\ 0.4790 & 0.4438 & 0.5612 & 0.4444 & 0.5479 \\ 0.8705 & 0.5661 & 1.0000 & 0.9391 & 0.6041 \\ 0.4435 & 0.4704 & 0.4375 & 0.5489 & 0.3973 \end{bmatrix}$$

Step 5 After calculations in accordance with formula (5), we can obtain the following grey relational degree λ_i between objective and subjective preference for concession candidates:

$$\lambda_1 = 0.6738,\ \lambda_2 = 0.6745,\ \lambda_3 = 0.4941,\ \lambda_4 = 0.7907,\ \lambda_5 = 0.4553$$

From value λ, it can be seen that $\lambda_4 > \lambda_2 > \lambda_1 > \lambda_3 > \lambda_5$. And the five candidate concessions are sorted in order: $T_4 \quad T_2 \quad T_1 \quad T_3 \quad T_5$. Therefore, T_4 is judged as the best concession candidate.

CONCLUSIONS

For any BOT project, the degree of the realization of social benefits of the project rather than merely the project construction cost is what truly matters. The evaluation of concession candidates and the award of a concession is a decision-making process involving multiple factors, indexes and levels. This paper creatively includes social cost into the standard for bid evaluation of concession candidates. In case of known weighted attributes, the bid evaluation committee can solve the concession candidate selection problem based on multi-attribute decision of interval number and GAR, if it faces uncertainties concerning the attributes themselves and the Owner's preference for concession candidates. After introduction of distance between interval numbers, we work out the grey relational coefficient of interval numbers, obtain the grey relational degree of objective and subjective preference of bid evaluation committee and the Owner for concession candidates, and thus sort all concession candidates. The feasibility and effectiveness of the model have been proved through analysis of numerical example. Therefore, this model is set to contribute to less social costs by forcing a concession candidate to work out a more reasonable operational scheme. Meanwhile, uncertain information for decision making is offset by interval numbers, leading to more practical evaluation results.

This paper can be extended in the following aspects: (1) we can research the components of social cost in China's BOT project and discuss more accurate social cost observation method; (2) in this paper, the model for bid evaluation is established in case of known weighted attributes of bid evaluation of concession candidates. However, the weighted information cannot be sure in reality. We can consider expressing weighted attribute information in interval number or fuzzy number, and the scientificity of research results must be improved largely.

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Controvertible Information – The Missing Piece in the Supply Chain Management and Financial Performance Link

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ABSTRACT

Many models have been built linking supply chain management (SCM) and financial performance. As inputs, these models have used a variety of information about the supply chain, but they have not treated analyst opinion about firm excellence in SCM as an input variable. Opinion is *controvertible* as it can be challenged. Gartner provides its opinion in an annual publication on the top 25 firms in SCM. This article examines the information in Gartner's list and its impact on stock returns of the listed firms. The article thus makes a novel contribution by exploring the SCM-finance link using controvertible information.

KEYWORDS: *Supply chain management, financial performance, event study methodology*

INTRODUCTION

The issue of the relationship between effective management of the supply chain and the financial performance of the firm has been studied from many perspectives precisely because understanding this linkage is very important to business managers (D'Avenzo, Lewinksi, & Wassenhove, 2003). As our literature review demonstrates in the next section, many different models and methodologies using a variety of input variables of supply chain performance and output variables of financial performance have been used to study this relationship. The diversity of models range from survey-based structural equation models where managers are asked about their subjective perceptions of supply chain and financial performance (Kroes & Ghosh, 2010) to time-series analysis of changes in accounting measures such as return on assets before and after the deployment of supply chain management systems (Dehning, Richardson, & Zmud, 2007) to event studies of the impact on capital markets of disclosure of information about disruptions to the supply chain (Hendricks & Singhal, 2003).

Given the effort that has gone into exploring the supply chain and financial performance link over many years, it is somewhat surprising that an important class of information has been largely ignored in studying this relationship. This class of information pertains to analyst opinion about the supply chain performance of firms. Analyst firms such as Gartner annually publish a list of who they believe are the top 25 firms in effectively managing their supply chain. We will refer to this list of the top 25 firms as the SCT25. Event study methodology can be used to examine if Gartner's disclosure of the SCT25 information has capital market impact or not. Our literature review indicates that only one study has been done of the value-relevance of the

SCT25 information using event study methodology (McCarthy & Nayar, 2010). However, as we argue later in this article, their methodology has significant flaws. McCarthy and Nayar (2010) essentially treat the SCT25 information as factual, such as an announcement of earnings or a new product by a firm, rather than as controvertible information. As opposed to facts, controvertible information is opinion which can be challenged by other people who hold a different opinion. Gartner's SCT25 list is their opinion of who they consider are the best firms in managing their supply chain. This opinion may not necessarily be shared by other analysts. Hence, we need to modify the standard event study methodology, which has historically been used to study the value-relevance of factual information, to apply it to that of controvertible information.

This article is the first to do a deep analysis of the information contained in the SCT25 list using a modified event study methodology that is appropriate for studying the value-relevance of controvertible information such as the SCT25 list.

LITERATURE REVIEW

The effectiveness of a firm in supply chain management (SCM) and its financial performance has been studied using a variety of methodologies and input and output variables (D'Avenzo et al., 2003; Presutti & Mawhinney, 2007). Input variables include some aspect of the design of the supply chain or an intermediate performance indicator or a discrete event affecting the supply chain. Thus, input variables could be the design of the supply chain to fit uncertainty, inventory turns, or the disclosure of information about an earthquake that puts a portion of the supply chain out of commission. Output variables include financial metrics such as ROA, ROI, and stock market return. With regard to designing the supply chain, Wagner, Grosse-Ruyken, and Erhun (2012) find that supply chains that are designed to fit uncertainty deliver a higher return on assets (ROA). In their model, the input variable of supply chain fit is managerial perception collected via a survey, the output variable is objective ROA data obtained from Bloomberg, and OLS regression is used to examine the relationship between the two.

The issue of the firm's sourcing strategy and the impact on financial performance is a staple research area and has been approached from many perspectives (Noordewier, John, & Nevin, 1990; Chen, Paulraj, & Lado, 2004; Kroes & Ghosh, 2010). Chen, Paulraj, and Lado (2004) find that having fewer strategic suppliers with whom sensitive information can be shared quickly results in greater customer responsiveness. This is in turn results in improved financial performance. All variables in their model are subjective managerial perceptions and they use structural equation modeling (SEM) as their methodology. Kroes and Ghosh (2010) examine whether the degree of alignment of a firm's outsourcing strategy with its competitive strategy affects supply chain performance, which in turn affects financial performance. Kroes and Ghosh (2010) use various intermediate performance indicators for assessing supply chain performance such as delivery and manufacturing cycle times, on-time delivery performance, and orders filled correctly. ROA and return on sales (ROS) are used as key measures of financial performance. All measures in their study are subjective managerial perceptions and they use structural equation modeling (SEM) to examine the dependence of financial performance on the alignment of outsourcing and competitive strategy. They find that the congruence of outsourcing and competitive strategy does improve supply chain performance and that in turn helps financial performance.

The connection between the use of information technology (IT), such as enterprise resource planning (ERP) systems and information systems for managing the supply chain, and financial performance of the firm has also been examined using different types of information and

methodologies. Vickery et al. (2003) use survey data, or managerial perceptions, to examine this link. Using structural equation modeling (SEM), they find that the use of IT in the supply chain does improve financial performance. It does so mainly indirectly by improving customer service. Unlike Wagner et al.'s study (2012), the financial performance measures of ROA, ROI, and ROS were managerial perceptions of how well the firm was doing with respect to the rest of the industry (Vickery et al., 2003). In another study of the financial impact of information systems such as ERP and SCM systems, Hendricks, Singhal, and Stratman (2007) find that adopters of information systems for SCM experience positive stock returns and improved profitability.

The use of IT to digitally integrate the supply chain allows for the quick transfer of information across the supply chain, which is necessary for just-in-time (JIT) production processes. Fullerton**,** McWatters, and Fawson (2003) show that firms that operate just-in-time (JIT) supply chains reap significant financial rewards. Dehning et al. (2007) also explore the link between the use of IT to manage the supply chain and financial performance. They use a time-series approach where they test for the change in financial performance measures, such as ROS and ROA, one year and two years after the implementation of an SCM information system relative to the financial performance one year before the implementation of the SCM system. They examine how much of the change in the financial performance measures is explained by the change in supply chain performance measures, such as the increase in inventory turns and decrease in selling, general, and administrative expenses (SG&A). They use general linear model (GLM) regression to explain changes in financial performance to changes in supply chain performance measures. Values of variables are based on secondary financial data, such as in SEC filings or other audited external data. They are not managerial perceptions. They find that the use of an SCM information system does improve supply chain performance in terms of increasing inventory turns and reducing SG&A expenses, which in turn improves overall financial measures such as ROA and ROS.

Another approach to study the link between the use of information systems, such as SCM and enterprise resource planning (ERP) systems, and financial performance is to use the event study methodology to gauge the short-term stock market reaction to announcements of the deployment of such systems (Hayes, Hunton, & Reck, 2001). These studies find statistically significant positive abnormal returns to supply chain-related IT investment announcements. Hendricks and Singhal (2003) use the event study methodology to examine the effect of announcements of disruptions to the supply chain on the firm's stock price. In another study employing event study methodology, Hendricks and Singhal (2009) examine how information about inventory build-up in the supply chain can affect stock market performance.
The wealth of studies targeted at exploring the SCM-finance link testifies to the critical importance of this relationship. It underscores the importance to firms of building a distinctive competence in SCM. However, developing a superior capability in SCM is not a simple proposition. It is a complex challenge involving different dimensions such as strategy, business process, and technology. In terms of strategy, Christopher and Ryals (1999) underline the importance of having a corporate-wide strategy for the supply chain that embraces all the business units. At the business process level, new processes and practices such as collaborative planning, forecasting, and replenishment, or CPFR, must be implemented to ensure that the entire supply chain works in unison (Petersen, Ragatz, & Monczka, 2005). These business practices also include innovations such as vendor managed inventory (VMI) (Niranjan, Wagner, & Nguyen, 2012). These new business processes are necessary to ameliorate the bull-whip effect which leads to a pile up of inventory in the upstream portion of the supply chain (Lee, 2010).

Information systems such as supply chain management systems must be used at the operational level to facilitate the execution of strategy and the implementation of best practices (Gunasekaran & Ngai, 2004). Firms must also master a range of complex information technologies to facilitate the integration of information systems of various organizations in the supply chain. This complex IT includes XML and Web Services (Krafzig, Banke, and Slama, 2005; Erl, 2006) for integrating software applications such as enterprise resource planning (ERP) and materials requirements planning (MRP) across the various business entities in the supply chain (Makris & Chryssolouris, 2013). Firms setting out to improve their supply chains are clearly facing a complex multi-facetted challenge with ramifications for strategy, business process, and technology.

Given the daunting challenge of effectively mastering how to manage the supply chain, it should come as no surprise that firms would look to exemplars in SCM and try to emulate their strategies and business practices. But how are these exemplars in SCM capability to be found? Analyst firms who publish their opinion on the best firms in SCM is a source that businesses rely on when seeking exemplars. Gartner, one such analyst firm, publishes the SCT25 list annually where it identifies the 25 best companies worldwide in SCM. But Gartner's list cannot simply be taken as an article of faith. The question must be asked whether Gartner has indeed correctly identified the best firms in SCM. The list after all represents Gartner's opinion of the best firms in SCM. A different analyst may have a different opinion. Gartner's SCT25 list is thus *controvertible* information as other analysts can challenge Gartner's opinion. The methodology of event study can be used to examine if the disclosure of Gartner's SCT25 list indeed pushes up the stock prices of firms listed in the SCT25. If it does, then Gartner's SCT25 list can be said to contain valuable information or that the information has value-relevance.

Our literature review revealed that there has been only one study published of examining the value-relevance of the SCT25 information. This was a conference proceedings paper by McCarthy and Nayar (2010), which perhaps indicates that their research was still at an early stage. There are significant methodological errors in McCarthy and Nayar's study (2010). First of all, McCarthy and Nayar do not treat the SCT25 list as controvertible information. They use the standard two-day window to study the stock market impact of the SCT25 list without taking into account the fact that other analysts can refute or at best partially agree with Gartner's opinion in the industry discussion that occurs in the days following the release of the SCT25 list. But to assess if the SCT25 information is truly value-relevant, it is necessary to consider both Gartner's opinion and those of other analysts, which might indeed be somewhat different from Gartner's.

Gartner's release of the SCT25 list might have initially pushed up the stock prices of the firms featured in that list but as more analysts express their opinion, which might be partially opposed to Gartner's view, the initial stock market bounce that firms received might be reduced or eliminated. As this industry discussion typically occurs in the days following the release of Gartner's report, the event window must be larger than the standard [-1, 0] window typically used in event studies, where day 0 is the day the news appears in mass media and day -1 is the day before that. The day before is included in the window to account for the effect of leakage of information.

Given the controvertible nature of the SCT25 information, a larger window such as a window that is a week-long, which would then pick up the voices of other analysts in the industry discussion in the days following the release of Gartner's report would be more appropriate. It should be noted that Gartner representatives are also actively involved in these discussions. They defend and clarify their positions as they interact with the media and participate in various

industry fora. Hence, a full understanding of the information contained in the SCT25 list and its correctness, or the lack thereof, can only be obtained through having a longer event window and gathering the stock market returns over this longer window.

If a longer event window of several days is chosen, the issue of confounding events can no longer be avoided as it is typically done in the traditional event study methodology. McWilliams and Siegel (1997) have shown that ignoring confounding events can put the results of the study in peril. In fact, they show that in a few cases, the results of the study would actually change if confounding events were to be taken into consideration. In addition to the methodological problems in McCarthy and Nayar's (2010), the time frame of their study covers only the years 2004 to 2008, whereas our study covers the years 2008 to 2014. The SCT25 report was first published in 2004. Also, there was no publication in the year 2006.

The focus of our study is not so much on value-relevance of the SCT25 information, per se, but it is on a deeper analysis of how the information contained in the SCT25 list drives the stock market reaction. Value-relevance is simply about whether the SCT25 information moves capital markets or not. In other words, whether being in the SCT25 list results on average in a positive bounce in the stock prices of the firms in the list. Basic value-relevance is simply a byproduct of the hypotheses tested in this study. The SCT25 list contains more than just binary information of whether a firm is in the list or not. The SCT25 list is also ranking the firms. The change in the ranking of a firm from one year to the next is important information as well. One could hypothesize that the improvement in the rank of a firm from one year to the next, assuming the firm features in the SCT25 list in both years, should result in a positive stock market return. This would be the case if the SCT25 list is indeed doing a good job in identifying the best firms and ranking them relative to each other. One could also hypothesize that getting on the list the very first time, even if it is at the very bottom or at the rank of 25, should create a greater stock market impact than an improvement in rank in a later year. If the list is legitimately identifying the best firms in SCM globally, then being recognized the first time as one of these top 25 firms out of the universe of firms worldwide should be a great achievement that would cause quite a stir in the stock market.

We can thus formulate a set of hypotheses about the total information contained in the SCT25 list. If these hypotheses are indeed borne out in the way they are expected to be, then that lends a great deal of credence to the information in Gartner's SCT25 list. McCarthy and Nayar (2010) also tested a set of hypotheses about the information in the SCT25 list, and we base some of our own hypotheses on those that they tested. However, our hypotheses are tested using data from the larger time frame of 2004 to 2014. Also, as we have noted, there are serious methodological problems in McCarthy and Nayar's study (2010) as they did not treat the SCT25 as a disclosure of controvertible information necessitating a longer event window and a correction for the occurrence of confounding events in the long window. This study assumes a window of [-1, +7] and corrects for confounding events occurring in that window.

THEORETICAL DEVELOPMENT

Hypotheses

Different firms in the SCT25 list experience different stock market returns in any given year in which they feature on the SCT25 list. Clearly, a key driver of the magnitude of the return experienced by a firm should be an improvement in the rank of the firm from one year to the next, assuming the firm appeared in the list in both years. A larger improvement in rank should result in a greater return. The firm at the top of the SCT25 list, or the best firm among the 25,

has a rank of 1 and the firm at the bottom has a rank of 25. The improvement in rank from the previous year to the current year is defined as the difference between the previous year's and the current year's rank.

Hypothesis 1: *The abnormal stock return that a firm receives from appearing in the SCT25 list is positively related to an improvement in the rank of the firm from the previous year to the current year.*

Furthermore, if a firm reappears in a given year in the same position as it was in the previous year, and thus there is no improvement in rank, it is arguable that there should still be some value associated with the reaffirmation of the firm's status as one of the top 25 firms worldwide in SCM. Therefore, we posit:

Hypothesis 2: *There is a positive abnormal stock return associated with reappearing in the SCT25 list in a given year even if there is no improvement in the firm's rank from the previous year*.

We have stated before that Gartner's list of the top 25 companies worldwide who excel in managing their supply chain is opinion and a different analyst can have a different view. Opinion therefore always has a built-in credibility problem. Because there is always some doubt about the veracity of opinion, a rational investor before rushing out and purchasing the stock of firms in the SCT25 list can be expected to also consider other established metrics of SCM excellence, particularly those that are objective rather than subjective measures. A firm's cash-to-cash cycle (CCC) has long been viewed as an important metric of how good firms are at managing their supply chains, at least with respect to the management of cash flows. The smaller the CCC, the better is the firm at managing its supply chain (Hutchison, Farris II, & Anders, 2007; Akgün & Gürünlü, 2010). Large negative values of CCC such as -50 or -100 imply that the firm is even better at managing its supply chain with regard to cash flows. Cash-to-cash cycle (CCC) is defined as:

$$\text{cash-to-cash cycle} = \text{days sales outstanding} + \text{days inventory outstanding} - \text{days payables outstanding} \quad (1)$$

CCC's definition implies that firms should not only delay payment of their accounts payables but should also quickly collect on accounts receivables while maintaining minimum inventory. It should be underscored that CCC is reflecting only one facet of SCM capability and being good at managing cash flows does not necessarily mean that the firm is good at something else, such as the use of IT to digitally integrate the supply chain. Still, a rational investor can be expected to look for other signs of confirmation of Gartner's signal of the SCM exemplars in these other established metrics of SCM excellence such as CCC.

It is arguable that if Gartner's signal of the SCM ability of a firm is aligned with the message that established metrics such as CCC send about a firm's SCM performance, then Gartner's opinion can have a larger impact on the stock return for that firm. Gartner's opinion and the established objective measures are in synchrony and thus have a synergistic effect in boosting the firm's stock price. Similarly, if Gartner's signal and the established metrics were not that well-aligned or were in opposition for a firm, then the stock return for that firm to Gartner's signal could be expected to be more muted. Gartner's signal of SCM excellence in each year is essentially delivered in the form of an improvement in the rank of the firm in that year from what was reported in the previous year. Hence, we are arguing that the impact of the improvement in rank on the stock return for the firm can be amplified or weakened depending on the firm's CCC. The

smaller the value of CCC, the more is the amplification, since small CCC values imply superior SCM capability. Also, as we have mentioned, a negative value for CCC is even better and it fits the definition of being an algebraically smaller number. This results in the following hypothesis:

Hypothesis 3: *The abnormal stock return of an improvement in the rank of the firm in the SCT25 list is moderated by key objective measures of SCM capability such as the firm's CCC. If two different firms in the SCT25 list experience the same improvement in rank, then the abnormal return will be larger for the firm with the smaller CCC or the more negative CCC.*

The next two hypotheses focus on the circumstances of a firm's appearance in the SCT25 list. One could expect a difference in the stock market reaction between a firm's first appearance in the SCT25 list versus a reappearance. There is evidence that the market responds more to information that is novel than to information that is partly anticipated (Malatesta and Thompson, 1985). If news that is novel has more impact, then one could argue that a firm's first-time listing in the SCT25 list should cause a greater stock-market reaction than a continuing listing. Of course, the exception to this would be if the continuing listing were to be accompanied by a large increase in rank, which means that the firm substantially improved its position relative to the other firms in the group of 25 exemplars. But if the continuing listing is not accompanied by a large improvement in rank, and the improvement in rank in the continuing listing was only of one step, then one could argue that the first-time listing even at the bottom of the ladder should be better than the continuing listing. Hence, we posit:

Hypothesis 4: *The abnormal return on a firm's stock upon a first-time entry into the SCT25 list, even at the lowest rank of 25, is better than the return accruing to the firm in a continuing appearance with a one-step improvement in rank.*

Hypothesis 4 stems from the novelty of being named the first time in the very exclusive club of the top 25 companies in the world which excel at managing their supply chains. There is however another aspect of information novelty that plays a role in determining stock market reaction to the SCT25 information. This is the erosion of novelty that occurs as the firm appears again and again in the SCT25 list over the years. The larger the number of times the firm appears in the SCT25 list, the more anticipated its presence on the list becomes thereby reducing the stock market bounce the firm gets from appearing in the list. Hence, to capture this aspect of the gradual erosion of novelty that occurs from repeatedly featuring in the SCT25 list, we formulate the following hypothesis:

Hypothesis 5: *The number of times a firm has previously been on the SCT25 list is negatively related to the abnormal stock return the firm receives from being listed in the SCT25.*

Methodology

These hypotheses are tested using the procedure of hierarchical regression. We introduce the following variables:

$\overline{AR} =$ This is the dependent variable in the hierarchical regression models. It is the average abnormal return over the event window [-1, +7] for a given firm's stock in the SCT25 list in a given year after removing the days in the window when confounding information disclosures are made about that firm. Confounding events correspond to major public disclosures, such as earnings announcements, and these events are given the standard [-1, 0] window.

$\Delta Position$ =	The improvement in the rank of a firm in the SCT25 list in a given year as measured by (previous year rank – given year rank). The firm in the topmost position in the list has a rank of 1 and the firm in the last position has a rank of 25. For this computation, if a firm is not in the SCT25 list in any year, then its rank in that year is deemed to be 26.
CCC =	cash-to-cash cycle for the given firm in a given year. CCC is used as a control variable in the model.
X_{entry} =	1 for the case of a given firm appearing in the SCT25 list for the first time. It is 0 otherwise.
PrevTimes =	the number of times that a firm has appeared in the SCT25 list before the given year.

The first model in the hierarchical regressions that we estimate is:

$$\overline{AR} = b_0 + b_1 \Delta Position + \varepsilon \quad (2)$$

For Hypothesis 1 to be true, the coefficient $b_1$must test as statistically significant and positive in Equation (2). Hypothesis 2 implies that the coefficient b_0 must also positive in Equation (2). To test the moderating influence of CCC on the relationship between $\Delta Position$ and $\overline{AR}$, the second regression model estimated is:

$$\overline{AR} = b_0 + b_1 \Delta Position + b_2 CCC + b_3 CCC.\Delta Position + \varepsilon \quad (3)$$

Hypothesis 3 says that the firm with the smaller CCC will enjoy a greater stock market return for the same improvement in rank as compared to a firm with a larger CCC. From Equation (3), we obtain:

$$\frac{\delta E\{\overline{AR}\}}{\delta \Delta Position} = b_1 + b_3 CCC \quad (4)$$

Hypothesis 3 will be satisfied if the coefficient b_3 in Equation (4) is statistically significant and $b_3 < 0$ as that would indicate that a larger value for CCC reduces $\frac{\delta E\{\overline{AR}\}}{\delta \Delta Position}$. In other words, larger the CCC, the smaller is the increase in the expected average return $E\{\overline{AR}\}$ for the same improvement in position given by $\Delta Position$.

The next model focuses on the role that the specific circumstances surrounding a change in position in the SCT25 play in the magnitude of the stock market return. In other words, does the first-time appearance in the SCT25, even at the lowest rung of the ladder, result in a higher return than a continuing listing with a one-step improvement in rank. This regression addresses the moderating role that the indicator variable X_{entry} plays on the relationship between $E\{\overline{AR}\}$ and $\Delta Position$. Of course, if Hypothesis 3 is true, then we know that the relationship between $E\{\overline{AR}\}$ and $\Delta Position$ is already moderated by CCC. Thus, Hypothesis 4 brings a second moderator, which is the indicator variable X_{entry} into this relationship, where X_{entry} = 1 for a case of first-time entry and is 0 otherwise.

The regression model estimated for the test of Hypothesis 4 is:

$$\overline{AR} = b_0 + b_1 \Delta\text{Position} + b_2 CCC + b_3 X_{entry} + b_4 \Delta\text{Position} * CCC + b_5 \Delta\text{Position} * X_{entry} + b_6 CCC * X_{entry} + b_7 \Delta\text{Position} * CCC * X_{entry} + \varepsilon \quad (5)$$

If this regression is statistically significant, then the difference in the average stock return between getting on the SCT25 for the first time even at the lowest rank of 25 and a one-step improvement in rank in a subsequent year after having been on the SCT25 is given by:

$$E\{\overline{AR}\}_{first-time\ in\ SCT25\ at\ lowest\ rank} - E\{\overline{AR}\}_{one-step\ improvement\ in\ rank\ later} = b_3 + b_5 + (b_6 + b_7)CCC \quad (6)$$

The term $b_3 + b_5 + (b_6 + b_7)CCC$ could loosely be viewed as a measure of the relative value associated with the novelty of being named to the top 25 companies worldwide who excel in SCM.

The value of novelty of being listed in the SCT25 the first time will gradually erode if the firm continues to be listed on the SCT25 year after year. In the fourth regression model, we test Hypothesis 5 of the gradual erosion of the value of novelty by introducing into the model the number of previous times, denoted as *PrevTimes*, the firm has been on the SCT25. Hypothesis 5 would be established if the coefficient $b_4 < 0$ in the following model:

$$\overline{AR} = b_0 + b_1\Delta\text{Position} + b_2CCC + b_3X_{entry} + b_4PrevTimes + b_5\Delta\text{Position} * CCC + b_6\Delta\text{Position} * X_{entry} + b_7CCC * X_{entry} + b_8\Delta\text{Position} * CCC * X_{entry} + \varepsilon \quad (7)$$

RESULTS

The list of the Top 25 supply chain companies from 2004 through 2014 produced by Gartner was partly obtained from McCarthy and Nayar (2010), which had the data from 2004 through 2008, and partly from various vendor web sites. Table A.1 in Appendix A gives the consolidated rankings of the firms in the SCT25 list over the 2004 to 2014 timeframe. Table A.2 in Appendix A shows the market-move dates of confounding information disclosures about the firms in the SCT25 list each year in the [-1, +15] window around the nominal publication date of the SCT25 report for that year. Although we used a [-1, +7] window, we had collected data on confounding events for a larger [-1, +15] window to test for the sensitivity of the results if a shorter [-1, +6] or a longer [-1, +8] window was used. All results remained robust to this marginal change in window size. The confounding event dates were obtained by searching the LexisNexis database. The standard two-day [-1, 0] window was allocated for discounting the confounding information by the capital markets.

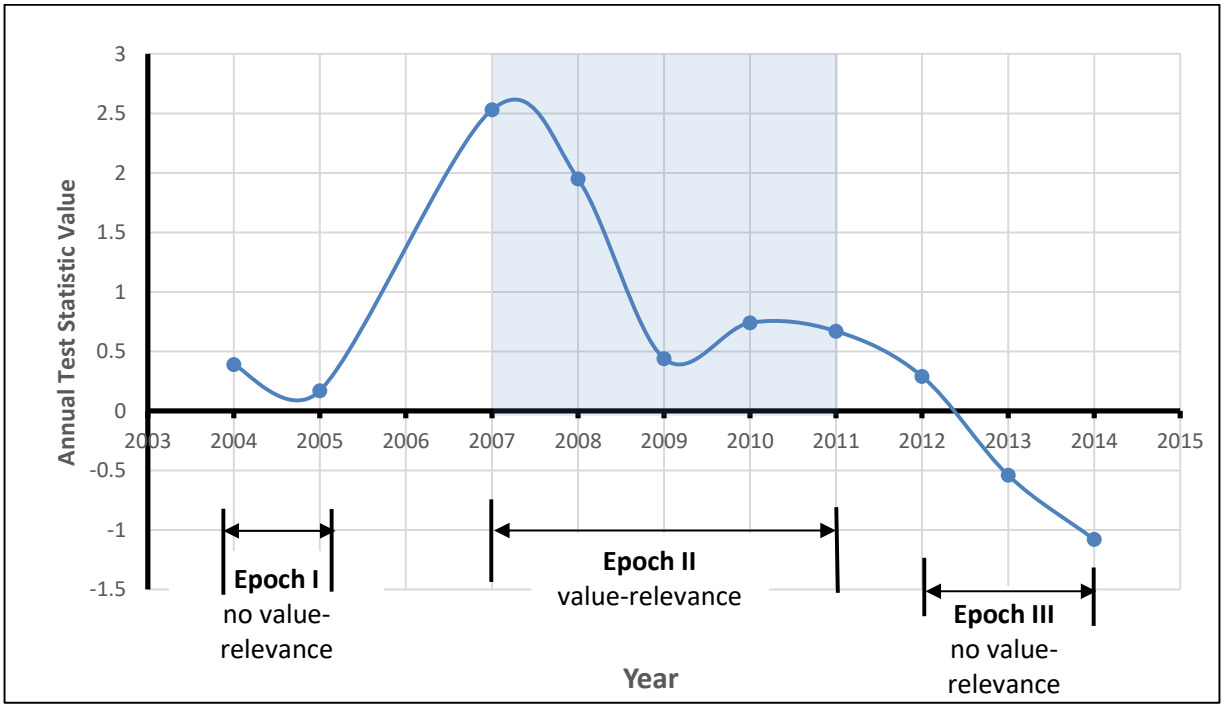
Epochs of Value-Relevance

An interesting result is that if the value of test statistic for value-relevance is computed on a yearly basis on plotted on a graph as shown in Figure 1, we observe that there are certain epochs in the 2004 to 2014 time frame of the study. In the initial two years 2004 to 2005, the value is low, and in the final three years 2012 to 2014, the value is also low and it steadily declines. In fact, if the 2004 to 2014 time frame is segmented into three epochs where Epoch 1 is 2004 to 2005, Epoch II is 2007 to 2011, and Epoch III is 2012 to 2014, the SCT25 information is actually value-relevant only in Epoch II. This result is actually not that surprising. Since the SCT25 information is opinion, clearly the analysts had to first build credibility for their opinion and the methodology used for developing their ranking. It should also be noted that when this report was first published in 2004, the authors were with AMR Research and not with Gartner, which is a larger and better-known analyst firm. Gartner actually purchased AMR Research in 2009 (Supply Chain Digest 2009), which gave the authors of this report a great deal of

credibility. But in the initial years, the authors did not enjoy the instant credibility that the Gartner acquisition brought them. Hence, it is quite plausible that in the initial years of the publication of this report, the market was assessing whether the opinion of the AMR Research analysts of the best firms in SCM actually correlated with reality. Once, the market was convinced that AMR Research's opinion was credible, the disclosure of the SCT25 information began to make a significant impact on the stock market from 2007 onwards.

The lack of value-relevance of the SCT25 information towards the tail-end of the 2004 to 2014 time frame, or in the 2012 to 2014 epoch, could arise from the necessity of updating the methodology Gartner is using to identify the best firms in SCM. Methodologies do need to be updated to account for changing business conditions. In the aftermath of the financial crisis of 2007 to 2009, many fundamental business assumptions have had to be revisited. Although the crisis arose in the financial services industry through an imperfect understanding of the riskiness of mortgage-backed securities, other industries have taken note of the wrong estimation of risk by professionals who should have been experts at doing this. Risk pervades all sectors of the economy and how well it is assessed and managed is certainly an element of superior supply chain management. Hence, many business models and assumptions across the board have had to be reexamined in the wake of 2007 to 2009 crisis. Hence, a plausible reason for the lack of value-relevance of the SCT25 information in the 2012 to 2014 epoch is that the methodology that Gartner is using in identifying the best firms in SCM may need updating. We use this result by focusing on the 2007 to 2011 epoch in examining the drivers of abnormal stock performance upon the release of the SCT25 information in the years in this epoch.

Figure 1: Epochs of Value-Relevance



Hierarchical Regressions

We employed the methodology of hierarchical regression to test Hypotheses 1 through 5. The succession of models tested follows the sequence described earlier in the section on the hierarchical regression models for assessing the differential market reaction to the stocks in the SCT25 list. Table 1 shows the sequence of models tested along with the p-values of the highest-order terms in each model. As shown in Table 1, Model 1 includes only the term $\Delta Position$ corresponding to the improvement in rank. As expected by Hypothesis 1, the improvement in the rank of a firm in the SCT25 list from the previous year to the current year is positively related to the abnormal return as the coefficient of $\Delta Position$ is significant and positive. Hypothesis 2 is also borne out because of the positive intercept in Model 1.

Hypothesis 3 is about the moderating role played by CCC on the relationship between an improvement in rank and the abnormal return on the firm's stock. Small positive or negative values of CCC, which indicate that the firm is doing well in managing its supply chain, would amplify the effect of an improvement in rank in the SCT25 list on the abnormal stock return. Large positive CCC values, which indicate that the firm is not doing that well in managing the supply chain at least with respect to cash flows, would reduce the abnormal return resulting from an improvement in rank. As argued in the section on Methodology, Hypothesis 3 is borne out if the coefficient of the interactive term $\Delta\text{Position} * CCC$ in Model 2 in Table 1 is statistically significant and negative. As Model 2 in Table 1 shows, the coefficient of $\Delta\text{Position} * CCC$ is statistically significant at the 0.01 level and it also has a negative value. This supports Hypothesis 3.

Model 3 addresses the issue of the relative value of novelty of the SCT25 information. In other words, does the first appearance of a firm in the SCT25 list even at the lowest rank of 25 result in a higher stock market bounce for its stock as compared to a one-step improvement in the firm's rank in a subsequent year after the firm has already been in the SCT25? We had argued previously that Hypothesis 4 is true if the coefficients in Equation (6), which corresponds to Model 1 in Table 2, are such that the inequality $b_3 + b_5 + (b_6 + b_7)CCC > 0$. Using the values of these coefficients from Model 3, we see that the inequality is satisfied if:

$$CCC > -9.3 \quad (9)$$

Thus, there is qualified support for Hypothesis 4 in that for firms with CCC greater than -9.3, the first-time appearance in the SCT25 list even at the bottom-most rung creates a greater stock market impact than a reappearance with a one-step improvement.

In the last regression Model 4 in Table 1, we add the final variable *prevTimes* corresponding to the number of times the firm has previously been on the SCT25. Both the coefficient of *prevTimes* and the higher order term $\Delta\text{Position} * CCC * X_{entry}$ remain significant in this final model. The coefficient of *prevTimes* is negative which supports Hypothesis 5 that as the firm continues to reappear in the SCT25, the event of being listed in the SCT25 becomes more anticipated resulting in a progressively smaller stock market bounce. It should be noted that the final significant model has an R^2 of 18%, which means the final model explains a non-trivial amount of the variance in the stock market return resulting from appearing in the SCT25 list.

Table 1: Hierarchical Regression Models

Model No.	Equation	P-values of High-order Terms	R^2	Adjusted R^2
1	$\overline{AR} = 9.11 * 10^{-4} + 2.137 * 10^{-4}\Delta\text{Position}$	$\Delta\text{Position}$ (0.0042**)	0.06574	0.05802
2	$\overline{AR} = 9.166 * 10^{-4} + 2.602 * 10^{-4}\Delta\text{Position} - 2.418 * 10^{-6} * CCC - 3.244 * 10^{-6}\Delta\text{Position} * CCC$	$\Delta\text{Position} * CCC$ (0.008489**)	0.1205	0.09831
3	$\overline{AR} = 9.42 * 10^{-4} + 2.437 * 10^{-4}\Delta\text{Position} + 8.672 * 10^{-7} * CCC + 2.782 * 10^{-4}X_{entry} - 1.072 * 10^{-6}\Delta\text{Position} * CCC - 1.092 * 10^{-4}\Delta\text{Position} * X_{entry} + 2.581 * 10^{-5}CCC * X_{entry} - 7.635 * 10^{-6}\Delta\text{Position} * CCC * X_{entry}$	$\Delta\text{Position} * CCC * X_{entry}$ (0.0151*)	0.1687	0.1181
4	$\overline{AR} = 3.165 * 10^{-3} + 2.007 * 10^{-4}\Delta\text{Position} + 5.746 * 10^{-7} * CCC - 1.945 * 10^{-3}X_{entry} - 7.428 * 10^{-4}PrevTimes - 1.463 * 10^{-6}\Delta\text{Position} * CCC - 6.621 * 10^{-5}\Delta\text{Position} * X_{entry} + 2.61 * 10^{-5}CCC * X_{entry} - 7.245 * 10^{-6}\Delta\text{Position} * CCC * X_{entry}$	$\Delta\text{Position} * CCC * X_{entry}$ (0.01912*) $PrevTimes$ (0.02883*)	0.1802	0.1226

*** significant at 0.001, ** significant at 0.01, * significant at 0.05, ` significant at 0.1

DISCUSSION

The hypotheses all largely tested positive, albeit with one qualification. Hypotheses 1 and 2 tested positive, which lends a lot of credence to Gartner's opinion of the best firms in SCM and their ranking relative to each other. As Hypothesis 1 tested positive, an improvement in the rank of a given firm in Gartner's list results in a positive return to that firm which depends on the magnitude of the improvement in the rank. Given that Hypothesis 2 also tested positive, a firm enjoys a certain measure of a boost to its stock price simply from being listed in the SCT25 even if there is no improvement in its rank from the previous year. In other words, there is value to being reaffirmed in the list of the top 25 companies worldwide who excel in managing their supply chain. That these two hypotheses were established does clearly imply that Gartner's identification of the best companies in SCM and their relative ranking is credible.

Hypothesis 3 also tested positive. This implies that if a firm's SCM capability as reflected by other measures, such as the CCC, is in alignment with Gartner's signal of SCM capability reflected by an improvement in ranking, then the stock market return will be boosted further. On the other hand, if the CCC does not reflect that well on a firm's SCM capability, then the impact of an improvement in rank in Gartner's list on the stock return will be more muted. This result, which addresses the interaction between the information signal from Gartner's list and external measures of SCM excellence, nevertheless continues to support the integrity of Gartner's opinion. It would be reasonable to expect an amplification of the improvement in rank on the abnormal stock return if Gartner's signal and the external measures aligned and vice versa.

Hypothesis 4 can be deemed to have tested positive with one important qualification. Hypothesis 4 is essentially asserting that, since completely novel information creates more impact on the stock market than partially anticipated information, the appearance of a firm in the SCT25 list the first time should have greater stock market impact than a reappearance in the list. To more specifically define the cases of first-time appearance and the reappearance, Hypothesis 4 compares the stock return from a first-time appearance at the bottom of the list to that of a one-step improvement in rank in the case of a reappearance later. Hypothesis 4 tests positive for all firms except those firms whose CCC is less than -9.3. The vast majority of firms that have appeared in the SCT25 list in the 2007 to 2011 epoch have had a positive CCC. Hence, for the vast majority of firms, the first-time appearance does create a greater stir in the stock market than a reappearance, given the specific definitions of the cases of first-time appearance and reappearance.

There is a small number of firms with large, negative CCC's that have featured in the SCT25 list. Two such notable exceptions are DELL and Apple. Apple's CCC in the years it was listed in the SCT25 in the 2007 to 2011 epoch fluctuated from -44 to -82. DELL's CCC in the years it was listed in the SCT25 in the 2007 to 2011 epoch fluctuated from -35 to -47. Companies that have large negative CCCs are typically seen as managing their supply chains well. Therefore, for firms that are viewed as managing their supply chains very well based on other external measures such as CCC, being listed on the SCT25 is not such a surprise. Hence, for these firms, it is the not first-time listing that has a big impact, but it is an increase in the relative ranking of the firm that is of more consequence in terms of the abnormal return to the firm's stock.

Finally, Hypothesis 5 tested positive, which means that the repeated appearance of a firm in the SCT25 list tends to mute the stock market return since the market begins to anticipate more and more the appearance of the firm on the list.

Implications for Theory

The link between superior SCM capability and financial performance of the firm has been examined from many perspectives with different methodologies and different types of information. That so much effort has been expended in studying this relationship speaks to its key importance of this relationship. Models that have been built to study this relationship have used a variety of input variables as indicators of supply chain capability and performance. However, none of these studies have used analyst opinion of the excellence, or the lack thereof, of the supply chain capability of firms and the impact that the disclosure of this information has on the stock market. The lack of treatment of analyst opinion as an indicator of supply chain capability and performance is a key missing piece in the theoretical edifice that has so far been built to support the link between supply chain capability and performance and financial performance.

Our article completes the theoretical edifice of the SCM-finance relationship by examining the impact of analyst opinion of firm capability in SCM and financial performance. In examining this link using event study methodology, certain departures from the traditional event study methodology were necessary. This is because analyst opinion is not like factual information. It is not an earnings announcement or a news flash about a natural calamity that affected the supply chain. Analyst opinion is controvertible in that it can be challenged by a different analyst. Hence, to truly assess the net impact of the disclosure of analyst opinion on the market, such as that of Gartner's SCT25 information, a longer event window must be used to allow for the consideration of different opinions offered by other analysts who may not agree with Gartner. A longer event window of several days also means that the issue of confounding events can no longer be ignored. The occurrence of confounding events should not be ignored even in short event window studies (McWilliams and Siegel 1997), and this factor can certainly not be ignored in event studies where the window is a week or more.

Taking into account the necessity of a longer event window and the correction for confounding events, we show that analyst opinion, such as Gartner's SCT25 list, is indeed a legitimate indicator of supply chain capability and performance, and that this opinion does move capital markets. We have thus made a key theoretical contribution in the research examining the link between SCM capability and performance and financial performance. Analyst opinion of SCM capability and performance was the missing piece in the extensive research done on the link between SCM capability and performance and financial performance. Our article thus finishes building the theoretical edifice of the SCM-finance relationship.

Implications for Practice

This article establishes that Gartner's SCT25 list is important and valuable information. Disclosure of this information does move capital markets. It moves these markets in a way that is consistent with Gartner's opinion. In other words, if Gartner moves a firm up in ranking in the SCT25 list, there is a positive return to that firm's stock which is proportional to the extent of the improvement in the ranking. The fact that Hypotheses 1 through 5 largely all tested positive is actually a validation of Gartner's view of the firms that excel in SCM and how they rank relative to each other. This is very important to the industry as Gartner's list is identifying exemplar firms in SCM. As we stated before, acquiring superior capability in SCM is not easy as there are many facets to SCM capability. The firm has to master strategic sourcing strategies to new business processes such as CPFR to various types of information systems and technology such as ERP and SCM systems and Web Services for digitally integrating the supply chain.

Given this complex challenge, knowledge about SCM exemplars can be of great benefit to firms struggling with managing their supply chains. They can study and emulate the practices of these exemplars. There are many lists and rankings offered by industry analysts, consultants, and gurus. However, not all such rankings are equally good. We provide solid statistical proof that Gartner's SCT25 list has integrity and is a good barometer of companies exceling in SCM. However, while Gartner was able to successfully establish the value of the information in their SCT25 list as evidenced by its impact on the stock market, the concern is that their methodology may need updating. We focused on the 2007 to 2011 epoch in our in-depth examination of the impact of the information contained in the SCT25 list because that is the epoch where this report is value-relevant. Hence, we recommend that Gartner update its methodology of picking the best firms in SCM, so the list continues to be value-relevant in the future as it has clearly been in the past.

CONCLUSION

In this article, we complete building the theoretical foundation upon which the link between excellent supply chain management capability and superior financial performance is based. Although this link has been explored from numerous perspectives using a variety of methodologies and types of information, analyst opinion as an indicator of excellence in SCM has received little attention from researchers. This article fills that gap in the theoretical research that has been done in examining the SCM-finance link. Furthermore, by validating through rigorous statistical analysis that Gartner's opinion of the exemplars in SCM is legitimate, we are providing confidence to the managers who have utilized Gartner's list in the past that emulating the SCM strategies and business practices of the firms in Gartner's list was a worthwhile action. One caveat is that Gartner may need to update its methodology of picking SCM winners so that firms in general can safely continue to look to this list to identify exemplars whose SCM-related strategies and business practices they could emulate.

APPENDIX A

Table A.1: Yearly Rank of Firm in Gartner's Supply Chain Top 25 (SCT25)

Company	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014
3M	14	26	26	26	26	26	24	21	19	18
Amazon.com	26	26	26	26	26	10	5	2	3	3
Apple	26	26	2	1	1	1	1	1	1	1
AstraZeneca	26	26	25	26	26	26	26	26	26	26
Best Buy	18	17	9	14	21	24	26	26	26	26
Canon	24	26	26	26	26	26	26	26	26	26
Caterpillar	26	26	26	26	26	26	26	20	18	23
Cisco	26	18	11	8	5	3	6	8	7	7
Coca Cola	17	25	13	13	13	13	11	6	9	10
Colgate Palmolive	26	26	26	26	20	17	13	11	10	9
Cummins	26	26	26	26	26	26	26	23	23	24
Dell	1	1	26	3	2	5	2	4	11	26
Ford Motor	26	26	26	26	26	26	26	26	22	26
GlaxoSmithKline	15	26	20	26	26	26	26	26	26	26
Hewlett Packard	13	26	21	18	17	15	17	24	26	26
Home Depot	21	26	26	26	26	26	26	26	26	26
IBM	4	3	4	5	4	8	14	26	26	26
Intel	19	11	26	26	25	18	16	7	5	8
Johnson Controls	8	10	16	23	26	26	26	26	26	26
Johnson & Johnson	7	6	14	19	12	14	21	22	25	22
Kimberly-Clark	26	26	26	26	26	26	26	25	26	21
Lockheed Martin	26	26	22	22	19	22	26	26	26	26
Lowe's	22	20	19	26	26	26	26	26	26	26
McDonald's	26	26	26	26	26	11	8	3	2	2
Microsoft	26	26	26	26	26	12	12	26	26	26

TABLE A.1: Yearly Rank of Firm in Gartner's Supply Chain Top 25 (SCT25) (continued)

Company	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014
Motorola	26	15	12	26	26	26	26	26	26	26
Nike	26	21	18	15	14	16	20	14	14	12
Nokia	2	4	1	2	6	19	26	26	26	26
Paccar	26	26	24	26	26	26	26	26	26	26
PepsiCo	10	16	15	11	9	6	9	12	16	15
Posco	16	26	26	26	26	26	26	26	26	26
Proctor & Gamble	3	2	3	4	3	2	3	5	6	5
Schlumberger	26	26	26	20	11	25	26	26	26	26
Qualcomm	26	26	26	26	26	26	26	26	24	19
Starbucks	26	26	26	26	26	26	22	16	15	17
Research in Motion	26	26	26	26	26	9	4	19	26	26
Seagate	26	26	26	26	26	26	26	26	26	20
Sysco	26	24	26	26	26	26	26	26	26	26
Tesco	9	9	8	12	15	20	23	26	26	26
Texas Instruments	26	19	17	21	18	26	26	26	26	26
Toyota	6	5	5	7	10	26	26	26	26	26
Unilever	26	26	26	26	22	21	15	10	4	4
Walmart	5	8	6	6	7	4	7	9	13	14
Walt Disney	26	26	26	17	16	26	26	26	26	26

Notes:

a) Only companies whose stocks are traded on either the NYSE or NASDAQ exchanges are included. Foreign companies included in the study are those that have an ADR traded on either the NYSE or the NASDAQ.
b) The highest rank is 1 and 25 is the lowest rank in the Supply Chain Management Top 25 list.
c) The rank of 26 indicates that the firm was not in the SCT25 list in that year.

TABLE A.2: Two-Day Market Move Dates of Confounding Events

2004		2005		2007	
Company	**Market Move Dates**	**Company**	**Market Move Dates**	**Company**	**Market Move Dates**
Dell	11/12, 11/22, 11/23	Dell	11/7, 11/10, 11/11	Nokia	6/4
Nokia	12/1, 12/2	IBM	11/14, 11/16, 11/17	Apple	5/31, 6/1, 6/4, 6/5, 6/11, 6/12, 6/13, 6/14, 6/15, 6/18, 6/19
IBM	11/23, 11/24, 12/3, 12/6, 12/7	Nokia	11/16, 11/17, 11/25, 11/28	IBM	5/30, 6/1, 6/4, 6/5, 6/6, 6/7, 6/11, 6/12
Toyota Motor	11/17, 11/18, 11/24, 12/1, 12/2	Toyota Motor	11/7, 11/9, 11/10, 11/11, 11/14, 11/18, 11/21, 11/23, 11/25, 11/28	Toyota Motor	5/30, 6/1, 6/4
Johnson and Johnson	12/1, 12/2/2, 12/6, 12/7	Johnson and Johnson	11/7, 11/8	Best Buy	6/4, 6/5
Tesco	11/12	Tesco	11/7, 11/8, 11/25, 11/28	Cisco	6/1, 6/4
Hewlett Packard	11/23, 11/24, 12/1, 12/2	Intel	11/7, 11/8, 11/10, 11/11, 11/21, 11/22, 11/29, 11/30	Motorola	5/30, 5/31
Coca Cola	11/15, 11/18, 11/19, 11/23, 11/24	Motorola	11/16, 11/17, 11/29, 11/30	Coca Cola	5/31, 6/1, 6/4, 6/5, 6/6, 6/7
Best Buy	11/16, 11/17	PepsiCo	11/9, 11/10, 11/29, 11/30	Lowe's LOW	6/5, 6/6
Intel	11/12, 11/19, 11/22, 11/23, 11/24, 11/29, 12/2, 12/3, 12/6	Cisco	11/7, 11/8, 11/9, 11/10, 11/17, 11/18, 11/21	Hewlett Packard	6/18, 6/19
Home Depot	11/16, 11/17, 12/1, 12/2	Lowe's	11/14, 11/15		
Lowe's LOW	11/15, 11/16	Nike NKE	11/10, 11/11, 11/21, 11/22, 11/23		

TABLE A.2: Two-Day Market Move Dates of Confounding Events (continued)

2008		2009		2010	
Company	**Market Move Dates**	**Company**	**Market Move Dates**	**Company**	**Market Move Dates**
Apple	6/3, 6/4, 6/5, 6/6, 6/9, 6/10	Apple	6/3, 6/4, 6/5, 6/8, 6/9, 6/10, 6/11	Apple	6/1, 6/7, 6/8, 6/9, 6/10, 6/11, 6/14, 6/15, 6/16, 6/17
Nokia	6/9, 6/10, 6/11	Dell	5/27, 5/28, 5/29, 6/10, 6/11	Cisco	6/3, 6/4
Dell	5/28, 5/29, 5/30, 6/2, 6/3	Cisco	6/1, 6/2	Dell	6/3, 6/4, 6/10, 6/11, 6/13, 6/14
Toyota Motor	5/30, 6/2, 6/6, 6/9, 6/11, 6/12	Nokia	5/27, 6/15, 6/16	McDonald's	6/4, 6/7
PepsiCo	6/11, 6/12	Toyota Motor	5/27, 5/28, 6/10, 6/11	Microsoft	6/1, 6/2, 6/3, 6/4, 6/8, 6/9, 6/10, 6/14, 6/15
Tesco	6/10, 6/11	Tesco	6/16, 6/17	Intel	6/1, 6/14
Coca Cola	5/28, 5/29	Texas Instruments	6/8, 6/9	Nokia	6/16, 6/17
Best Buy	6/2, 6/16, 6/17	Lockheed Martin	5/27, 6/15	Tesco	6/8, 6/9
		Best Buy	5/27, 6/16, 6/17	Lockheed Martin	6/1, 6/2, 6/3, 6/7, 6/8, 6/9, 6/16, 6/17, 6/18
		Unilever	5/28, 5/29	Best Buy	6/14, 6/15, 6/16
		Intel	5/27, 6/4, 6/5, 6/9, 6/10		

TABLE A.2: Two-Day Market Move Dates of Confounding Events (continued)

2011		2012		2013	
Company	**Market Move Dates**	**Company**	**Market Move Dates**	**Company**	**Market Move Dates**
Apple	5/31, 6/1, 6/2, 6/3, 6/6, 6/7, 6/8, 6/9, 6/10, 6/13, 6/14, 6/15, 6/16, 6/17	Apple	5/18, 5/21, 5/29, 5/30, 5/31, 6/4, 6/5, 6/7, 6/8, 6/11	Apple	05/21, 05/22, 05/23, 05/24, 05/28, 06/03, 06/04, 06/05, 06/06, 06/10, 06/11
Research in Motion	6/13	Amazon.com	5/30, 5/31	McDonald's	05/23, 05/24, 05/28, 05/29
Amazon.com	6/13	McDonald's	5/24, 5/25, 5/29, 5/30	Amazon.com	05/22, 05/23, 06/10
McDonald's	6/8, 6/9, 6/10	Dell	5/21, 5/22, 5/23, 6/1, 6/4	Intel	06/04, 06/05
Microsoft	6/1, 6/2, 6/3, 6/6, 6/7, 6/9, 6/10	Nike	5/31, 6/1	Proctor & Gamble	05/24, 05/28
IBM	6/13, 6/15, 6/16	Starbucks	6/5, 6/6	Cisco	06/07, 06/10
Intel	6/6, 6/7, 6/21, 6/22	Research in Motion	5/24, 5/25	Dell	05/22, 05/23, 05/28, 05/29, 05/31, 06/03, 06/05, 06/06
Starbucks	6/2, 6/3	Caterpillar	5/18, 5/29, 5/30, 5/31, 6/5, 6/6	Nike	05/28, 05/29
Tesco	5/31, 6/1, 6/14, 6/15	Johnson and Johnson	5/29, 5/30, 6/4	Caterpillar	06/04, 06/05
		Hewlett Packard	5/21	Ford Motor	05/21, 05/22, 05/23, 05/24, 05/29, 05/30, 05/31, 06/03

2014	
Company	**Market Move Dates**
Apple	05/28, 05/29, 05/30, 06/01, 06/02, 06/03, 06/04, 06/05, 06/06, 06/09
McDonald's	05/28, 05/29, 06/09, 06/10
Amazon.com	06/26, 06/27, 05/19, 05/23, 05/27, 05/28, 05/29, 06/01, 06/02, 06/03, 06/04, 06/05, 06/09
Unilever	05/22, 05/23
Cisco	05/20, 06/03, 06/04
Intel	05/27, 05/28
Nike	05/28, 05/29
Caterpillar	06/10, 06/11

Notes:

a) Firms are listed in the order of their rank in the SCT25 in a given year.
b) The Lexis Nexis database was used to find the dates of other announcements in the SCT25 event window.
c) The media publication date about some major other news about the company is day 0. The market move dates for this confounding news is [-1, 0] provided that both day 0 and day -1 are both stock market open days. If day -1 is a stock market closed day, then the event window is just day 0 provided that this is a stock market open day. If day 0 is a closed day then the event window is day *t* where *t* is the first stock market open day after day 0 if day -1 is also a closed day. If day 0 is closed day but day -1 is an open day then the event window consists of day -1 and day *t*.

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DECISION SCIENCES INSTITUTE

Decision making: The process is the content in an experience based, autonomy-supportive classroom

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ABSTRACT

This is a multi-step exercise focused on decision making which helps students understand process issues in decision making in complex and uncertain scenarios. It employs a case and how students often focus on the content of decisions, instead of process issues. Process issues are revealed through the use of various tools such as creating a team contract, a team inventory, and the decisions required in the case analysis. These occur across three 75-minute classes but can be adapted to the time available. The paper's structure is organized according to Wiggins and McTighe's (2005) curriculum development model.

KEYWORDS: decision making; content; process; organizational behavior; experience based learning; autonomy-supportive; andragogy

INTRODUCTION

It is not uncommon for college course material to be sufficiently complex to be both interesting, and hold hidden gems of learning that apply to topics beyond the particular course focus. This is the case with a three-part experiential exercise dealing with individual and group decision making. Decision making refers to the process of generating and choosing from a set of alternatives to solve a problem. This process can be automatic, quick and relatively unconscious which may rely on intuition or it can be systematic and thoughtful relying more on individuals' rationality. In rational decision making individuals go through six steps: 1) define the problem, 2) identify the decision criteria, 3) allocate weights to criteria, 4) develop the alternatives, 5) evaluate the alternatives, and 6) select the best alternative (Harrison, 1999). This model is based on the assumption that the problem is clear to the decision-maker and she has all relevant information to make the best decision, free from biases and with no time or cost constraints (Hardman & Harries, 2002). However, in reality this is rarely the case as people often have very little information at hand, problems are often ambiguous, and biased perceptions and attributions influence their thinking. In addition, when this step-by-step approach to thinking through various alternative solutions takes place in groups, the process of decision making becomes even more complicated. The strengths of one often do not compensate for the flaws of others, and the flaws present in our individual approach can at times become magnified when in groups.

Despite group decision making's limitations, it does contain the advantages of bringing together people of diverse backgrounds and expertise, who combine their knowledge, experiences, ideas and viewpoints to produce novel solutions. This combination of divergent thinking and access to a wider range of information can produce higher quality decisions (e.g. Hollenbeck, Ilgen, Sego, Hedlund, Major, & Phillips, 1995). In addition, group decision making often increases members' commitment to the final decision, as they participate in the process and are more likely to accept the final decision and support its implementation (Brodbeck, Kerschreiter, Mojzisch, & Schulz-Hardt, 2007). Past research has shown that being part of a group decision making process increases participants' perceptions of fairness and identification with the decision (for reviews see, e.g., Moscovici & Doise, 1994).

On the other hand, diversity may serve as a detriment to group decision making if members fail to collaborate and benefit from divergent thinking (Brodbeck et al., 2007; Hollingshead, Jacobsohn, & Beck, 2007; Stasser & Titus, 2003). How members approach information processing within groups can have important negative implications on rational decision making. Members might focus only on dominant or majority opinions, or discuss and repeat information that is brought up first, neglecting unshared information, or be biased on how they evaluate information by evaluating their own ideas or ideas that are consistent with their personal preferences more favorably than others (e.g., Brodbeck et al., 2007; Edwards & Smith, 1996; Harvey & Fischer, 1997; Yaniv & Kleinberger, 2000). These limitations and inherent biases are at the root of this paper's focus on process as something that is often poorly considered in group decision making.

The decision making exercise discussed below aims to help students experience the benefits and the difficulties in group decision making. Through experiential learning students will have the opportunity to identify and understand the issues (e.g. information sharing, conflicts, diverse viewpoints, perception, and attribution biases) that arise within groups when it comes to making collective decisions and become more aware of their own and others' participation in this process. Highlighting these dynamics through this writing is key to more fully understanding the process of decision making in groups, as well as actually making more effective decisions which is poorly addressed in extant literature.

This exercise is designed to highlight the "how" of decision making, and reduce students' tendency to focus on the exercise's content, or the "what" of the decisions to be made. This

tendency can draw students' attention away from the decision making learning points that the exercise is intended to facilitate. The exercise can be used in organizational behavior, leadership, and strategy classes and helps to reveal and underscore the importance of decision making process. With this introduction, the objectives of this paper are to: 1) describe the exercise in sufficient detail to enable instructors to competently and confidently facilitate the exercise in their classes, 2) provide literary foundations that establish this as a worthy exercise in higher education, and 3) provide evidence that this exercise is effective in teaching adults decision making processes. The learning objectives (LO) of the exercise are to enable students to: 1) identify and develop individual and group decision making skills; 2) apply individual and group decision making skills to a case; 3) understand the ubiquity of decision making in work and life; and, 4) understand that decision making is a process, not a discrete event.

The paper contains four major sections. The first section contextualizes the exercise in the larger domain of the Experience Based Learning (EBL) literature (Andresen, Boud, & Cohen, 2000; Dewey, 1938; Kolb, 1984; Kolb & Kolb, 2005; Weil & McGill, 1989) which aids in the creation of an autonomy-supportive learning climate (Reeve, Bolt, & Cai, 1999; Reeve & Jang, 2006). This section includes literature on andragogy (Knowles, 1980, 1984) which is a broad based philosophy regarding the fundamentals of adult education and a set of ideas through which the entire paper takes form. The second section provides a description of the exercise and the three activities that comprise it. It is presented in detail sufficient for other instructors to deploy it. The third section discusses exercise effectiveness as measured qualitatively. The final section of the paper discusses results, limitations, future research and alternatives to the current practice.

LITERATURE REVIEW

Adult Learning

Adult learning is a large research area with many focus areas, including self-directed learning, critical reflection, learning to learn, and experiential learning (Brookfield, 1995; Malinen, 2000). The work on adult learning is closely aligned with experience based approaches.

Experience Based Learning

Experience based learning (EBL) includes writing on autonomy-supportive (AS) classrooms by Reeve, Bolt, and Cai (1999) and others (Reeve & Jang, 2006). Their thinking on AS classrooms serves as a general frame supporting the EBL teaching approach. AS classrooms are characterized by teachers with a more autonomous and facilitative approach rather than a controlled orientation. Students in AS classrooms are provided greater latitude in their behavior as they experiment with ideas and relevant concepts. Here, students are free to engage in volitional behaviors not specifically dictated by the instructor. Research on AS teaching styles has suggested that it increases students' intrinsic motivation and self-esteem (Cheon, Reeve, & Moon, 2012; Deci, Nezlek, & Sheinman, 1981; Furtak, & Kunter, 2012; Haerens, Aelterman, Vansteenkiste, Soenens, & Van Petegem, 2015). An AS teaching style is likely to facilitate greater levels of success in classes characterized by EBL (Andresen, Boud, & Cohen, 2000; Dewey, 1938; Kolb, 1984; Kolb & Kolb, 2005; Weil & McGill, 1989).

The exercise employs numerous elements that reflect EBL frames (Conklin, 2013). Specifically, student experiences in and out of the classroom are treated as focal points for learning and are valued in the EBL tradition. In addition, experiential learning is a cornerstone of the larger domain of andragogy which has been noted as central to constructing meaningful ways to facilitate adult learning (Forrest & Peterson, 2006; Knowles, 1980, 1984; Lindemann, 1926). Andragogy assumes that adults need to: 1) know why they need to learn; 2) learn

experientially; 3) approach learning as problem solving; 4) learn when the topic is immediately valuable; and, 5) become more self-directed in their learning (Knowles, 1980, 1984).

Andragogy bridges to the EBL literature and the power of engaging in activities that require student participation (Andresen, Boud, & Cohen, 2000; Dewey, 1938; Kolb, 1984; Kolb & Kolb, 2005; Weil & McGill, 1989). Particular calls for student participation have come from a broad array of thinkers. Arbaugh (2005) addressed this in his call for less lecture and more interaction. Whetten (2007) did likewise in discussing the need for greater focus on problem based learning, career relevant material, and interaction with practitioners. Boud and Pascoe (1978a, 1978b) believed that: 1) learners must have some control in the activities and process; 2) the learning environment must mirror, to some extent, the real world; and, 3) the learner must be self-involved. These three elements require dialogue and interaction among students which cannot be taken for granted, and likely encouraged in AS classrooms. Gilson (1990) has noted that the proclivity of students' interaction is contingent on the instructor's ability to facilitate an environment that invites such interaction. Given Gilson's words, anyone who adopts these methodologies must also assume the myriad responsibilities that attend that adoption.

Creating a teaching structure and an environment that accomplishes what the above literature describes is at the heart of Wiggins and McTighe's (2005) Understanding by Design (UbD) approach. Their thinking suggests that teachers begin with results in mind. Specifically, determining what students should know, understand, and be able to do is the first step. Second, instructors need to be able to determine if learning has occurred. The authors identify two forms of assessment: performance tasks which require students to apply their knowledge, and the second form of assessment, "other evidence" which includes more traditional elements such as tests, observation, and work samples. The third stage in the UbD model includes decisions about lessons and activities that will result in the outcomes identified. The goal of these activities is to have students be able to make meaning on their own and with teacher support. This requires the teacher to evolve from expert to one who facilitates the learning process and coaches through feedback and advice. These are behaviors consistent with the autonomy-supportive frame described above. The three steps of the UbD model will be referred to as the paper unfolds to tie the stages of the paper to this frame.

THE EXERCISE

The exercise falls into the third element of Wiggins and McTighe's (2005) model dealing with appropriate lessons and learning activities and accomplishes the first and second learning objectives (LO) by engaging with others and with a case. It addresses the third LO in that many decisions must be made regarding the case that often go unnoticed until they are identified in the debrief. The fourth LO is addressed when students begin to see the networked nature of decisions that often conflict with and impact other decisions.

Creating student groups and dealing with the case requires interaction with others as those groups attempt to understand, analyze, and make recommendations. These actions reflect the elements of andragogy cited above - they are relevant and meaningful in students' lives, they are experiential due to the interaction required, there are problems to identify and solve, they have immediate value in learning about and applying decision making processes, and finally, they enable students to discover issues and solutions for themselves rather than be guided strictly by the instructor. Table 1 provides details on where each objective is achieved.

Insert Table 1 about here

The in-class exercise is comprised of three main activities. Each activity takes place during one of three 75-minute class sessions and could be adapted to fit various timing formats. The first activity requires significant out-of-seat interaction as the class forms groups with as much diversity as possible (Coulson & Strickland, 1992). This is followed with the challenges present in the case (Gourville, 2005).

Activity 1. Step 1: The first activity is based on the Diversity game described by Coulson and Strickland (1992). We used this as a sorting mechanism that aided in creating groups with as much diversity as possible regarding thinking styles.

The activity begins with the random distribution of four cards to students (Coulson & Strickland, 1992). They are to trade those cards with others to arrive at a 'hand' that each believes best describes him or her. The 64-card deck (Coulson & Strickland, 1992) contains four color groups reflecting the Hermann Brain Dominance thinking styles (Bentley, 1989; Bunderson, 1989; Herrmann & Herrmann-Nehdi, 2015). Further distinctions are provided in Appendix A.

Each of the four thinking styles contains 16 cards. Each card contains an adjective and description of that style. Examples include helpful, artistic, industrious, etc. and the brief description mentioned. Depending on class size more than one deck may be necessary. When distributing the initial four cards to students we ensure that each card is from a different color group. That is the only criterion for this step.

The cards are used as a convenient means of compelling students to make numerous decisions regarding what adjectives apply to them and which do not. It is important to note that virtually any mechanism that requires a significant amount of decision making could be used to categorize students in some way[1]. Once students have four cards that they believe best describe them they are to take their seats so we can begin step 2.

Step 2: In this step of the activity students are asked to sacrifice the card that is least like them. Groans are often heard around the room. They are then instructed to prioritize the three remaining cards according to which best describes them and rank them as 1, 2, and 3. To ensure they have a record of these three cards we ask students to write down the adjective and description of each in ranked order on the sheet referred to above as Appendix A. They are then requested to return the two cards that are least like them, leaving them with the one card they believe best describes them. Holding only one card, students are asked to form a group with three other students with the stipulation that they maximize the diversity of the adjectives and card colors. Often, students are quite unaware of the numerous decisions they have made at this point in the activity. This provides a rich experience that will be explored in the debrief and reflects the LO regarding the ubiquity of decision making.

Once groups are formed they are asked to construct a team statement and contract (Appendix B) (St. Peter, 2013). This is another activity that compels many decisions. When completed, student groups are asked to stand and share their creations with the class. This can be shortened to a few select questions if the class is large or if time is limited.

Mini-debrief: At the end of this and each activity we ask what they had to do a great deal of in order to complete the tasks. Without fail students offer up good insights such as suspend judgment, collaborate, good communication skills, take leadership, etc. We ask the same question again and finally someone identifies the volume of decisions they had to make. We

[1] For example, using students' Myers Briggs Type Indicator (Myers, 1962) profiles or their Learning Style Inventory (Kolb, 1976) profiles would be suitable sorting devices that create distinctions for students and enable them to construct diverse groups. The cognitive style inventory cited here is simply the one we have chosen. A good review of various instruments can be found in Kozhevnikov, Evans, and Kosslyn (2014).

draw attention to the name of the course (Managerial Decision Making, but the same could be said of many courses which may have a module on decision making or a heavy focus on the roles and obligations of managers and executives) and it dawns on them that this activity has been riddled with decision making from the very start. Usually there is a bit of nervous laughter from the room as this otherwise obvious insight has been missed by most of the students.

Our intent is to draw attention to decision making processes and the subtle nature of decisions that pervade our lives, including the partial awareness we often bring to them. This helps us understand the ubiquity of decision making and the potential contribution to decision quality if we were to increase our consciousness as we craft lives and careers. We close by asking students what decisions create. Here again there are numerous worthy suggestions. Over the course, we have often commented that decisions are what create our reality. This 'truth' is an important element of the course and we want students to understand the significance of decisions in their lives. This debrief provides a pregnant moment to underscore this point.

Activity 2. This activity uses a Harvard Business Review case (Gourville, 2005)[2]. Students are asked to read the case prior to class and come prepared to work in their established groups to identify: 1) the problems and issues in the case that need to be solved; 2) the desired ends (DE) that solving the problems will achieve. DE are the new realities they would like to see the solutions create, or the problems they would like to see the solutions eliminate; and, 3) the criteria by which they will know that the reality is created or the problems are solved. We encourage students to use quantitative means if available as they consider the measurable criteria relative to each DE.

When groups have arrived at their responses to these prompts each is asked to come to the front of the room and describe to the class the issues they identified. Each group usually identifies a unique set of issues in the case that need to be resolved, and what resolving them will create.

Mini-debrief: The diversity of issues identified by each group provides an opportunity for a conversation around the broad variety of possible interpretations that cases provide. This can be further de-briefed by exploring the often hidden values and assumptions behind each group's assessment of what is most salient in the case. To the extent possible, this captures the experience of what happens at the managerial/executive level of organizations. It can be a moment to highlight the attending complexity/ambiguity that must be dealt with at that level when deciding what is most important in creating an organization's future.

Here, as in activity 1, groups have made a number of decisions, often without being fully aware of their process for doing so. To cement the learning it is helpful to discuss decision making issues along the way, rather than saving all discussion for the final event. In that way we have found it beneficial to use similar questions, in addition to new and relevant ones considering the specific activity each time. The students become accustomed to hearing them and as a result begin thinking about them as the three activities occur instead of only considering them once at the end, which would reduce the salience of the issues that they are intended to raise. We ask students what they have done much of (decision making) to arrive at their responses and what that has created (reality). In this step we also ask them to consider the challenges and insights they may have encountered in group decision making, which is a new

[2] While the case cited here is in the healthcare field, virtually any well written case would likely suffice so long as it requires making many significant decisions. For interesting commentaries on this case readers may want to refer to Lutz, R. A., Christensen, C. M., Wittes, J., & Galakatos N. (2005). Holding fast: HBR case commentary. *Harvard Business Review*, June, 40-46.

act for them. Questions that can facilitate the debrief include but are not limited to the following: What went well, what surprised you, where were you challenged, what were the challenges about, did you experience disagreements about what was important or what to do, how did you manage the disagreements around the issues and their relative importance?

Activity 3. This activity also uses the HBR case and requires each group to generate as many potential solutions as possible to the identified problems which will result in the Desired Ends (DE) they identified. They then establish levels of importance for the various DE and the likelihood of each proposed solution achieving each DE. All of this is represented in a Consequence Table (Hammond, Keeney, & Raiffa, 1998) (Table 2) containing the various DE down the left margin and the proposed Solutions across the top row. To be clear, the consequence table is simply a device that reflects the thinking and prior decisions that have been made and offers a structure for analyzing the wisdom of those decisions. It is not the decision making interface itself, only a mirror that helps analyze them. The table simply organizes the DE and the suggested solutions and then aids in the application of quantitative measures to arrive at a weighted score for each proposed solution. While the table construction requires additional decision making, the decisions made at this step are only as good as the intelligence that is reflected through the identified issues contained in the top and left margins of the table.

Each DE in the left margin is assessed with an Importance Score (IS) which is entered in the left margin. This reflects the relative importance of each DE vis-a-vis all other DE. Each proposed solution (contained in the top row) for that DE row is assigned an Achievement Score (AS) that estimates the extent to which that Solution achieves each DE that is found at each column/row intercept. AS are applied to each cell under each proposed solution.

Insert Table 2 here

The range of IS and AS scores selected is an important distinction. These scores should span a broad domain of numbers such as 1-20 or 1-50 and should exceed the raw number of DE and solutions identified. For instance, if a group identifies 10 DE they would like to accomplish, a range of 1-25 for IS would be adequate to reflect the relative importance of each vis-à-vis the other DE identified. This provides an interval ranking which is more meaningful than simple ordinal ranking. As example, on a scale of 1-25, the most desirable end should receive an importance score of 25. This reflects its status as the most important of all DE identified. The next most desirable end should receive an importance score that shows its relative importance compared to the most desirable. So, if the second most desirable end receives a score of 13 it is, apparently, about half as important as the most desirable end. Likewise, if it receives a score of 24 it is very comparable in its importance and desirability to the most desirable end which received a 25. A similar process is undertaken with the AS. As the groups work with each DE, each cell in that row, under each proposed solution is ranked in its likelihood of achieving that DE. When complete, each cell intercept within the table should have an AS.

The IS of each DE is then multiplied by the AS of each cell to arrive at a weighted score for that combination. These weighted scores are then summed to the bottom of each column to provide a total weighted score for each of the proposed solutions. That solution containing the largest sum theoretically identifies the best solution that will achieve the greatest number of DE identified. This step results in a Consequence Table (Hammond, Keeney, & Raiffa, 1998) that reflects the likelihood of desired ends achievement vis-a-vis importance.

When activity 3 is completed groups are asked to come to the front of the classroom and present their consequence table.

Mini-debrief: Once all groups have reported their results we ask the room which group is right. This can lead to lively debate. It is resolved however, when we discuss the idea that they are all correct given the analysis, assessment, and logic they applied to the case data. This often leads to a conversation on the challenges of decision making in general, and especially at the highest levels of organizations where the information is almost always partial and temporary, yet leaders are still required to move ahead despite this ambiguity. In that environment many solutions are likely to be suggested, most of which will achieve some of the DE. This can be a rich moment to discuss the roles of management and leadership and the necessary wisdom that must accompany decisions and which, ideally, informs leadership.

These three activities address Wiggins and McTighe's (2005) first concern focusing on what students should know and understand which would be considered topical questions, and their concern regarding lessons that cement their learning. This also addresses LO 2 which involves using a case as a learning tool, and LO 4 which considers decision making a process that is embedded in the ongoing flow of organizational life.

Final Debrief: The activity closes with groups beginning to understand the complexity and ambiguity of decision making, especially as it moves from individual to group which becomes more encumbered as one ascends in organizations. Closing comments often address the following:

1. All solutions are right and all importance estimates are accurate given the sense making and assessments/judgments of the group. These assessments and judgments are likely riddled with unconscious cognitive biases (Chugh, Bazerman, & Banaji, 2005; Milkman, Chugh, & Bazerman, 2009; Moore & Cain, 2007) which is a central theme reviewed in the course.
2. Group decision making is usually temporary and partial. Access to information and interpretation are often time bound as work and the world continue to evolve/devolve thereby altering current and future interpretations of the reality within which organizations function. It is partial in that apprehending all information relevant to a situation is beyond our reach.
3. Group decision making is difficult. It is not uncommon for group members to conflict with each other and have to debate and concede at some point in order to come to agreement.
4. Decision making tasks require good negotiation skills and a process of collaboration and compromise.
5. Complexity increases in organizations and in groups compared to individual decision making. More people with numerous and complex ideas make management of this process more complicated.
6. Complexity is exacerbated as group size increases and as one ascends into the upper levels of management and leadership. Ambiguity generally increases as one moves into higher levels of management and is exposed to greater amounts of often conflicting data. This creates greater uncertainty regarding the correct path to take.
7. Finally, in some ways it matters little what solutions/recommendations groups identify - this is a decision making course, not a strategy class. Hence, the focus ought to be on group decision making processes, and only partially on the content of the case.

This last issue is worth considerable dialogue. A meaningful and helpful frame through which to make sense of organizational decision making could be that of game models (Elias, 1970) which interprets the "relative strength of the players" (p. 75) regarding the shifting tides of power

in society, and by corollary, organizations. This model may be of some value as students consider their decisions in areas well beyond the narrow band of their careers, thereby bridging the significance of decision making to students' daily lives.

The third activity addresses Wiggins and McTighe's (2005) topical objective regarding what students should know.

EXERCISE EFFECTIVENESS

Wiggins and McTighe's (2005) second concern focuses on measuring achieved results. This section on effectiveness addresses that issue.

To determine student experience of the exercise we surveyed (Appendix C) 104 students after the exercise using two questions rated on a 7 point Likert (1932) scale, and one open-ended, short response question. The first question inquired about the usefulness of the activities. This question received 6.08 for the mean with a standard deviation (SD) of 1.14. The second question asked if students believed that the activities increased their understanding of the decision making process. This question received a mean of 6.01 and a SD of 1.15. These values reflect some consistency within each measure. Both questions were self report measures which have their limitations. These will be discussed below.

Short response

The open ended question asked students to comment on what changes they will make in their decision making going forward. Boyatzis' (1998) three stages of thematic analysis were applied to this data. The first stage regards sampling and design issues and was addressed by surveying all students who had participated in the exercise.

The second stage of thematic analysis requires developing a theme and a code. All student data was hand written and was in phrase or one word responses which was the level of analysis. Data was coded and themes identified following Braun and Clarke's (2006) definition of themes as "something important about the data…and…some level of *patterned* response or meaning within the data set" (p. 82). As a means of increasing the reliability of assessments these coding events were spaced across four weeks. The schedule of events is contained in Table 3

Insert Table 3 about here

The third stage in the analysis required validating and applying the code. Summary themes were shared with the classes of students who provided the data. Students concurred with the analysis and the themes. These themes are supported with response examples in Table 4.

Insert Table 4 about here

Other comments that were present but not thematic, meaning there was no consistent presence and there were no more than two related comments, include things such as "Take more prepared steps in decision making" "Read the case first" "Avoid biases in brainstorming" and "Do more background research." These comments are relevant regardless of their infrequent presence.

DISCUSSION

The purpose of this paper is to illustrate how adult students increase their understanding of the process of group-decision making through an in-class exercise. This exercise helps them identify and develop the necessary skills that can be applied in the work world. In this exercise, students had a central role experiencing the decision making process, while instructors adopted a more facilitative role to help students reflect on their learning experiences throughout the activities. Students were allowed to be autonomous throughout the exercise to maximize their intrinsic motivation and engagement. The design of the exercise required the active participation and interaction of students and was intended to draw students' attention towards the process of decision making rather than to the content of the decisions to be made. This helped them gain confidence on how to collaborate in group decision making, identify their limitations, and develop the necessary tools to apply this process in other domains.

The activities and the dynamics surrounding them stand upon a solid foundation offered by the autonomy-supportive (AS) classroom literature (Reeve, Bolt, & Cai, 1999; Reeve & Jang, 2006). AS classrooms are identified by a more interactive style where teachers are less controlling and often serve as guides and facilitators rather than experts. The three activities also align with ideas related to growth mindsets (Blackwell, Trzesniewski, & Dweck, 2007). Growth mindsets, as compared to fixed mindsets are characterized by a belief that one's abilities can be developed through work and effort. It is contrasted with fixed mindset thinking; one's talents and abilities are fixed, hence, there is little attempt to develop or grow one's capacity (Dweck, 2006). While the activities are compulsory as a course requirement, they bridge to AS in execution as students are provided significant freeboard to interpret the case and apply thinking from the course. Doing so creates a holding environment (Winnicott, 1965) where they are free but not abandoned. This reduces the pressure to be right and centers attention on learning as opposed to performing.

Finally, a recurring theme in the course and the three activities of the exercise is how the decisions of any group are accurate in the moment given their assessment and adjudication of what is and is not salient. Given this foundation we are then able to explore how it is that so many well educated and deeply experienced executives fail so significantly despite these qualifications. While this is a theme in the course material covered over the term, it appears that there is little that so teaches us the significance of an idea as actually experiencing it: a nod to the very essence of this paper - experiential learning.

Limitations and Future Research

This study may be limited by self report data as self determined measures of one's understanding may be easily influenced by cognitive bias (Hilbert, 2012) which, ironically, is a central feature of the course. Further bias may be unwittingly applied by the participants' personality characteristics, motivation, achievement orientation, and locus of control. Future iterations of the exercise could contain a follow-up objective to evaluate students' workplace settings, or perhaps, an application to employees' training programs to determine change in learning. Future research may also include administering the pre- and post-test at times other than just prior to, and following the exercise. Doing so would help establish what learning occurs and when, and enable instructors to determine what elements of the course provide the greatest learning. This could be correlated to learning goals established at the beginning of each course through the use of an appreciative inquiry exercise (Conklin, 2009) that helps identify them. Further distinctions could also be revealed by pursuing the discoveries here, such as the contributions of professional experience.

Summary

This paper has described a set of activities that differ from traditional lecture based teaching models. The insights that often occur are likely to increase retention as they stand outside the typical classroom experience. Still, the challenge is to more fully integrate activities and exercises that leverage the shared power of this form of teaching and learning. We confess, some of the courses used as the source for this paper are modeled on good old fashioned, stand and deliver, sage-on-the-stage (Gibson, 1996) lecture.

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APPENDIX A: THINKING PREFERENCES

Four Dominant Thinking Preferences

Analytical (Blue) • Logical problem solving approach • Analytical and quantitative • Rational • Learns by mental analysis	**Conceptual/Strategic (Yellow)** • Imaginative thinker • Intuitive about ideas • Visionary • Holistic/integrating • Learns by experimenting
Structural/Organizer (Green) • Practical, organized, sequential • Likes procedures • Detail-oriented • Cautious about new ideas • Learns by doing	**Social/Personal (Red)** • Intuitive about people • Socially aware • Sympathetic/empathetic • Focused on interpersonal • Learns from others

Communication Styles of Each Thinking Preference

The Analytical wants: • Budget in #'s or graphs • Data • Logical and concise • Credible speaker • Value for time expended • Problem solving orientation • Written info for review later	**The Conceptual/Strategic wants:** • Budget in pictures and graphs • Symbols, metaphors, analogies, myths • Use brainstorming as a tool • Change every 15-20 minutes • Option generation and integration • Overview and summary
The Structural/Organizer wants: • Agenda or outline • Guided discussion and recitation • Practice and feedback • Rules and procedures • Specific information and detail • Dates/times for implementation • An action plan	**The Social/Personal wants:** • Stories and vignettes • Rapport with audience and presenter • To celebrate achievements • To address emotions • A collaborative approach • Information applied to self

1. What was the color, adjective and phrase on your favorite card?

_____

2. Provide an example where something you did in a team setting represented the adjective and phrase on your favorite card:

_____

APPENDIX B: TEAM STATEMENT AND CONTRACT

This is a written statement with the signature of all the team members at the bottom. It should address the following:

1. Team name and team members
2. The expectations about good performance behaviors (core norms) that you are agreeing to hold yourselves mutually accountable for during the next three sessions.
3. The expectations about unacceptable behaviors (core norms) that you are agreeing to hold yourselves mutually accountable for during the next three sessions.
4. The consequences for breaking these core norms.
5. A positive goal for the sessions that all members of the team feel committed to achieve.
6. A description of how your team will address conflicts
7. A description of how your team will celebrate success

APPENDIX C: STUDENT EXPERIENCE SURVEY

Please rate the overall usefulness of these activities.

Not useful Very useful

1 2 3 4 5 6 7

To what extent was this workshop effective in increasing your understanding of the topic?

Ineffective Very effective

1 2 3 4 5 6 7

What changes will you make in your decision making habits based on the exercise?

_____
_____
_____
_____

TABLE 1: LEARNING OBJECTIVES IN 3 PART EXERCISE

Learning Objectives	Exercise sections that address L.O.
Identify and develop individual and group decision making skills.	Activities 1, 2, 3: team formation, use of the Holding Fast HBR case and the variety of problems and solutions groups identify.
Apply individual and group decision making skills to a case.	Activity 2, 3
Understand the ubiquity of decision making in work and life.	Activity1: steps 1 (card sort) and 2 (group formation), 2, 3: All three sections of the exercise are rich with many small decisions that are often unrecognized as decisions at all.
Understand that decision making is a process, not a discrete event.	Activity 3: Achieved near the end of the exercise as students become aware of the networked decisions they have been making in the case that often conflict with other priorities and decision in the case without their awareness.

TABLE 2: CONSEQUENCE TABLE

	Solution 1	Solution 2	Solution 3
Desired end 1; IS	AS X IS = Product	AS X IS = Product	AS X IS = Product
Desired end 2; IS	AS X IS = Product	AS X IS = Product	AS X IS = Product
Desired end 3; IS	AS X IS = Product	AS X IS = Product	AS X IS = Product
Desired end 4; IS	AS X IS = Product	AS X IS = Product	AS X IS = Product
Total	**Sum of Products**	**Sum of Products**	**Sum of Products**

TABLE 3: SCHEDULE OF DATA ANALYSIS

Week 1	Quickly read all comments and make notes of general impression on a separate document
Week 2	Transcribe student comments into a separate file for each question. Read this summary document attending to each word and making tentative thematic notes in the margin
Week 3	Read fresh copy of summary document of student comments and thematized their comments
Week 4	Compared notes on the two summary documents of students' comments from week 2 and 3 to arrive at final themes and supporting student commentary.

TABLE 4: OPEN-ENDED QUESTION THEMES

What changes will you make going forward in your decision making?	
Theme	Supporting Quotes
1. Will consider others' ideas and opinions more fully as they move forward	"I will listen before making decisions. Consult members when in a group. Ask others' opinions."
2. Will consider a broader variety of important factors that impact the decisions they are making	"Weigh many alternatives before making a decision. Think about the value of the alternatives more. Consider alternatives outside the box."
3. The exercise was meaningful and will affect how they make decisions in the future.	"I will add numbers to my decision making process. I will change how I make decisions and use the consequence table more. I will generate more desired ends relative to the alternatives that I am considering."

DECISION SCIENCES INSTITUTE
Determinants of Colleges and Universities Rankings
A Statistical Analysis

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ABSTRACT

This article uses Data Envelopment Analysis to measure relative efficiencies of several universities in three different time periods. Using this technique, it is possible to identify which schools are relatively inefficient compared to the composite school. The efficiency ratings varied from 25% to 100% in 2018 and when compared to 2005-06 and 1998-99 data the index deteriorated for two schools and improved for another. This change in efficiency ratings could be attributed to changes in their inputs and outputs.

KEYWORDS: Linear Programming, Data Envelopment Analysis, College Rankings, Efficiency, Composite School

INTRODUCTION

Every year, US News and World Report releases its famous College Rankings lists. Parents, high school guidance, academicians and college administrators, counselors, and students eagerly await the rankings, so they can impress others with the numbers.
In 2014, for the first time in over two decades, Emory University fell out of the top 20 in the rankings. Although the drop from 20 to 21 is superficially trivial, it is of great symbolic significance given that many students, parents, academicians and college administrators rely on the “top 20” as a rough benchmark for university quality.
According to Lilienfeld and Candler Dobbs (2014) “the rankings drop is indeed a big deal.” Despite the administration unwillingness to admit, “these rankings impart a sobering reality: Emory is a good university, but not a great one.” But compared with MIT, Harvard, Cal Tech or University of Chicago, “cutting-edge discoveries and breakthroughs at Emory tend to be few and far between.” Having followed the rankings of some of these universities since 1998 one is curious to see what factors cause rankings to go up and down.

LITERATURE REVIEW

This article uses Data Envelopment Analysis (DEA) to explore this issue. Since the original introduction of data envelopment analysis (DEA) by Charnes, Cooper, and Rhodes (1978) this technique has been extensively applied to different operating units such as banks, colleges, schools, and others. Ray (1991) used DEA to estimate relative efficiency in the public-school districts of Connecticut. Bougnol and Dula (2006) used DEA to assess performance in higher education. Bates (1997) used categorical variables to measure the efficiency of educational outputs, and Banker and Morey (1986) introduced a case where categorical variables are divided into controllable and uncontrollable by the managers.

METHODOLOGY

In DEA the objective is to identify technical inefficiencies of operating units with same goals and objectives and focus on either saving inputs or increasing outputs. As far as resource conservation is concerned, a decision-making unit (DMU) is considered efficient if it uses less of at least one input and produces same outputs as other units. Alternatively, with respect to increasing outputs a DMU is efficient if it uses no more inputs as other units but produces more of at least one output. Applying Data Envelopment Analysis (DEA) will help measure the relative efficiency of some of the colleges in these states making the decision to enroll in these colleges an informed one. The DEA will point out which colleges to avoid.

The schools of interest in this study are Georgia Institute of Technology (GT), California Institute of Technology (Cal Tech), Massachusetts Institute of technology (MIT), Harvard University, Emory University, and University of Chicago. Therefore, the system is composed of these six schools. The objective is to measure the efficiency of Georgia Tech, Emory University, and University of Chicago and compare them with Cal Tech, Harvard and MIT.

The following five input measures and four output measures are identified to be crucial:

Input Measures:

Acceptance Rate – It measures the percentage of students accepted to the university.

Student/Faculty Ratio – This indicates the number of students per faculty member.

Faculty Resources Rank- This is a measure of school's commitment to instruction. It is obtained as a weighted average of small class size, faculty salary, proportion of faculty with highest degree in their field and proportion of full time faculty.

Financial Resources Rank – It measures that average spending per student on instruction, research, student services, and related educational expenditures.

Student Selectivity Rank – The academic climate of school is determined in part by the abilities and ambitions of the student body. Therefore, schools tend to select those who performed well in high school or who have higher scores on SAT, etc.

Output Measures:

Academic Reputation – The measure is chosen because a diploma from a distinguished college so clearly helps graduates get good jobs or gain admission to top graduate programs.

Alumni Giving Rate – The percentage of alumni who gave to their school is an indicator of alumni satisfaction.

Actual Graduating Rate – This measure captures the effect of the college's programs and policies on the graduation rate of students.

Average Freshman Retention Rate – The higher the proportion of freshmen who return to campus and complete their studies, the better a school is likely to be at offering the classes and services students need to succeed.

QUANTITATIVE ANALYSIS AND INTERPRETATION

The analysis is conducted for three colleges separately.

Emory University:

The general form of the output constraint is:

Output for the best practice school ≥ output for Emory University

and the general form of the input constraint is:

Input for the best practice school ≤ input available to the best practice school

The right-hand side of the input constraint is the fraction of Emory University's input available to the best practice school. If E is used as the fraction, then the input constraint can be rewritten as:

Input for the best practice school ≤ input available to Emory University × E

If E=1 then the input used by the best practice school is the same used by Emory. Therefore, there is no evidence that Emory University is inefficient. However, if E<1 then best practice school does not need as much input as Emory University requires, thus Emory University can be considered relatively inefficient. So, in the linear programming model the objective function is to minimize E, the fraction of resources of Emory University available to the best practice school (composite school).

The objective function and constraints for Emory University are as follows:

Objective Function: Minimize E

Constraints:

$W_c + W_h + W_m + W_e + W_g + W_{ch} = 1$	Weights of Operating Units
$4.6W_c + 4.9W_h + 4.9W_m + 4.4W_e + 4.5W_g + 4.5W_{ch} \geq 4.4$	Academic Reputation
$25W_c + 35W_h + 36W_m + 21W_e + 24W_g + 41W_{ch} \geq 21$	Alumni Giving Rate
$94W_c + 97W_h + 93W_m + 91W_e + 86W_g + 94W_{ch} \geq 91$	Actual Graduation Rate
$97W_c + 97W_h + 98W_m + 94W_e + 97W_g + 99W_{ch} \geq 94$	Avg. Freshman Retention Rate
$8W_c + 5W_h + 8W_m + 25W_e + 26W_g + 8W_{ch} \leq 25E$	Acceptance Rate
$3W_c + 7W_h + 3W_m + 9W_e + 20W_g + 5W_{ch} \leq 9E$	Student Faculty Ratio
$9W_c + 4W_h + 12W_m + 19W_e + 178W_g + 3W_{ch} \leq 19E$	Faculty Resources Rank
$2W_c + 8W_h + 3W_m + 18W_e + 55W_g + 4W_{ch} \leq 18E$	Financial Resources Rank
$1W_c + 3W_h + 3W_m + 23W_e + 22W_g + 1W_{ch} \leq 23E$	Student Selectivity Rank
$E, W_c, W_h, W_m, W_e, W_g, W_{ch} \geq 0$	

Analyzing the Emory University results, it is noted that the objective function shows that the efficiency score for Emory University is 0.3913. This value shows that the composite college can obtain at least the level of each output that Emory University obtains by having available only 39.13% of the input resources required by Emory University. Therefore, it can be concluded that the composite college is more efficient. In other words, Emory University is relatively inefficient compared to the other colleges in the group, namely California Institute of Technology and University of Chicago.

The data envelopment analysis (DEA) revealed that the composite college is formed from the weighted average of California Institute of Technology (W_c =0.7391) and University of Chicago (W_{ch} = 0.2609). The inputs and outputs of the composite college are determined using the weighted average of the inputs and outputs of these two schools.

Outputs/inputs	Emory University	Composite University
Academic Reputation	4.40	4.60
Alumni Giving Rate	21	29.17
Actual Graduation Rate	91	94
Avg. Freshman Retention Rate	94	97.52
Acceptance Rate	25	8
Student Faculty Ratio	9	3.52
Faculty Resources Rank	19	7.43
Financial Resources Rank	18	2.52
Student Selectivity Rank	23	1

The above table summarizes the inputs and outputs of Emory University and composite college. For example, the output "Academic Reputation" of the composite school is determined as follows: Academic Reputation (AR) of the Composite school = W_c (AR_c) + W_{ch} (AR_{ch}) where

AR_c = Academic reputation of California Institute of Technology

AR_{ch} = Academic Reputation of University of Chicago,

= 0.7391 (4.6) + 0.2609 (4.6)

= 4.6.

The Composite school has an academic reputation of 4.6 that is .2 units higher than Emory University. The actual graduation rate for the composite college is determined in similar fashion. The actual graduation rate for the composite college is 94% which is 3% higher than Emory's. The average freshman retention rate for the composite college is 3.52% higher than Emory's rate. Also, the alumni giving rate is 8.17 units higher for composite school than that of Emory University.

Moving to the input constraints, it is noticed that the composite college can obtain at least the level of each output that Emory University obtains by having available no more that 39.13% of the input resources required by Emory University. For example, the acceptance rate of Emory University is 25%. The acceptance rate constraint shows that at the composite college the acceptance rate is at most 39.13% that of Emory University. As a matter of fact, the acceptance rate at the composite college is even lower than the 39.13% of the acceptance rate of Emory. A slack value of 1.78% indicates that acceptance rate at composite college is less than 39.13% of the acceptance rate of Emory University.

The information in the table suggests managerial actions that should be taken to move Emory University toward efficiency frontier. Some actions are feasible and can be carried out in the short term like changing the student faculty ratio or providing more faculty resources

Considering the dual values, the student faculty ratio constraint shows a dual value of 0.0652. It indicates that one unit increase in student faculty ratio at Emory University will increase its inefficiency by 6.52%. According to Lilienfeld and Candler Dobbs (2014) the student faculty ratio climbed from seven to one to eight to one in 2014 and nine to one in 2018. This is "despite the fact that Emory's endowment has rebounded, and its capital campaign has been strikingly successful". Moreover, the dual value of the faculty resource rank is 0.0217. It shows that as the faculty resource rank at Emory increases by one unit the school's inefficiency increases by 2.17%. As a matter of fact, the university has invested much more heavily in Emory HealthCare than in the College, meaning that the hiring of outstanding college faculty has taken a back seat.

This study was repeated using the data for 1998-99 and 2005-06 for Emory university and found out that E=0.5143 in 1998-09 and E=0.6735 in 2005-06, meaning that in 20 years the school's efficiency ratings has become a roller coaster with ups and downs. Interestingly in 1998-99 the composite school was formed from the weighted average of Cal. Tech. (W_c =0.80) and MIT (W_m=0.20) whereas in 2005-06 the composite school was formed from the weighted average of Cal.Tech. (W_c=.5714) and Harvard University (W_h=.4286).

If Emory rankings continue to stagnate or drop, the school will find it increasingly difficult to attract the same quality students and faculty that had kept Emory among the top 20 schools.

University of Chicago:

For the University of Chicago, the objective function and constraints are as follows:

Objective Function: Minimize E

Constraints:

Wc + Wh + Wm + We + Wg + Wch = 1	Weights of Operating Units
4.6Wc + 4.9Wh + 4.9Wm + 4.4We + 4.5Wg + 4.5Wch ≥4.6	Academic Reputation
25Wc + 35Wh + 36Wm + 21We + 24Wg + 41Wch ≥41	Alumni Giving Rate
94Wc + 97Wh + 93Wm + 91We + 86Wg + 94Wch ≥94	Actual Graduation Rate
97Wc + 97Wh + 98Wm + 94We + 97Wg + 99Wch ≥99	Avg. Freshman Retention Rate
8Wc + 5Wh + 8Wm + 25We + 26Wg + 8Wch ≤8E	Acceptance Rate
3Wc + 7Wh + 3Wm + 9We + 20Wg + 5Wch ≤5E	Student Faculty Ratio
9Wc + 4Wh + 12Wm + 19We + 178Wg + 3Wch ≤3E	Faculty Resources Rank
2Wc + 8Wh + 3Wm + 18We + 55Wg + 4Wch ≤4E	Financial Resources Rank
1Wc + 3Wh + 3Wm + 23We + 22Wg + 1Wch ≤1E	Student Selectivity Rank
E, Wc, Wh, Wm, We, Wg, Wch ≥ 0	

Applying the DEA to the University of Chicago inputs and outputs the objective function (efficiency index) E=1. This means that the composite college requires as much input as the University of Chicago does. There is no evidence that the University of Chicago is relatively inefficient. With unit efficiency index the amount of the resources used by University of Chicago is necessary to produce the output of the school itself. In other words, the Composite school is, in fact, made up of the University of Chicago itself.

Using the data for 2005-06, University of Chicago's efficiency index E= 0.6129. This value shows that the composite college can obtain at least the level of each output that University of Chicago obtains by having available only 61.29% of the input resources required by University of Chicago. Therefore, it can be concluded that the composite college is more efficient. In other words, University of Chicago is relatively inefficient compared to the other colleges in the group, namely California Institute of Technology and Harvard University. The data envelopment analysis (DEA) revealed that the composite college is formed from the weighted average of California Institute of Technology (W_c =0.6774) and Harvard university (W_h = 0.3226).

Using the data for 1998-99 University of Chicago's efficiency index is found to be E= 1. Comparing the two periods one can conclude that University of Chicago has become less efficient in 2005-06 and more efficient in 2018. The change in efficiency for the past several years explain why University of Chicago rise from #15 in 2005 to #3 in 2018 in university rankings.

According to Dan Mané (2012), a senior student, "Historically, UChicago has marketed itself for those seeking a totally rigorous intellectual environment at the expense of other niceties like fun, social life, etc. "Where Fun Comes to Die" was our slogan." This policy turned away many great students who wanted a more balanced college experience.

In the past few years the administration has made an effective shift to the brand and perception. One change was to use a common application essay, so more students can apply. Now the university has the intention of achieving more applicant pool and declines higher percentage. Another change was to hire a new admissions director and put more emphasis on career planning. So according to Dan Mané (2012), "UChicago has maintained its quirky and intellectually devoted character while also broadening its appeal and offering a more balanced college experience. (More fun.)"

Georgia Institute of Technology:

The objective function and constraints for Georgia Tech

Objective Function: Minimize E

Constraints:

$W_c + W_h + W_m + W_e + W_g + W_{ch} = 1$	Weights of Operating Units
$4.6W_c + 4.9W_h + 4.9W_m + 4.4W_e + 4.5W_g + 4.5W_{ch} \geq 4.5$	Academic Reputation
$25W_c + 35W_h + 36W_m + 21W_e + 24W_g + 41W_{ch} \geq 24$	Alumni Giving Rate
$94W_c + 97W_h + 93W_m + 91W_e + 86W_g + 94W_{ch} \geq 86$	Actual Graduation Rate
$97W_c + 97W_h + 98W_m + 94W_e + 97W_g + 99W_{ch} \geq 97$	Avg. Freshman Retention Rate

$8W_c + 5W_h + 8W_m + 25W_e + 26W_g + 8W_{ch} \leq 26E$	Acceptance Rate
$3W_c + 7W_h + 3W_m + 9W_e + 20W_g + 5W_{ch} \leq 20E$	Student Faculty Ratio
$9W_c + 4W_h + 12W_m + 19W_e + 178W_g + 3W_{ch} \leq 178E$	Faculty Resources Rank
$2W_c + 8W_h + 3W_m + 18W_e + 55W_g + 4W_{ch} \leq 55E$	Financial Resources Rank
$1W_c + 3W_h + 3W_m + 23W_e + 22W_g + 1W_{ch} \leq 22E$	Student Selectivity Rank
$E, W_c, W_h, W_m, W_e, W_g, W_{ch} \geq 0$	

Another DEA is conducted on Georgia Institute of Technology measures. Efficiency index is at 25% and that the Composite school is formed from the weighted average of California Institute of Technology ($W_c = 0.50$) and Harvard University ($W_h = 0.50$). Similar interpretation to that of Emory's can be stated. The efficiency index at 25% shows that the Composite school can obtain at least the same level of each output that Georgia Tech obtains by having available no more than 25% of the input resources required by the composite school. Obviously, Georgia Tech is relatively inefficient. The actual graduation rate (GR) has surplus of 9.5%. This difference shows that composite college is performing better than Georgia Tech. Another example is the faculty resources rank. The slack of 38 shows that as far as the faculty resources are concerned the composite school is in a position much higher than Georgia Tech.

Applying DEA to this school using previous data revealed that the school efficiency index was 0.2653 in 2005-06. Georgia Tech is a public university and according to Tagami (2016), "Georgia had some of the biggest school budget cuts in the nation during and after the Great Recession. According to the report by the Center on Budget and Policy Priorities, Georgia had the fourth-largest proportional cut in state per-student funding from 2008 to 2014". Comparing the outputs, during this period from 2005-2018 the actual graduation rate increased by 10% and alumni giving rate dropped by 7%.

Finally, for the sake of completeness DEA is performed on MIT, Harvard University, and California Institute of Technology and efficiency index is found to be E=1. It indicates that there is no evidence that above mentioned universities are inefficient. As conventional wisdom goes elite universities usually remain elite and have "sticky" reputations.

CONCLUSION

Based on the findings, there is evidence that Georgia Tech and Emory University are relatively inefficient compared to the schools in the system. University of Chicago relative to the other two Universities is much more efficient. The composite schools can provide the current level of outputs with fewer inputs. It can also be concluded that Emory and Georgia Tech efficiency index deteriorated over this period whereas University of Chicago's index improved from E=0.6129 to E=1. This could be due to increase in alumni giving rate and drop in student faculty ratio.

Other methods like regression analysis are also used in literature to rank efficiency of different operating units. Both DEA and regression analysis methods have their advantages and disadvantages. The advantage of DEA is that it measures the efficiency of a DMU against well performed units not against average performance, which is the case in regression analysis. DEA does not require a functional relationship between output and inputs and multiple outputs

can be used. On the other hand, regression analysis results are more stable and lend themselves to hypothesis testing.

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DECISION SCIENCES INSTITUTE
Determinants of Intention to Undergo a Gastric Sleeve Surgery

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ABSTRACT

This paper examines factors that affect the behavioral intention (BI) towards undergoing a gastric sleeve surgery (GSS). A research model, based on the theory of reasoned action (TRA) and the decomposed version of theory of planned behavior (TPB), was developed and empirically tested using an online survey questionnaire. Antecedent variables are attitude (A), body appreciation (BA), subjective norm (SN), price value (PV), satisfaction with life (SWL), relative advantage (RA), and perceived risk (R). The results showed that attitude toward gastric sleeve surgery, body appreciation, and subjective norm have significant positive effects on the intention to undergo a gastric sleeve surgery.

KEYWORDS: Gastric sleeve surgery, Obesity, theory of planned behavior, decomposed theory of planned behavior, Qatar

INTRODUCTION

Obesity has reached epidemic and disastrous proportions during the 21st century; the worldwide prevalence of obesity is more than 20% (Leitzmann et al., 2006). Obese people could result in disease like type 2 diabetes, hypertension, obstructive sleep apnea, several cancers, depression, diminished average life expectancy and significant impairments in quality of life. Obesity occurs if the energy intake was greater than energy expenditure on the long term and this eventually result in positive energy imbalance. This imbalance can develop from excess in calorie intake and/or a deficit in calorie expenditure (Shepherd et al., 2011). The prevalence of obesity has reached epidemic proportions; nearly 37 % of men and 38 of women worldwide are with a body-mass index (BMI) of 25 kg/m2 or greater (Ng et al., 2014). The obesity in Qatar may have just passed the United States, which was long the world leader. According to a report released by the Qatar Biobank more than 70 percent of the population in Qatar is either overweight or obese (Gichuki, 2017). For that reason, people in Qatar must put more effort to ensure a healthy future, free of diabetes and obesity illnesses, for themselves and their children. According to Katz (2013), the prevalence of diabetes in Qatar is approximately twice as great as in the United States, some 17% of the population as compared to the United States 8.3%. Morbidly obese patients have chosen surgical options like the weight loss bariatric surgeries to lose weight and to maintain the weight loss because diet and exercise alone have been shown to be largely unsuccessful in managing their obesity (Karmali et al., 2012). There are many surgical options that provide significant degrees of weight loss; however, Bariatric surgery is not risk free. Illness and mortality rates resulting from bariatric surgery continue to be a major concern (Habermann et al., 2009). The gastric sleeve surgery (GSS) is considered as the magical solution once done, the ultimate goal of having a thin ideal body is fulfilled. The GSS

also called vertical sleeve gastrectomy or laparoscopic sleeve gastrectomy is a surgical weight loss procedure in which the stomach is reduced to at least 75% of its original size, resulting in a new, tube-shaped stomach or “sleeve” and leads to significant decreases in Ghrelin production, leading to further weight loss. So many people have done it and so many people are willing to do it and more shockingly people who don’t suffer from any overweight issues intend to do it to control their weight. In this paper, we will investigate the factors that would influence the people intentions to undergo a gastric sleeve surgery, which is a weight loss surgery. Knowing those factors will help the health institutions and the society as a whole to control this surgical trend.

LITERATURE REVIEW

Theory of reasoned action (TRA) was developed by Fishbein and Ajzen (1975). This theory posits that the strongest predictor of a volitional behavior is the behavioral intention (BI). And the behavioral intention (BI) is thought to be the result of individual influence or behavioral attitude (A) (attitude towards a behavior) and nominal influence, the subjective norms (SN) of peer influence (Dillard, 2002). Theory of planned behavior (TPB) implied that human behavior is determined by intention to perform the behavior, which is affected jointly by attitude toward behavior (A), subjective norm (SN) and perceived behavioral control (Ajzen, 1991). Attitude (A) refers to a one’s attitude towards a certain behavior; it describes the general feeling of one’s desirability or undesirability of a specific behavior. Subjective norm (SN) expresses the perceived social pressure – pressure of significant people- on a person who intends to perform a particular behavior. On the other hand, Perceived behavioral control (PBC) measures one’s perception of the ease or difficulty of executing a particular behavior. Taylor & Todd (1995) developed the decomposed TPB model which includes additional factors such as relative advantages, compatibility, complexity, and facilitating conditions. The proposed model is based on theory of reasoned action and the decomposed version of (TPB) but with some modifications.

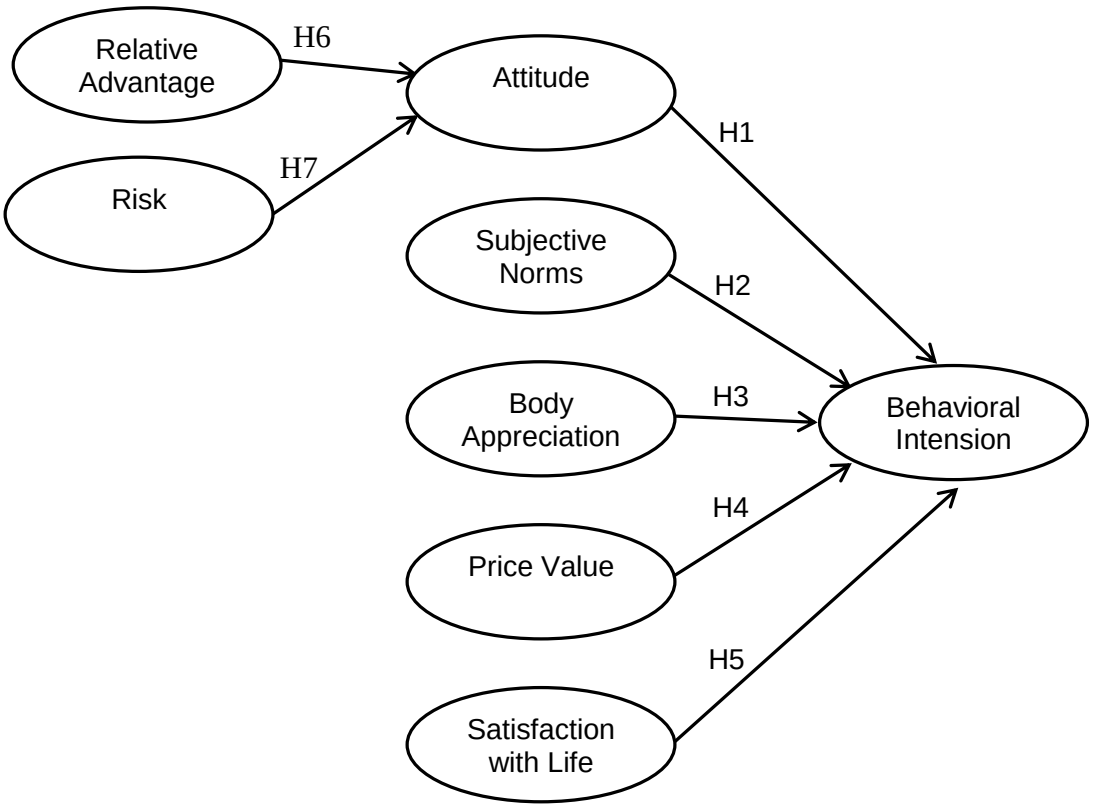
THE RESEARCH MODEL AND FORMULATION OF THE HYPOTHESES

In this study, the dependent variable is the intentions to undergo a gastric sleeve surgery as shown in Figure 1. Behavioral attitude (A) refers to an individual’s acceptance to undergo a GSS. The acceptance or positive behavioral attitude (A) will be affected by the positive influence of the relative advantages (RA) and the negative influence of the perceived risk (R) associated with GSS. This association indicates how important it is for that individual to have specific advantages and risk free surgery. The subjective norm (SN) refers to an individual’s perception of undergoing a GSS by peers (family and friends). The complexity transformed into perceived risk to better suite the study. Some additions were added by the researchers to this model; the effect of body appreciation, price value and satisfaction with life to the behavioral intention as shown in Figure 1.

Behavioral Intention (BI)

Intention is a sign of a person's willingness to do a given behavior, and it is considered to be the direct predecessor of behavior (Ajzen, 1991). In the TRA, The intention is based on attitude toward a behavior, and the subjective norm. In this paper, the following factors will be considered as predictors of the individual’s intention to undergo a GSS. These factors include attitude, subjective norms, price value, body appreciation, and satisfaction with life.

Figure 1: Research Model



Attitude (A)

Attitude is a psychological tendency that is reflected by examining a particular matter with some degree of favor or disfavor (Eagly and Chaiken, 1993). The behavioral attitude in TRA and TPB models refers to the person's attitude towards a certain behavior and in this paper; the behavior is undergoing a GSS. Furthermore, an attitude is an effective response toward performing some behavior and not toward some generalized attitude object (Dillard, 2002). Research on the association between attitudes and intention is extensive, and suggests attitudes toward cosmetic surgery should positively relate to future intention for the practice (Cho & Seong, 2010). Thus, we propose the following hypothesis:

H1: There is a significant positive relationship between attitude toward GSS and intention to undergo GSS.

Subjective Norms (SN)

According to Ajzen (1991), the subjective norm is defined as the perceived social pressure to engage or not to engage in an act or a behavior. In addition, it can be defined as a person's belief whether important people feel that she or he should perform a target behavior (Dillard, 2002). Significant or important people can be characterized as people who influence one's decisions and behaviors such as parents, friends, experts, and celebrities. In this paper, the researchers will examine the influence of significant people on one's intention about whether or not to undergo a GSS. Although no research to date has examined parental and peer influences on positive intention to undergo a GSS, Cafri et al., (2006) has found that there are family influences related to intentions to suntan, which is an activity also aimed at improving physical appearance that just like any bariatric surgery that carries a health risk. We predict that the more an individual parents and friends focused on body appearance, the more positive an individual will be toward undergoing a GSS. We posit the following hypothesis:

H2: There is a significant positive relationship between subjective norms and intention to undergo GSS.

Body Appreciation (BA)

In this paper, the concept of body appreciation is defined as how an individual recognizes and enjoys the good features of his or her body. Avalos, Tylka & Wood-Barcalow (2005) defined body appreciation by holding a positive evaluation of the body, accepting it as it is, respecting and attending to its needs and protecting it by rejecting unrealistic appearance ideals. Based on previous research done by Cash et al., (2005); Henderson-King & Henderson-King, (2005); Sperry et al., (2009); and Swami et al., (2009), it was predicted that individuals with less body appreciation, a higher body mass index (BMI), would report greater consideration of cosmetic surgery (Swami, 2009). Self-perceptions of attractiveness and satisfaction with appearance, which both are under the body appreciation umbrella, have been shown to be substantial predictor of interest in cosmetic surgery (Diraddo et al., 2009). As a contribution to literature, the researchers will study the influence of an individual's body appreciation on the intention towards undergoing a GSS, so the following hypothesis is proposed:

H3: There is a significant negative relationship between body appreciation and the intention to undergo a GSS.

Price Value (PV)

In marketing research, the monetary cost or price is usually hypothesized together with the quality of products or services to determine the perceived value of products or services (Zeithaml, 1988). Price value can be defined as consumers' cognitive compromise between the perceived benefits of the applications and the monetary cost for using them (Dodds et al. 1991). The price value is positive when the benefits of undergoing a GSS are perceived to be greater than the monetary cost and such price value has a positive impact on intention undergoing the surgery. Thus, price value is included as a predictor of behavioral intention to undergo the GSS. Literature suggests that the cost of surgical procedures has decreased as the number of surgeries performed has increased, which makes the option affordable for more people (American Society for Aesthetic Plastic Surgery, 2009). Another contribution to literature is to

measure the influence of price value on an individual's intention to undergo a GSS, so the following hypothesis is proposed:

H4: There is a positive significant relationship between price value of GSS and Intention to undergo GSS.

Satisfaction with Life (SWL)

Life satisfaction can be defined as the cognitive or mental factor of personal wellbeing (Martikainen, 2008). According to Diener (2000), satisfaction with life is a cognitive evaluation of overall quality of the life. Life satisfaction is one of the essential constructs of well-being. There are many potential factors that affect the level of satisfaction with life. These include personality, social expectations, socioeconomic factors, relationships with significant others, physical and psychological health, accommodation, employment and problem with authority (Schimmack et al., 2002). The physical and psychological health factors are definitely negatively affected by obesity, and this may result in low levels of life satisfaction. The level of satisfaction with life could result in high health status (like being fit) or low health status (like being Obese), and commonly when the person is obese he or she will look for solutions reduce their weight (positive intention to have a GSS), so we propose the following the hypothesis:

H5: There is a significant negative relationship between satisfaction with life and intention to undergo a GSS.

Relative Advantage (RA)

In this paper, we investigate the influence of two constructs; relative advantage of GSS and perceived risk on the behavioral attitude of an individual that will result in impacting the intention to undergo a GSS. Relative advantage refers to the case where an invention provides benefits, which surpass those of its predecessor and may incorporate factors such as financial benefits, image, enhancement, convenience and satisfaction (Rogers, 1983). Relative advantages should be positively related to an innovation's rate of adoption (Rogers, 1983; Tan & Teo, 2000). Relative advantage represents the extent to which the innovation is perceived to be superior in both economic and non-economic considerations to alternatives that are already available. And for this paper, the innovation is the invention of GSS. Undergoing a GSS will allow the individual to have a better look, health, and feeling. Therefore, the surgery provides a tremendous advantage and convenience to individuals. People will look for innovations that provide an advantage over the current products or services (Kleijnen et al, 2011). It can be concluded that relative advantage will also play a role in respect to the attitude and intention toward the GSS, so the following hypothesis is proposed:

H6: There is a significant positive relationship between relative advantage of the GSS and the attitude towards GSS.

Perceived Risk (R)

The International Organization for Standardization (ISO) defines risk as the "effect of uncertainty on objectives" (ISO, 2009). Uncertainty is the reason for any risk and uncertainty means not reliable and not identified (Borek et al., 2014). Introducing a new surgical advances may involve both benefits and risks to the patients, and before deciding to undergo any surgical advances, the patient may want to weigh risks and benefits. According (Gutteling et al., 2007), whenever

the perception of the risk is large, the perceived benefits will be less. Undergoing a GSS will have some risks that will negatively affect the attitude towards undergoing it. The perceived risk increases with the higher level of uncertainty or with an increased chance of negative outcomes (Lu et al., 2005). Moreover, it has been found that social risk has a negative impact on attitude for consumers (Yang et al., 2007). The perceived risks of having a cosmetic surgery – risks could be unfavorable physical and psychological outcomes- will negatively influence attitudes toward the practice (Cho & Seong, 2010). Therefore, it can be concluded that perceived risk of having a GSS will influence the attitude and consequently the intention toward undergoing the surgery, so we propose the following hypothesis:

H7: There is a significant negative relationship between the perceived risk of the GSS and the attitude towards GSS.

METHODOLOGY

Data Collection

An online survey was used for data collection. The questionnaire included 37 questions excluding demographics, and distributed in two languages Arabic and English. The questionnaire was distributed through emails and social networks.

Measures

The questionnaire items in this study were adopted from the literature. The scales where modified and tailored to suit the research topic of this study. A five-item Likert scale (ranging from 1-strongly disagree to 5-strongly agree) was used for all measures except demographics. Items measuring body appreciation were adopted from (Avalos et al., 2005). The three items that measure price value were adopted from (Dodds et al., 1991). Perceived risk scale items were adopted from (Featherman & Pavlou, 2003). Intention scale items were adopted from (Cheng et al., 2006); (Venkatesh et al., 2003); and (Taylor & Todd, 1995). Items to measure the relative advantage, behavioral attitude and subjective norms were adopted from (Taylor & Todd, 1995). Satisfactions with life items were adopted from (Diener et al., 1985).

DATA ANALYSIS

Characteristics of the Sample

A total of 256 participants returned the questionnaire; all the respondents complete the questionnaire fully except 10 respondents didn't fill the demographics part. The demographics part of the survey covered: gender, marital status, age, monthly income, education level, nationality, a question asking the participant if he or she had undergone the GSS, body shape, and a question about the influencing factor what might make the participant to undergo the GSS. The sample had 81 percent females. The majority of the participants were Qataris and between 26 and 35 years old. Approximately 60 percent of the participants are married. Almost 45 percent of participants receive a monthly income above 30,000 QAT. The majority (56 percent) has a bachelor degree. Eleven percent of the participant did undergo the GSS and almost 60 percent of the sample described their bodies as plump and overweight.

Reliability and Validity Assessment

It was important to ensure the reliability of the data before examining the factors that influence the positive intention of having a GSS. Cronbach's alpha is used to measure the reliability. According to Nunnally (1978), the standard reliability value of a scale should be above 0.7. In the Appendix, the means, standard deviations, and Cronbach's alpha for all items were reported. The values for all Cronbach's alphas were greater than 0.80 except one construct that is Risk, its' Cronbach's alpha was 0.584 and after dropping one statement (R3), the Cronbach's alpha increased to 0.646; and therefore, they all displayed good internal consistency. The validity was assessed using exploratory factor analysis. Factor analysis was performed on all items that are predictors of the dependent variable, the Intention. The assessment was done including the six predictors. Principle component analysis with varimax was used, the measures of each construct clustered together. All items loaded on their intended factor. A confirmatory factor analysis was performed to assess the model fit. The NFI index was 0.93 and the CFI index was 0.96 both exceeded 0.9 the accepted value as suggested by Comrey and Lee (2013). The other index, the root mean square error of approximation (RMSEA) was 0.07, which is less than 0.08, the accepted value as suggested by Hu & Bentler (1999). Additionally, we employed Harman's single factor test to assess if common method bias exists in this study. Only 31% of the variance was accounted for one single factor, which is less than the threshold value of 50% as suggested by Podsakoff et al. (2003).

RESULTS

Several tests were performed to ensure that the assumptions of the multiple regression models were not undermined. Multicollinearity was not a problem because the variance inflation factors (VIFs) were low 1.566. From the Durbin-Watson statistic test, it was concluded that autocorrelation did not exist (D.W. =2.028). In addition, the plot of the dependent variable against each of the independent variables showed a linear relationship between these respective variables.

Hypotheses Testing

To answer the first research questions (What are the factors that influence the one' intention to undergo a GSS?); the multiple regression analysis was performed to test hypotheses H1, H2, H3, H4 and H5. The dependent variable behavior intentions (BI) was regressed against behavioral attitude (A), price value (PV), satisfaction with life (SWL), body appreciation (BA), and subjective norm (SN). As shown in Table 1, the regression result indicated that H1, H2, and H3 were significant and explained 78 percent of the variance in behavioral intention for the sample. The second research question was (What are the factors that influence the behavioral attitude (A) towards the GSS?), another multiple regression analysis was performed to test hypotheses H6, and H7; the dependent variable behavior attitude (A) was regressed against relative advantage (RA), and risk (R). The regression result indicated that the two factors were significant and explained 45 percent of the variance in behavioral attitude (A).

Table 1: Regression Results

Reg. Model	Dep. Variable	R^2	Independent Variables

Model 1	Intention	0.779	Attitude (H1)	Subjective Norm (H2)	Body Appreciation (H3)	Price Value (H4)	Satisfaction with Life (H5)
			0.705 (0.000)	0.199 (0.000)	-0.143 (0.000)	-0.009 (0.769)	0.049 (0.156)
Model 2	Attitude	0.451	Relative Advantage (H6)	Risk (H7)			
			0.554 (0.000)	-0.281(0.000)			

DISCUSSION AND CONCLUSION

This study examined how factors like (attitude)--the feelings, and behavioral tendencies towards the GSS; (subject norm)--the perceived social pressure to engage or not to engage in undergoing a GSS; (body appreciation)--how an individual recognize and enjoy the good features of his or her body; (price value)--the cognitive compromise between the perceived benefits of the GSS and the monetary cost for it; (satisfaction with life)--the cognitive assessment of one's life, influence the individual's intention to undergo a GSS. The study intended to examine influences of the above-mentioned factors on individuals' intentions to undergo a GSS. The findings of the research showed three significant factors in model 1 and two significant factors in model 2. The results showed compatibility with the theory of planned behavior (TPB) framework as suggested by (Ajzen, 1991). The higher positive attitude towards the GSS, and the higher subjective norm influence, the higher the positive intention of undergoing it will be. In addition, the research findings supported prior research results in which, self-perceptions of attractiveness and satisfaction with appearance, which both are under the body appreciation umbrella, have been shown to be substantial predictor of interest in cosmetic surgery (Diraddo et al., 2009). It should be noted that attitude (Beta=0.705, Sig.= 0.000) towards the GSS had the most significant impact on behavioral intention, followed by subjective norm (Beta=0.199, Sig.= 0.000) and body appreciation (Beta=-0.143, Sig.= 0.000). Since the objective of this study goes beyond finding the major influences on individuals' intention only, the researchers hope once those major factors are identified, they are controlled and get close attention in order to gauge the increase in the number of gastric sleeve procedures.

Since attitude has the highest influence on the intention, a close attention must be paid to it. In this research, attitude was predicted by risk (Beta=-0.281, Sig.= 0.000) and relative advantage (Beta=0.554, Sig.= 0.000), and both factors were significant. These two factors can be controlled to reduce the positive attitude on undergoing a GSS. The risk and negative circumstances of this surgery must be highlighted more than its advantages. Having the relative advantage as the highest influencing factor on the attitude was not surprising. Recently in Qatar, people who were well known for their big bodies and obesity; suddenly transforming into models. This phenomenon made individuals, whether they are overweight or not, to see the GSS as a miracle that offers the ideal body in a very short period, which is a remarkable advantage that overweighs the risk. Thus, few people who know the risks of the GSS or even challenge it.

The subjective norm was also another influencer on the intention, this complies with the theory in general, but more specifically when talking about Qatar, we live in a collectivism or in other words socialism community, so the chances of being affected by parents, relatives, and friends is high. Thus, opposing to individualism society, where individuals pursue their own goals

without being, to some extent, affected by others. In collectivism cultures, people put higher importance on belonging to a group and respect opinion of the other members of the society (McCoy et al., 2007). Body appreciation effect on the behavioral intention was significant. People who appreciate their bodies will have a negative intention towards changing anything in their bodies. It should be noted that price value and satisfaction with life were not significant. The insignificance of price value might be caused by the fact that Qatar income is considered as one of the highest in the world, in addition almost 45 percent of the respondents have a monthly income of 30,000 and above. For the satisfaction with life, the insignificance maybe because the scale used was very general. Satisfaction with body scale might be more appropriate.
The results of this study provide insights for both practitioners and public. Practitioners should raise the awareness of the Gastric Sleeve Surgery in terms of its short and long term risks, benefits, and limitations. With the support of health institutions, they should work harder in changing the unhealthy mindset of people in regards to sport, healthy food and healthy life style. This could be achieved through social media messages about the GSS. In addition, outreaching the school students, who are the future of any society, and involve them in activities that reinforce the importance of healthy diet and sport. Achieving this will build a negative attitude toward any weight loss surgical practice and will shift their actions towards sport, and healthy diet. Same responsibility applies to the individuals themselves. They should be more attentive to their body needs and must try all possible solution before undergoing a surgical procedure for weight loss rather than being hasty and look for the immediate solution, also they should not be directed by the word of mouth of peers.

LIMITATIONS AND FUTURE RESEARCH

Although the findings of the study offer valuable insights into obesity and weight loss surgeries literature; however, these findings should be interpreted in light of the following limitations: The relatively small sample size, and self-reported information. Future research could include more factors such as complexity, perceived behavior control, and facilitating condition. Increase the sample size and conduct a similar study in deferent countries.

APPENDIX: DESCRIPTIVE STATISTICS AND RELIABITITY			
Items	Measures	Statistics	
		Mean	S.D.
Intention: Cronbach's Alpha=0.953			
IN1	Given that I have access to a gastric sleeve surgery, I predict that I would undergo the surgery if I gained weight	2.63	1.31
IN2	I intend to undergo gastric sleeve surgery in the future if I am overweight	2.57	1.336
IN3	I plan to receive gastric sleeve surgery in the future to look better	2.39	1.27
IN4	I will consider gastric sleeve surgery as my first option if I gain weight	2.18	1.221
Price Value: Cronbach's Alpha=0.866			
PV1	A gastric sleeve surgery is reasonably priced	2.75	1.062
PV2	A gastric sleeve surgery is a good value for the money	3.01	1.074
PV3	At the current price, a gastric sleeve surgery provides a good value	2.93	1.058
Body Appreciation: Cronbach's Alpha=0.890			
BA1	On the whole, I am satisfied with my body	3.55	1.197
BA2	Despite its flaws, I accept my body for what it is	3.58	1.195
BA3	I take a positive attitude toward my body	3.75	1.043

BA4	My feelings toward my body are positive, for the most part	3.69	1.019
BA5	I respect my body	4.05	0.85
BA6	I am attentive to my body's needs	3.66	1.031
BA7	I engage in healthy behaviors to take care of my body	3.52	1.036
Subjective Norm: Cronbach's Alpha=0.952			
SN1	People who are important to me would want me to undergo the gastric sleeve surgery if I gained weight	2.21	1.196
SN2	People who influence my behavior would want me to undergo the gastric sleeve surgery if I gained weight	2.27	1.181
SN3	People whose opinions that I value would prefer that I undergo a gastric sleeve surgery if I gained weight	2.25	1.198
SN4	Most people who are important to me would think that receiving a gastric sleeve surgery is a wise idea if I gained weight	2.29	1.169
SN5	Most people who are important to me would think that receiving a gastric sleeve surgery is a good idea if I gained weight	2.34	1.223
Attitude : Cronbach's Alpha=0.919			
A1	I would like to undergo a gastric sleeve surgery if I need it	2.81	1.304
A2	I feel receiving a gastric sleeve surgery is a wise idea	2.62	1.228
A3	I feel receiving a gastric sleeve surgery is a good idea	2.73	1.269
Satisfaction with Life: Cronbach's Alpha=0.848			
SWL1	The conditions of my life are excellent	4.04	0.74
SWL2	I am happy in my life	4.18	0.693
SWL3	I have gotten the important things I want in my life	4.16	0.726
Relative Advantage: Cronbach's Alpha=0.873			

RA1	If I gained weight, receiving a gastric sleeve surgery will make me feel better than before	3.18	1.283
RA2	If I gained weight, receiving a gastric sleeve surgery will make my health better than before	3.11	1.311
RA3	If I gained weight, receiving a gastric sleeve surgery will make me look better than before	3.41	1.316
Risk: Cronbach's Alpha=0.646			
R1	The Gastric sleeve surgery may not be successful and result in sever circumstances	3.82	1.081
R2	It would take me lots of time to cope with a reduced stomach size if I did the surgery	3.86	1.014
R3	If an error occurs during the surgery, I worry that I cannot get the result I wanted (lose weight)	4.02	1.021

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Developing a Data Analytics Course to Build Undergraduate Experiential Learning in Technology Entrepreneurship

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ABSTRACT

Over the past decades, data analytics and related applications and technologies have become increasingly important. Accordingly, job postings seeking data analytics specialists abound. In response to the tremendous needs of the job market, higher education institutions have invested millions of dollars to develop data analytics curriculums, minors, majors, and certificate programs. Based on the nature of big data and data analytics, this paper proposes a data analytics course to enhance undergraduate experiential learning in technology entrepreneurship. Course description, learning objectives, pedagogical approaches, faculty team of course development, and supportive entrepreneurial ecosystem for the course teaching are discussed.

KEYWORDS: Data Analytics, Course Development, Undergraduate, Information Systems

INTRODUCTION

Data analytics refers to collect, analyze, and present the user-generated contents and data to gain meaningful insights into organizational practice, processes, and trends (Chen et al, 2012). Over the past decades, data analytics and related applications and technologies have become increasingly important in both academic and business communities, suggesting the ways in which enterprises such as businesses, non-profits, and governments use various data to gain insights and make better decisions. Nowadays, companies and organizations (e.g., Walmart, Google, Capital One, and Disney) are embracing data analytics applications and technologies to reengineer business operations and decision making (McAfee et al, 2012).

Accordingly, in the labor market, job postings seeking data analytics specialists abound. Manyika et al (2004) predicted that by 2018, the United States alone will need 2 million data-savvy workers and managers with analytical skills and education. Business demands are in increase for

employees with skills and training needed to manage the three “perspectives” of decision making: descriptive, predictive, and prescriptive analytics. Boasting a base salary of $110,000 and a job-satisfaction score of 4.4 of 5, data analytics were ranked No. 1 on the “Best Jobs in America” list in 2016 and 2017 (The Market Watch Reports, 2018).

In response to the tremendous needs of the job market, higher education institutions have invested millions of dollars to develop data analytics curriculums, minors, majors, and certificate programs. In the local area, however, our survey shows that the local businesses and companies are still in large need for data analytics workers at the entry undergraduate level. To fill this gap, we propose the data analytics course to enhance undergraduate experiential learning in technology entrepreneurship.

BIG DATA & BIG DATA ANALYTICS

Big data can be characterized with the following dimensions (De Mauro et al, 2016; McAfee et al, 2012; Suthaharan, 2014). (1) Variety. The scope, types and formats of big data extend from traditional structured to semi-structured and unstructured data of all varieties. (2) Volume. The word, big, describes the vast quantity of the data explosion. (3) Velocity concerns both frequency and speed of big data explosion. And, (4) variability refers to the wide inconsistencies of big data. The essential of big data is to collect, analyze, and present the user-generated contents and data to gain meaningful insights into businesses practice, processes and trends. This process has been referred to as data analytics in which the dataset can be so large, various, complex, and ever changing that unique advanced computing technologies and techniques of data management, analysis, and visualization have to be deployed to address the significant impacts (Fan & Gorden, 2014).

DEVELOPING A DATA ANALYTICS COURSE TO BUILD UNDERGRADUATE EXPERIENTIAL LEARNING

Course Description & Learning Objectives

Big data analytics focus on understanding, interpretation, strategizing, and taking action to further business interests. To reflect the characteristics of big data, and map major techniques and technologies of data analytics to the organizational needs for skilled undergraduate learners, we propose the course description as,

> With the increasing availability of broad and various sources of data – so-called “Big Data” that refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze – data analytics is becoming an even more critical capability for enterprises of all types and all sizes. In this course, students will learn to identify, evaluate, and capture data analytic opportunities that create business value. Toward this end, students will learn basic data analytics principles and methods and analyze case studies on organizations that successfully deployed these techniques. Throughout the course, we will explore the challenges that arise in implementing analytical approaches within an organization. Specifically, the course provides an overview of data analytics concepts, principles, procedures, techniques, technologies and applications for business data gathering, storing, processing, manipulating, and interpreting. The course discusses and demonstrates the associated statistical approaches and data mining techniques that arise in the area. Students will learn

key procedures and techniques of data analytics such as parallel algorithms, text mining, social network analytics, machine leaning, data mining, and descriptive, predictive and prescriptive analysis. The applications associated with each technique (such as the fundamental platforms, Hadoop/MapReduce, R, Python, and Tableau) will be hand-on-practice in the form of individual assignments and teamwork project.

Throughout the course, we will emphasize the entire data analytics cycle, which includes the following stages: (1) understanding of business and its opportunities, challenges, and problems; (2) data understanding and preparation; (3) modelling: construct a model to address business interests; (4) evaluating: evaluate possible models and solutions; and (5) deployment and recommendations of data analytics modeling. Accordingly, we have three goals in this course. The first is to help you develop mindset of analytics and think critically about business and data. The second is to enable you to identify opportunities for creating value using data analytics. The third is to help you analyze and estimate the value created using data analytics to address an opportunity.

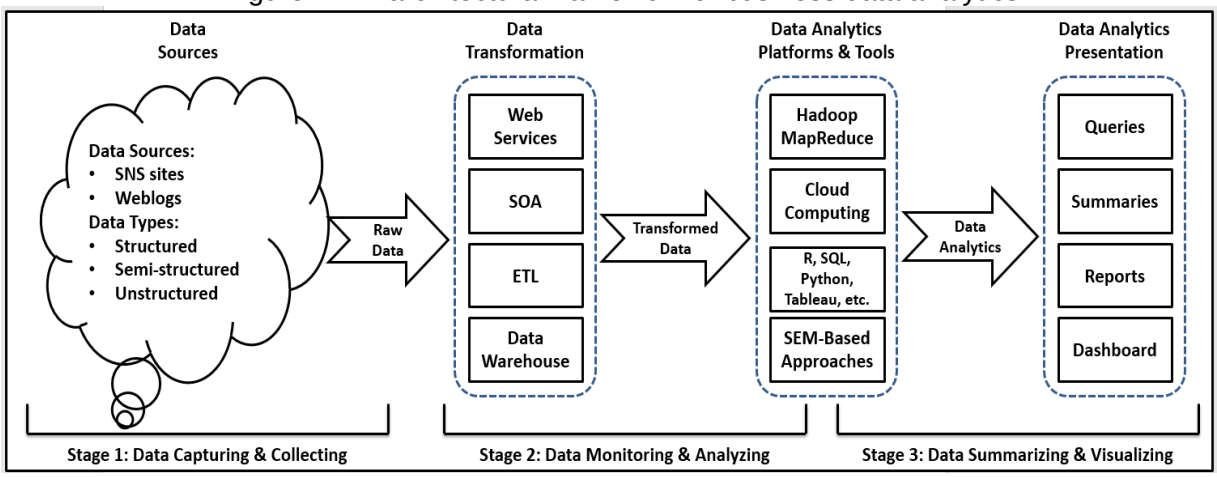
In line with the course description, the prerequisites for the course are required regarding the general understanding of database, information systems (IS) analysis and design, network and data communication (Chen et al, 2012; Fan & Gorden, 2014; Raghupathi & Raghupathi, 2014; Stigelitz & Xuan, 2014; Zeng et al, 2010). Upon the successful completion of the course, undergraduate students should be able to,

- Explain the ideas of data analytics to support business operations and decision making.
- Understand how to determine the appropriate data analytics tools, technologies, techniques for intended business analysis.
- Understand how to extract, transform, load and analyze business dataset upon defining business objectives.
- Design and implement data analytics solutions to address business interests, problems and opportunities.
- Report and illustrate to business stakeholders the procedures, interpretations, and deployment and recommendations of data analytics.

Data Analytics Architecture

We propose a data analytics architecture to facilitate the course teaching. As illustrated in Figure 1 below, the architecture integrates Hadoop/MapReduce, cloud computing, R, SQL, SEM, and other associated technologies and applications of data analytics into the organizational decision making setting (Hu et al, 2018). The content coverage systematically trains students with data analytics skillset and mindset.

Figure 1: An architectural framework of business data analytics



- Hadoop/MapReduce – an open source software framework providing computational capabilities for distributed storage and processing of large, various and complex datasets.
- Python – Python has a powerful data analysis library that provides powerful analytics tools suited to handle big datasets.
- Cloud Computing. Due to the flexibility and effectiveness of cloud computing, many data analytics technologies can be deployed without specific setup expertise.
- R & Tableau. R is an integrated suite of database environment for predictive analytics, data mining and data visualization. Tableau is an interactive data visualization tool. R and Tableau are bundled with an integrated collection of intermediate tools for data analytics.
- SEM-Based Approaches – A diverse set of computing algorithms and statistical methods for factor analysis, path analysis, and latent growth modeling.
- SQL & NoSQL. The SOL is still used heavily as a primary approach to querying big data. Meanwhile, applications of NoSQL and Interactive SQL can be embraced to examine semi-structured and unstructured data.
- Others: For data analytics methods (e.g., content analysis, text mining, opinion/sentiment analysis, social network analysis etc.), many tools provide programing interfaces for business use.

Pedagogical Approaches

The course will be taught in the form of student teamwork modules covering interrelated topics of data analytics technologies, procedures, and techniques. Teaching activities consist of instruction lectures, demos of analytics techniques and technologies, hand-on-exercises, teamwork projects, team presentations and discussions, and invited talks of researchers and business practitioners. The textbooks and materials will be reviewed; requests for review copies will be made to determine the required and complementary readings for the course.

Student Teamwork Projects

Modular teamwork projects will be assigned and used to evaluate student performance in the course; project teams of 3-4 students will be formed. The purpose of the teamwork projects is to

allow students to apply many of data analytics concepts, techniques and technologies to a specific business context. The projects will provide students with significant experiential leaning on which they can develop relationships and enhance technology entrepreneurship with companies. Many skills in data analytics will be learned and reinforced in depth as the student teams work on the projects.

For the projects, student teams will either be provided the open source datasets, or will identify by themselves a company that has a significant business problem or opportunity that can be addressed through the collection and analytics of corporate data resources. The teamwork projects will be conducted based on business procedures, thus it is important that teams are able to define the business characteristics and processes to complete the various requirements of data collection and analytics. Essentially students will follow the stages of big data gathering, storing, manipulating, interpreting, and visualizing to address particular needs of the business.

FACULTY TEAM OF COURSE DEVELOPMENT

By nature, the data analytics course is multidisciplinary in that information systems (IS), computer science, statistics, management, and marketing are involved. It covers organizational behavior, critical analytical thinking, business domain knowledge, and oral and written communications that are critically needed in a complex data-centric business environment (Chen et al, 2012). Thus, IS programs and faculty are uniquely positioned to develop and teach the course and train data analytics workers.

Our team of the course development consists of four full time IS faculty members. Among them, the principal investigator takes primary responsibility to coordinate course development activities, and review teaching materials and textbooks. In the team, one of the faculty members currently serves as the Associate Chair of the Department, and will be responsible for maintaining the institutional support and the entrepreneurial ecosystem for the student teams, and establishing course evaluation criteria and assessing teaching outcomes. The rest of the team provides support for the construction, assessment and management of the course.

SUPPORTIVE ENTREPRENEURIAL ECOSYSTEM FOR STUDENT TEAMWORK TEACHING

The Department, the Business School, and the university, where the proposed course is housed, all have long established a welcoming supportive entrepreneurial ecosystem that focuses on providing students with practical business resources, skills and solid theoretical foundation needed for success in the business environment. The faculty and staff members of the departments, student career center, and college entrepreneurship centers have maintained long term relationships with alumni organizations, and internal and external business communities. The culture of collegiality, community, and commitment within the college largely facilitates students to interact with the real business world and market and commercialize their knowledge, skills and technologies.

CONCLUSION

Given the tremendous needs of both academic and business communities for data analytics workers, and the tradition and commitment of the department and college in establishing the supportive entrepreneurial ecosystem, we have full confidence that the proposed efforts in the construction and teaching of the data analytics course will continue well into the future in developing minor, major, and certificate and graduate programs in the subject matter. We also

have the strong faith that the course will be successful in satisfying the learning objectives, establishing best student teamwork practice, building data analytics skillset and technology entrepreneurship for undergraduate students, and further, helping student teams market and commercialize their skills, knowledge and technologies in data analytics.

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Development of a Composite Sustainability Risk Index for Outsourcing Country in Apparel Industry

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ABSTRACT

This paper presents the application of the data envelopment analysis cross efficiency method for creating a composite sustainability risk index and ranking of a country in terms of outsourcing production for contract manufacturing in the apparel industry. We consider sustainability-related supply chain risks found in the literature and group them into four major categories, (in use by Nike Inc.) for analyzing country level sourcing risk, namely: political, economic, social/compliance, and infrastructure and climate risks. The results of this study show that this method can be used to identify low-risk countries for making effective outsourcing decisions.

KEYWORDS: Data Envelopment Analysis, Supply Chain Risks, Sustainability, Outsourcing

INTRODUCTION

Global supply chains are complex, fragmented and often influenced by factors beyond the control and purview of individual firms, especially in terms of offshore outsourcing of production. Offshore outsourcing is a common cost reduction strategy in global supply chains but managing such a supply chain is often quite challenging. The U.S. apparel industry outsourced over 40% of its production to low-cost manufacturing countries (VF Corporation, 2016). This makes the supply chain vulnerable to external risks beyond the control of a company outsourcing its production. Such risks differ from country to country. These include: foreign government political risks, legislation and regulation, ethical labor practices such as fair wages, health & safety of workers, maintaining acceptable working conditions at production facilities in different countries, environmental issues such as use and/or disposal practices of toxic or harmful chemicals in manufacturing processes (for example, dyes and softeners), availability and cost of natural resources such as energy, cotton, rubber, and water, among others.

However, the first most important step in offshore outsourcing for global companies is the assessment of its offshore outsourcing countries for the overall risk that might disrupt its supply chain. Therefore, it is imperative to identify countries with low-risk based on both qualitative and quantitative approaches involving multiple criteria. This paper presents quantitative models for measuring and ranking of countries based on the overall outsourcing risk before selecting a contract manufacturer to add to its supply base. Traditionally, most global companies focus on low-cost countries which are not adequate in the current global business environment. Managing risks,

complexity and marketplace dynamics have become crucial for remaining competitive in the current global economy. In this study, we characterize supply chain sustainability-related risks found in the literature into four major categories, namely: political risk, economic risk, social/compliance risk, and infrastructure and climate risk; which are in use by Nike Inc. for analyzing country level sourcing risk.

Based on the unethical practice found in some countries, a factory owner might fail to comply with wage regulations and labor standards. A study by Maplecroft (2012) reveal that supply chains are exposed to the risk of child labor practices in some of the fastest growing economies, including the Philippines, India, China, Vietnam, Indonesia, and Brazil, all of which are classified as 'extreme risk' nations. This might have a negative impact on companies that outsource manufacturing to these countries. For instance, Nike's use of foreign manufacturers has periodically tarnished its image, and its campaign to eliminate such problems hasn't been easy (Banjo, 2014). Bangladesh, the No. 2 exporter of apparel after China is associated with unsafe working conditions, low wages, and persistent fire incidents at many of its garment factories for more than a decade, with hundreds of workers killed over the years (Manik and Yardley, 2012). This country's national economy depends largely on this industry, both as a source of employment and foreign currency because garments constitute about four-fifths of the country's manufacturing exports. Global retailers like Walmart and Sears outsource production to Bangladesh. In 2014, Walt Disney Co. pulled its manufacturing out of Bangladesh in response to a building collapse in the previous year. But retailers, including Wal-Mart Stores Inc., Hennes & Mauritz AB, and 170 others have chose to stay, signing five-year agreements, pledging to draw up safety standards and help fund improvements (Banjo, 2014). There is a need for companies to take a balanced approach to sourcing by taking into consideration environmental, social, quality and cost factors.

The apparel industry is unique and one of the most globalized industries in the world. For example, Nike Inc. value chain has more than 900 contract factories with more than 1 million workers and more than 500,000 different products - each with its own environmental and social footprint (NikeFY10/11 Report, 2011). Also, VF Corporation the world's largest publicly owned apparel company manufactures 21% of its products in China, 40% in Americas, 2% in India, 3% in Egypt, 3% in Indonesia, 11% in Vietnam, 12% in Bangladesh, and 12% in other countries (VF Corporation, 2016). A typical global supply chain comprises of multiple entities such as: a combination of retailers, contractors, subcontractors, merchandisers, buyers, manufacturers and suppliers. The whole supply chain system has become very critical for managing risk in a dynamic, and complex environment (i.e. a supply-driven commodity chain where each player's role is important in the supply network, which spans from fibers to yarn, to fabrics, to accessories, to garments, to trading, and to marketing) (Ramesh and Bahinipati, 2011). Thus, it is difficult in managing multiple priorities of controlling costs, environmental pressures, and maintaining acceptable working conditions. Although there are numerous articles studying the (decision) criteria to be used for the supplier selection process, relatively few papers address criteria related to safety and security issues, which have become extremely important, given the present threats to security and the current 'climate' around the world (Sonmez, 2006).

The remainder of this paper is organized as follows: section 2 gives a brief overview of Data Envelopment Analysis (DEA) model and cross efficiency ranking methodology. Section 3 presents the basic DEA model and solution approach used in this study. Section 4 provides the details of the DEA model evaluation and the analysis results. The last section concludes with a summary as well as some managerial implications of this study.

DATA ENVELOPMENT ANALYSIS (DEA)

Data Envelopment Analysis (DEA) is a linear programming-based method (non-parametric) originally developed by Charnes et al. (1978). Since its introduction, DEA has been extensively studied and applied by researchers in various fields such as management, healthcare, agriculture, environment, transportation, social sciences, public policy, engineering, and education, among others. Unambiguously, this shows DEA's significance and relevance to researchers far and beyond OR/MS, the disciplinary base of the field's founders (Gattoufi et al., 2004). The DEA model allows us to evaluate the relative performance of decision-making units (DMU) by determining a set of optimal weights for each of its inputs and outputs so as to maximize its efficiency. Cook and Seiford (2009) provide a comprehensive review of DEA research covering theoretical developments, as well as "real-world" applications from its inception to 2007 (i.e. the first 30 years of the history of DEA). There are far too many papers on the application of DEA to thoroughly document here. Some works applying DEA in various disciplines include Partovi (2011), Malul et al. (2009), Cherchye et al. (2008), Cook and Green (2004) and many others. We refer interested readers to Cook and Seiford (2009) and Cooper et al. (2000).

The DEA model considers k DMUs that are evaluated in terms of n outputs and m inputs. Let O_{ik} and $I_{jk}, i = 1, 2, ..., n, j = 1, 2, ..., m$, be the output and input values of DMU_k where $k = 1, 2, ..., K$. The CCR (Charnes, Cooper, Rhodes, 1978) model for evaluating the efficiency of e^{th} DMU can be expressed as shown below:

$$Max: \quad E_e = \frac{\sum_{i=1}^{n} w_i O_{ie}}{\sum_{j=1}^{m} v_j I_{je}}$$

Subject to:

$$\begin{aligned} &\frac{\sum_{i=1}^{n} w_i O_{ik}}{\sum_{j=1}^{m} v_j I_{jk}} \leq 1 \quad k = 1, 2, ..., K \\ &w_i \geq 0, \quad v_j \geq 0, \quad i = 1, 2, ..., n, \quad j = 1, 2, ..., m, \end{aligned} \tag{1}$$

In model (1) above, the index i,j, and k refer to a specific sets of outputs, inputs, and DMUs, respectively. The variables w_i and v_j are the relative weights of the output i and input j to be determined by the solution of the model in (1) above.

Output-Oriented Model

Model (1) can easily be transformed to an output maximization linear programming problem as shown in (2) below. This is referred to as the output-oriented model. In an output-oriented model, an inefficient unit is made efficient through the proportional increase of its outputs, while the inputs proportions remain unchanged (Emrouznejad, 2011).

$$Max: \quad E_e = \sum_{i=1}^{n} w_i O_{ie}$$

Subject to:

$$\begin{aligned} &\sum_{j=1}^{m} v_j I_{je} = 1 \\ &\sum_{i=1}^{n} w_i O_{ik} - \sum_{j=1}^{m} v_j I_{jk} \leq 0 \quad k = 1, 2, ..., K \\ &w_i \geq 0, \quad v_j \geq 0, \quad i = 1, 2, ..., n, \quad j = 1, 2, ..., m, \end{aligned} \tag{2}$$

The solution to model (2) gives a dichotomy classification of the DMUs into two distinct groups: efficient and inefficient DMUs. This classification does not provide a way of selecting the best DMU, but rather efficient ones. Several previous researchers have proposed different approaches for ranking and selecting the best DMU. The most widely used ranking methodologies are cross-efficiency, super-efficiency which has proved to be popular in the literature, and the benchmarking approach. For other ranking models in DEA, we refer interested reader to Adler et al. (2002) and Hosseinzadeh Lotfi et al. (2013).

Cross-Efficiency

Cross-efficiency is a ranking method in which the units are self and peer evaluated, resulting in a cross-efficiency matrix. It was first introduced by Sexton et al. (1986). This method simply evaluates the efficiency score k times, using the optimal weights obtained from model (2). Suppose that $w_i^*(i = 1, 2, ..., n,)$ and $v_j^*(j = 1, 2, ..., m)$ are the optimal solution to model (2). Then, the cross-efficiency of any DMU k using the outputs and inputs of a chosen e^{th} DMU can be determined using the following equation:

$$\theta_{ke} = \frac{\sum_{i=1}^{n} w_{ki}^* O_{ei}}{\sum_{j=1}^{m} v_{kj}^* I_{ej}} \quad k = 1, 2, ..., K \tag{3}$$

Where $\theta_{ke} \in [0 - 1]$ indicates that DMU_e is evaluated using the weights of DMU_k.

Note that the results of equation (3) above give the cross-efficiency matrix with the diagonal elements representing the standard DEA efficiency score. If $\theta_{ee} = 1$, DMU_e is efficient, otherwise it is inefficient. Therefore, the cross-efficiency score of DMU_e is given by the average of the θ_{ke} values and can be expressed as follows:

$$\hat{\theta_e} = \frac{\sum_{k=1}^{K} \theta_{ke}}{K} \tag{4}$$

However, averaging is not the only approach; some authors suggest that minimum, median or variance of scores could be applied (Adler et al., 2002). For further understanding of detailed ideas of cross-efficiency, both mathematically and intuitively, see Doyle and Green (1994).

MODEL APPLICATION

This section presents the basic DEA model used in this analysis for creating a single composite sustainability risk index for each country. In this study, we have four major indicators with sub-indicators to evaluate different countries to be selected for the DEA analysis. The indicators are political risk, economic risk, social/compliance risk, and infrastructure and climate risk. The sub-indicators will be referred to as outputs in this study. Similar to Cherchye et al. (2008) and the first model in Malul et al. (2009), our input is standardized to 1. Therefore, the standard DEA model in (2) become the same with DEA model in Cherchye et al. (2008) as shown below:

$$Max: \quad E_e = \sum_{i=1}^{n} w_i O_{ie}$$

Subject to:

$$\sum_{i=1}^{n} w_i O_{ik} \leq 1 \quad k = 1, 2, ..., K \tag{5}$$
$$w_i \geq 0, \quad i = 1, 2, ..., n.$$

Cross efficiency methods in (3) and (4) are applied to the resulting weights obtained from of the model in equation (5). This cross efficiency is referred to as the Sustainability Risk Index (SRI) for each country. To apply the model in (3), we use readily available r-data envelopment analysis package called “Benchmarking" (Bogetoft and Otto, 2015) and the cross efficiency computation method is coded using MATLAB.

DEA Evaluations

We consider forty five (45) countries for the DEA analysis based on three main criteria as follows: countries with cotton yarn production, woven cotton fabrics production (from http://unstats.un.org/unsd/mbs/table_list.aspx) and factory locations of major apparel company such as Nike Inc. In this study, we assume that inputs are standardized to one. The indicators and sub-indicators used for representing outputs in this analysis are: political stability and absence of violence (PSAV), Rule of law (ROL), corruption perception score (CPS), inflation (INF), ease of doing business (EDB), debt to GDP ratio (DTGDP), human development index (HDI) rank, overall logistics performance index (LPI) score, world risk index (WRI) and environment protection index (EPI). Table 1 shows the correlation matrix between DEA outputs and Table 2 shows the data used for the DEA model evaluation.

Table 1: DEA Outputs Correlation Matrix

Outputs	**LPI**	**WRI**	**EPI**	**PSAV**	**ROL**	**CPS**	**HDI**	**EDB**	**INF**	**DTGDP**
LPI	1									
WRI	-0.21	1								
EPI	0.08	-0.47	1							
PSAV	0.56	-0.15	0.41	1						
ROL	0.73	-0.27	0.33	0.85	1					
CPS	0.73	-0.27	0.41	0.81	0.91	1				
HDI	-0.50	0.53	-0.71	-0.58	-0.66	-0.72	1			
EDB	-0.31	0.40	-0.66	-0.78	-0.62	-0.61	0.74	1		
INF	-0.22	-0.19	0.03	-0.59	-0.46	-0.36	0.03	0.33	1	
DTGDP	0.41	0.01	0.12	0.22	0.40	0.50	-0.24	-0.02	-0.06	1

Table 2: Selected Countries Outputs Data

DMU	Country	Code	LPI	WRI	EPI	PSAV	ROL	CPS	HDI	EDB	INF	DTGDP
1	Argentina	ARG	2.96	0.276	79.84	12.98	18.27	32	0.025	0.008	0.034	0.021
2	Armenia	ARM	2.21	0.162	81.6	60.1	43.75	35	0.012	0.029	0.368	0.024
3	Azerbaijan	AZE	2.45	0.167	83.78	43.75	30.77	29	0.013	0.016	5.099	0.063
4	Bangladesh	BGD	2.66	0.052	41.77	18.27	25.96	25	0.007	0.006	0.176	0.056
5	Belarus	BLR	2.40	0.326	82.3	13.94	22.6	32	0.02	0.023	0.055	0.042
6	Brazil	BRA	3.09	0.238	78.9	50.48	55.29	38	0.013	0.009	0.146	0.015
7	Bulgaria	BGR	2.81	0.235	83.4	71.15	55.77	41	0.017	0.026	2.247	0.034
8	Cambodia	KHM	2.80	0.06	51.24	37.02	17.31	21	0.007	0.008	0.594	0.03
9	China	CHN	3.66	0.147	65.1	45.19	42.79	37	0.011	0.012	1.172	0.023
10	Croatia	HRV	3.16	0.238	86.98	65.87	65.87	51	0.021	0.025	69.735	0.012
11	Ecuador	ECU	2.78	0.134	66.58	14.9	13.46	32	0.011	0.009	0.37	0.034
12	Egypt	EGY	3.18	0.443	66.45	25	31.25	36	0.009	0.008	0.087	0.011
13	El Salvador	SLV	2.71	0.06	68.07	64.42	35.58	39	0.009	0.012	0.736	0.016
14	Georgia	GEO	2.35	0.153	64.96	79.33	64.42	52	0.013	0.042	0.265	0.027
15	Germany	DEU	4.23	0.333	84.26	94.23	93.27	81	0.167	0.067	0.577	0.014
16	Guatemala	GTM	2.48	0.05	69.64	47.6	14.42	28	0.008	0.012	0.32	0.041
17	Honduras	HND	2.46	0.094	69.64	38.94	14.9	31	0.008	0.009	0.181	0.024
18	India	IND	3.42	0.145	53.58	34.62	54.33	38	0.008	0.008	0.329	0.015
19	Indonesia	IDN	2.98	0.096	65.85	49.04	41.83	36	0.009	0.009	0.186	0.037
20	Japan	JPN	3.97	0.075	80.59	84.13	89.42	75	0.05	0.029	0.609	0.004
21	Jordan	JOR	2.96	0.214	72.24	54.81	69.71	53	0.013	0.009	0.29	0.011
22	Kazakhstan	KAZ	2.75	0.273	73.29	44.71	34.13	28	0.018	0.024	0.166	0.043
23	Korea, Rep.	KOR	3.72	0.209	70.61	83.65	80.77	56	0.059	0.25	1.776	0.028
24	Kyrgyz Republic	KGZ	2.16	0.121	73.13	36.06	15.87	28	0.008	0.015	0.126	0.018
25	Lithuania	LTU	3.63	0.336	85.49	87.02	78.37	61	0.027	0.05	0.854	0.023
26	Macedonia, FYR	MKD	2.51	0.163	78.02	67.31	56.73	42	0.012	0.083	0.695	0.022
27	Malaysia	MYS	3.43	0.155	74.23	75.96	75	50	0.016	0.056	0.404	0.019
28	Mexico	MEX	3.11	0.161	73.59	66.83	37.98	35	0.014	0.026	0.212	0.023
29	Moldova	MDA	2.61	0.205	76.69	53.85	46.63	33	0.009	0.019	0.159	0.041
30	Nicaragua	NIC	2.53	0.068	64.19	38.46	28.85	27	0.008	0.008	0.11	0.022
31	Pakistan	PAK	2.92	0.142	51.42	27.88	23.56	30	0.007	0.007	0.144	0.015
32	Peru	PER	2.89	0.147	72.95	69.23	33.17	36	0.012	0.02	0.331	0.048
33	Philippines	PHL	2.86	0.036	73.7	51.92	43.27	35	0.009	0.01	0.312	0.022
34	Poland	POL	3.43	0.306	81.26	81.73	77.4	62	0.028	0.04	2.272	0.02
35	Romania	ROM	2.99	0.154	83.24	71.63	63.46	46	0.019	0.027	0.578	0.026
36	Russian Federation	RUS	2.57	0.26	83.52	36.54	26.44	29	0.02	0.02	0.139	0.056
37	Serbia	SRB	2.76	0.145	78.67	56.25	50.48	40	0.015	0.017	0.529	0.014
38	South Africa	ZAF	3.78	0.184	70.52	63.94	63.94	44	0.009	0.014	0.173	0.02
39	Sri Lanka	LKA	2.70	0.136	65.55	50	51.92	37	0.014	0.009	0.369	0.013
40	Taiwan	TWN	3.70	0.147	74.88	88.94	85.58	62	0.048	0.091	0.532	0.027
41	Tajikistan	TJK	2.06	0.14	73.05	15.87	15.38	26	0.0078	0.0076	0.183	0.0353
42	Thailand	THA	3.26	0.157	69.54	62.02	51.44	38	0.0108	0.0204	1.0269	0.0219
43	Turkey	TUR	3.42	0.186	67.68	66.35	59.62	42	0.0139	0.0182	0.12	0.0304
44	Ukraine	UKR	2.74	0.324	79.69	28.85	23.08	27	0.0123	0.012	0.0679	0.014
45	Vietnam	VNM	2.98	0.0776	58.5	30.29	44.71	31	0.0086	0.0111	0.273	0.0198

We used the inverse of inflation(INF), ease of doing business(EDB), debt to GDP ratio (DTGDP), human development index (HDI) rank, world risk index (WRI) for each country since the lower score is better. Also, we excluded the rule of law (ROL) output in the final DEA evaluation, because it is highly correlated with the corruption perception score(CPS) and Political stability and absence of violence (PSAV) score, as shown in Table 1.

Outputs Definitions

Political Risk

We select three dimensions from the world bank (WGI) world governance indicators to measure the political risk of a country.

1. Political stability and absence of violence (PSAV): This measures the perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism for a country(Kaufmann et al., 2011). We use the percentile rank score for the countries selected for the DEA analysis. The percentile rank ranges from 0-100 (0 corresponding to the lowest rank, and 100 to the highest rank). A higher percentile rank is more favorable, because it indicates that the country is relatively less likely to be disrupted politically.

2. Rule of law (ROL): This captures perceptions of the extent to which agents have confidence

in and abide by the rules of society, in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence(Kaufmann et al., 2011).

3. Transparency and corruption: This is measured using the corruption perception score (CPS) of various countries under consideration,which can be found on www.transparency.org/cpi2015/.

Economic Risk

We consider three dimensions relevant to general economic and business & trade environment as a measure of economic risk of a country.

4. Inflation (INF): Data for inflation was taken from World Bank Country Indicators (Available online at http://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG). We expect a country with a lower inflation level to be of less economic risk.

5. Ease of doing business (EDB): The ease of doing business ranking ranges from 1 to 189 with a lower value indicating a more desirable ranking. The rankings are determined by sorting the aggregate distance to frontier scores on 10 topics, each consisting of several indicators, with equal weight to each topic (World Bank, 2015). These topics are: starting a business, dealing with construction permits, obtaining electrical power, registering property, credit availability, protection of minority investors, paying taxes, trading across borders, enforcing contracts, resolving insolvency. We only use the country ranking in our analysis.

6. Debt to GDP ratio (DTGDP): Generally, investors use Government debt as a percent of GDP to measure a country's ability to make future payments on its debt, thus affecting its borrowing costs and government bond yields (http://www.tradingeconomics.com/). Data for debt to GDP were collected from http://www.tradingeconomics.com/.

Social/Compliance Risk

This captures how a country deals with issues related to labor and other social well-being of its workers. In order to measure the social/compliance risk, we use the Human Development Index (HDI) published yearly by the United Nation (UNDP, 2015).

7. Human Development Index (HDI): This is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living (from http://hdr.undp.org/en/content/human-development-index-hdi) as shown in figure 1 below.

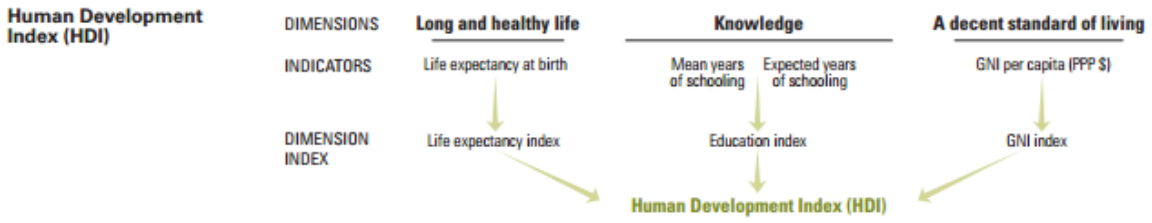

Figure 1: HDI Dimensions

Infrastructure and Climate Risk

The following are the three indicators used to measure infrastructure and climate Risk:

8. Logistics Infrastructure: This is measured through the use of the logistics performance index (LPI) score for countries. Logistics performance is strongly associated with the reliability of supply chains and the predictability of service delivery for producers and exporters (Arvis et al., 2016). The overall score reflects perceptions of a country's logistics based on the efficiency of the customs clearance process, quality of trade- and transport-related infrastructure, ease of arranging competitively priced shipments, quality of logistics services, ability to track and trace consignments, and the frequency with which shipments reach the consignee within the scheduled time. The index ranges from 1 to 5, with a higher score representing better performance.

9. World Risk Index (WRI): This Index calculates the disaster risk for 171 countries worldwide using four components which consist of indicators that capture exposure towards natural hazards such as earthquakes, cyclones, flooding, drought and sea level rise, susceptibility of infrastructure, food, housing and economic framework conditions, coping capacities depending on governance, risk reduction, early warning, health-care, social and material coverage and adaptive capacities related to future natural hazards and the impacts of climate change (WRI, 2015). In this study, we obtained data for the WRI 2015 (from http://www.worldriskreport.org/).

10. Environment Protection Index (EPI): The data for each country EPI was taken from the 2016 report (Hu et al., 2016). A higher score indicates better performance with a range of 0 to 100. The EPI ranks countries based on high-priority environmental issues in two areas: protection of human health and protection of ecosystems.

DEA Results

Table 3 presents the cross-efficiency (CE) values which represent the sustainability risk index and are used for ranking these countries. The higher the index the less is the risk. It can be seen that top five(5) countries are: Germany, Lithuania, Azerbaijan, Russia, and the Korea Rep. with index values greater than 0.85 and the bottom five (5) are: Nicaragua, India, Vietnam, Cambodia, and Pakistan with index values less than 0.62.

Table 3: Sustainability Risk Index (SRI) and Country's Rank

DMU	Country	Code	CE=SR Index	Ranking
15	Germany	DEU	0.9334	1
25	Lithuania	LTU	0.9034	2
3	Azerbaijan	AZE	0.8948	3
36	Russian Federation	RUS	0.8917	4
23	Korea, Rep.	KOR	0.8513	5
34	Poland	POL	0.8475	6
10	Croatia	HRV	0.8444	7
7	Bulgaria	BGR	0.8417	8
40	Taiwan	TWN	0.8338	9
5	Belarus	BLR	0.8260	10
32	Peru	PER	0.8201	11
22	Kazakhstan	KAZ	0.8106	12
35	Romania	ROM	0.8040	13
29	Moldova	MDA	0.7991	14
43	Turkey	TUR	0.7707	15
20	Japan	JPN	0.7693	16
38	South Africa	ZAF	0.7672	17
27	Malaysia	MYS	0.7669	18
1	Argentina	ARG	0.7589	19
6	Brazil	BRA	0.7513	20
28	Mexico	MEX	0.7482	21
26	Macedonia, FYR	MKD	0.7367	22
44	Ukraine	UKR	0.7361	23
2	Armenia	ARM	0.7308	24
42	Thailand	THA	0.7291	25
9	China	CHN	0.7237	26
19	Indonesia	IDN	0.7236	27
16	Guatemala	GTM	0.7132	28
12	Egypt	EGY	0.7114	29
37	Serbia	SRB	0.7080	30
11	Ecuador	ECU	0.6931	31
21	Jordan	JOR	0.6921	32
33	Philippines	PHL	0.6881	33
41	Tajikistan	TJK	0.6847	34
14	Georgia	GEO	0.6779	35
17	Honduras	HND	0.6541	36
13	El Salvador	SLV	0.6409	37
24	Kyrgyz Republic	KGZ	0.6356	38
39	Sri Lanka	LKA	0.6261	39
4	Bangladesh	BGD	0.6206	40
30	Nicaragua	NIC	0.6167	41
18	India	IND	0.6117	42
45	Vietnam	VNM	0.6076	43
8	Cambodia	KHM	0.5944	44
31	Pakistan	PAK	0.5624	45

It is evident that these results can be easily verified based on the information provided in Table 2. For instance, Germany is ranked number 1 based on the cross-efficiency score, thus, it is the least risky country. This can be attributed to its best logistics performance, lack of corruption, political stability and excellent environmental protection policies.

CONCLUDING REMARKS

In this paper, we adopt the use of the DEA cross efficiency method for creating a single composite sustainability risk index and rank countries in terms of outsourced manufacturing with respect to the US apparel industry. This study explores the application of DEA beyond the standard efficiency

analysis. We show how manufacturing companies can use this technique to create a composite index for assessing a country's overall risk, before making the outsourcing decision. This composite index captures both qualitative and quantitative factors that can pose risks to the supply chain based on the location of the country of the contract manufacturer. In addition, engaging in a proactive and responsible sourcing practices using this approach, may lead to more consistent outsourcing decisions. Eventually, supply chain managers can utilize a more-strategic approach in sourcing, which will significantly reduce the long time required to reach such an outsourcing decision. Finally, this approach can be used to identify low-risk countries with factories that have high quality, as well as social and environmental performance for making effective outsourcing decisions.

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DECISION SCIENCES INSTITUTE

Did They Learn Anything? - Learning Assessment in a General Business Analytics Course

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ABSTRACT

There is a projected need for 2 to 4 million of business translators who are not only experts in their business disciplines but also conversant and familiar with the use and limitations of business analytics. Preparing business students to step into the business translator role requires a general introductory analytics course. This paper presents a multi-component learning assessment to evaluate the depth of learning from such a course. This learning assessment is novel in a sense that it uses four distinct tools, both quantitative and qualitative ones, to measure students' improvements in a comprehensive manner.

KEYWORDS: Learning Assessment, Business Analytics, Analytics Instruction, Business Analytics Curriculum

INTRODUCTION

The Need for General Business Analytics Course Learning Assessment

With analytics becoming an indispensable tools for business competitiveness in the last decade (Davenport & Harris, 2011), academic institutions responded to the emerging need of hundreds of thousands of data experts and 2 to 4 million of 'business translators' (Bughin et al., 2016) by developing numerous programs, both at the graduate and undergraduate levels (Wixom et al., 2014.) The majority of academic research and papers target the development of full analytics programs aiming to train data experts. At the same time, a general introductory business analytics course is necessary to address the need to make all future business practitioners at least conversant in the language of analytics so that they could become a member of the predicted million-strong business translator group (Ugray, 2016.) It is hard to underestimate the importance of the success of such a course. This makes it necessary to study the outcome of such a course and to develop a learning assessment mechanism to evaluate the learning that takes place. This paper presents the design and results of a four-piece comprehensive learning assessment effort that took place at an Intermountain university. The assessment utilizes both quantitative and qualitative tools to not only prove students' improvements in knowledge, skills, and comprehension, but to also gain a more granular understanding of students' experiences and their perceptions of the usefulness, advantages, and confidences in what they learnt.

Business Analytics

Data is being generated at an ever accelerating pace. By the year 2025, an astonishing 163 ZB (Zettabytes; 2^{70}, or approximately 10^{21} bytes) of data might be created (Reinsel et al. 2017). Handling this vast amount of data is stretching organizations' abilities (McAfee & Brynjolfsson, 2012). To gain and to keep competitive advantage in today's business landscape, firms need to continuously innovate and become early adopters of evolving technologies, data analytics being one of the most crucial capabilities (Davenport & Harris, 2010; Barton & Court, 2012; Bell, 2013). Knowledge from multiple, often overlapping, disciplines are forming the foundations for the skillset that is in high demand by today's organizations.

For simplicity's sake, in this paper we use the term business analytics to refer to the general collection of related disciplines that include data analytics, data mining, data science, data engineering, machine learning, advanced statistics, and artificial intelligence, among others. As the abundance of discipline names suggests, there are different approaches, backgrounds, and skills that might be necessary to successfully deal with the amount, speed, and variety of data and their analyses. It became a constant challenge to train, keep, and find people with business analytics skills (Davenport & Patil, 2012; Davenport, 2013; Santaferraro, 2013).

Business Analytics Education

Business professionals, consultants, and educators started to study the state of business analytics educational programs no later than a split second after defining business analytics as an emerging field and the identification of its importance. Wixom et al. (2011) referred to 15 full time programs, with 3 at the undergraduate level. Just 3 years later, in another study, Wixom et al. (2014) counted 131 programs, including 47 at the undergraduate level. There is even a website (www.mastersindatascience.org) dedicated to aggregating information about the increasing number of master's programs in business analytics, data science, and related fields. According to Schuff (2018), the website listed 117 graduate level programs at some point in 2017. These programs address the need of training data analysts to fill the large number of missing professionals forecasted: Bughin et al. (2016) posit the number of missing professionals to 250,000 within a decade, updating the 2011 forecast of Manyika et al. from 140,000 to 190,000 missing experts by 2018.

While the number of missing data experts is quite large, the need for business translators, those who serve as the link between data analysts and the business questions that require industry specific expertise and organizational knowledge, is even greater: Bughin et al. (2016) puts that number to between 2 and 4 million for the next decade, updating the forecast of Manyika et al. (2011) from 1.5 million by 2018. What makes these numbers even more concerning is the finding of Wixom et al. (2014) describing how employers find the skills and practical experiences of recent university graduates lacking. Organizations' needs are growing for people with adequate skills for understanding and translating between their domain of expertise and data science practitioners, who can work with the large volumes of data prevalent in more and more business fields. These business translators are essential for companies to effectively compete in their businesses (Davenport & Harris, 2010.)

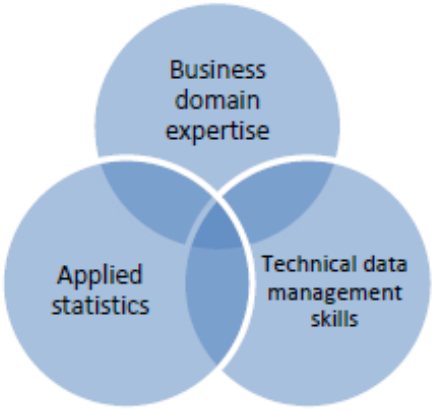
Research into the area of delivering basic data skills to future business translators does not match up to the amount of research addressing curricular needs of data analysts. Some examples include Schuff's (2018) description of a university-wide course in data literacy and Ugray's 2016 report on a general data analytics course for all business undergraduates.

BUSINESS ANALYTICS COURSE FOR ALL BUSINESS UNDERGRADUATES

Course Information

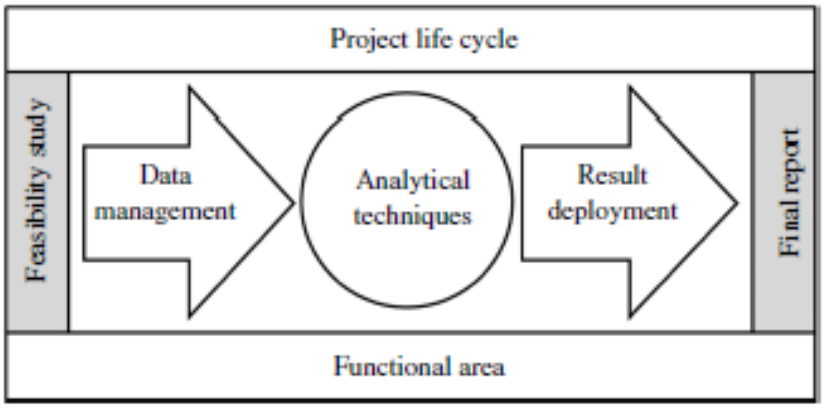
The origins of the course under study at an Intermountain university's Business School go back to 2014, when the approval to develop a college-wide introductory level undergraduate analytics class came from the Dean's office. A group of four faculty, with the help of two graduate students, designed the course in the spring of 2015. All four faculty and the two graduate students had a combination of data management, informatics, analytics, statistics, computer science, or operations research background (Ugray, 2016.) Two sections of the new course were offered in the fall of 2015, 4 in the spring of 2016 and it officially became a required course for all business school undergraduates in the fall of 2016. At this point, there are typically 8 sections offered a semester and an online section is offered once or twice a year as well.
The course outline, after reviewing extant educational research, academic programs, business requirements, and employer expectations, followed the components of business analytics, as illustrated in Figure 1 (Conway, 2013). The domain expertise component relies on student's skills and knowledge acquired from a set of business school acumen courses. Meaningful datasets are selected to demonstrate the relevance of examples to various business domains. Applied statistics concepts are reviewed, refreshed, and introduced throughout the course at relevant times, acknowledging that the amount of statistics remembered by a typical business undergraduate student from her business statistics course is often minimal. Technical data management skills are either refreshed or newly introduced. The course is embedded among other required business courses in a way that knowledge and skills form a synergistic learning surrounding.

Figure 1: Business analytics skillset



Wilder & Ozgur (2015) discussed five knowledge domains of business analytics and described their relations with the chart in Figure 2. While this framework nicely sets up the need for different specialized courses, an introductory course can only tangentially cover some of the knowledge areas.

Figure 2: Knowledge domains



The introductory business analytics course developed consists of three major modules: Data Management (acquisition, querying, cleansing), Data Visualization and Summarization, and Predictive Analytics. Each module consists of conceptual topics and hands-on skill development exercises using appropriate software tools. SQL Server Management Studio (2018), PowerBI (2018) and OpenRefine (2018) are utilized for the Data Management module. PowerBI and RapidMiner (2018) are used for Data Visualization and Summarization, and RapidMiner is the main tool for Predictive Analytics.

LEARNING ASSESSMENT

Data regarding learning assessment included both qualitative and quantitative data. The four assessment tools included the following: 19 pre- and post-test questions administered to students; 12 questions measuring students' perception related to the usefulness, advantages, confidence, and future expectation of task self-execution related to areas of the three major modules of the class, answered twice, once before and once after the course; 3 Short essay questions regarding the value, purpose and usefulness of course topics; and semi-structured interviews conducted with six students after the conclusion of the class.
Data was collected from a total of 68 students from 2 sections in one semester in 2017. There were 65 usable observations for the pre- and post-test question comparisons, with 44 males and 21 females in the sample. For the perception estimates and the short-answer question the 63 usable samples were split between 20 females and 43 males.
Table 1 describes the distribution of majors participating in the class. There were similar numbers of MIS, marketing and finance/economics students, while number of accounting and business administration (including all other business majors) were somewhat lower.

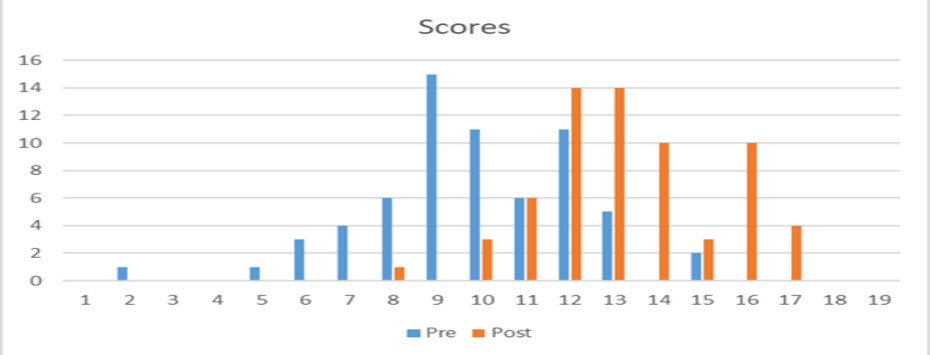
Table1: Distribution of majors in the sample

MIS	ACC	MKT	ECON/FIN	BA
14	7	18	16	10
22%	11%	27%	25%	15%

Pre- and Post-test Quizzes

This part of the learning assessment consisted of 19 multiple choice questions (about 2 per course objectives) administered twice, once at the very beginning of the course and once at the end. The questions aimed to address understanding, critical thinking, and possible application of concepts rather than lexical knowledge. Figure 3 shows the distribution of pre- and post-test scores.

Figure 3: Pre- and post-test scores



The post-test average score of 12.34 was significantly larger ($p<10^{-6}$) than the pre-test score average score of 8.83.
55 (85%) of student had higher scores, 3 (5%) had the same and 7 (10%) had lower scored at the post-test. 14 (75%) of the 19 questions had more correct answers in the post-test (7 questions by 28%-52% more, 7 questions by 2%-25% more), 1 question (5%) had the same number of correct answers, and 4 questions (20%) had lower number of correct answers (3 questions with 1 or 2 respondents lower, and 1 question with 34% lower.) Reviewing this last question reinforces the observation that for more complex questions, as one's knowledge increases, sometimes different answers might appear to be correct.)

Student Perception Questions

For this learning assessment measurement, changes in the answers given to four perception questions related to the three major course topic modules (12 questions total) were calculated. A 5 level Likert scale was used both at the beginning and at the end of the course. Students had to express their agreements with the statements, "strongly agreeing" coded as 5, "agreeing" as 4, "neutral" as 3, "disagreeing" as 2, and "strongly disagreeing" as 1. The four questions were the following:

1. (Useful): Learning about and understanding ____ is useful in my field of study (i.e. major or prospective profession)
2. (Advantageous): Being able to perform ___ will be advantageous in my future job.
3. (Confident): I feel confident about performing ___ tasks.
4. (Expect): I expect that in the future, rather than relying on someone else, I would be able to perform ___ tasks myself.

The three topic modules: 1. (Data): Data querying, cleansing; 2. (Visualization): Data summarization and visualization; and 3. (Mining): Predictive analytics and data mining. Results

of changes in the perceptions are summarized in Table 2, with the significant differences in bold letters.

Table 2. Perception changes (*: p<0.05; **: p<0.01; ***: $p<10^{-6}$)

	Data	Visualization	Mining
Useful	-0.03, (n/s) (3.98,3.95)	+0.03, (n/s) (4.11,4.14)	**-0.44, (**)** (4.35, 3.91)
Advantageous	-0.06, (n/s) (3.97,3.91)	-0.11, (n/s) (4.25,4.14)	-0.10, (n/s) (4.21,4.11)
Confident	**+1.06, (***)** (2.32,3.38)	**+1.19, (***)** (2.43,3.62)	**+1.1, (***)** (2.35,3.45)
Expect	**-0.32, (*)** (3.73,3.41)	**-0.27, (*)** (3.84,3.57)	**-0.52, (**)** (3.85,3.33)

Answers to two questions show significant changes in perceptions after students took the course. Their confidence in performing tasks belonging to the 3 major course modules (data manipulation, visualization, data mining) increased significantly. Interestingly, their expectations about whether they will perform these same tasks showed a statistically significant decrease. While this may seem discouraging at first, this reaction is not irrational: the course is an introductory analytics course with the purpose of making all business students familiar with the broad areas of business analytics. It is not the goal of the course, and it is not reasonable to expect, that student will possess the skills that is expected to perform rigorous data analytics tasks in a real life business setting. If anything, it is encouraging that they seem to realize the limitations of their skills at this point.

The last remaining statistically significant change is the evaluation of the usefulness of data mining. It shows a negative value, meaning that after the course students' perception of the usefulness of data mining is diminished. This artifact could have several explanation. Maybe data mining is too complex of a task at the educational level when students take the course. It is possible that either fewer or simpler examples need to be used. Somewhat relatedly, maybe examples and data sets that are more relatable to the broader set of business majors could be used. Finally, it is not impossible that the instructor needs to sharpen his skills to better convey the usefulness of data mining.

Short Answer Questions

Students were given the opportunity to offer their thoughts to three questions. The questions were asked both at the beginning and end of the course:

- *Why do you think Business Analytics is valuable?* – Answers to this question became more detailed and more sophisticated after taking the course, often referring to the usefulness of predictions that can be gained from analyzing data. Students tended to give examples from their major.
- *How is Business Analytics used in your field?* – More specific examples and benefits gained from analytics were often mentioned in the answers. The most specific examples came from marketing and MIS students who planned to specialize in analytics.
- *What (do you expect to learn / are the most useful things you learned) in the course? What topics will you most likely use later in your career?* – There were many different items listed in

the answers to this questions. Most frequently, gaining general understanding business analytics concepts and the acquisition of the relevant 'language' were mentioned. It was followed by the appreciation of the ability to better interpret data. Many students liked both the opportunity to get acquainted with the software tools and the learning of the concepts behind the tools.

Interviews

After the conclusion of the course a 5 students were interviewed. Selection of the students included a mix of 2 females and 3 males, 3 different majors, and students with final grades ranging from C to A. The direction of the questions focused on students' self-evaluation of their learning and the experiences they had in the course. Among a rich set of qualitative evaluations a few themes emerged. There was a general appreciation of the importance and depth of the fields within business analytics. Even students who described themselves as not particularly number and data oriented developed and appreciation for the insights that can be gained from looking at data from multiple angles. There was a general consensus that the course is one of the toughest and busiest courses within the business curriculum. It resulted in references to many students' strategies to just 'get by' and to just 'successfully pass with a reasonable grade'. Several, often contradictory, suggestions were made to omit or include some topics; to utilize more or fewer example data sets; to spend more or less time on elaborating details of the concepts.

CONCLUSIONS

A comprehensive learning assessment was implemented for a general introductory business analytics course required for all business undergraduates at an Intermountain university. The assessment has quantitative and qualitative components. It utilized quizzes, questionnaires, short answer questions and interviews. Results from the broad assessment convincingly demonstrated that a course addressed to the general business student population can be useful, successful, and it can provide the foundation for many to fulfill the role of the 2 to 4 million future 'business translators' projected by the McKinsey Global Institute. Quantitative assessment tools proved that the knowledge and skill base of students improved after taking the class. Students' confidence and understanding of the importance of their knowledge also improved, complemented with the realization that taking just one introductory course does not make them capable of executing rigorous analytics tasks at a real life working environment. Qualitative assessment tools reinforced the findings of the qualitative tools and brought further nuanced elements to the understanding of the strength and weaknesses present in the course. They revealed improvements in the details and sophistication of how data is looked at, manipulated, and interpreted. They also added more granularity to the particulars of what students learned and what they considered important and useful: the ability to interpret data, the skills to use appropriate software tools, the understanding of the concepts behind the software tools, and a general understanding of the field and the tasks involved.

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DECISION SCIENCES INSTITUTE
Diffusion of Generation and Consumption of Energy

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ABSTRACT

The electricity generation scenario in the world is changing as countries like China and Germany have started leading the efforts of energy generation moving from the use of non-renewable resources, like fuels, and more into hydro, solar and wind electricity generation plants. Within the United States there are also some effort for this shift, but just a few states are leading the move while others are staying with the traditional contaminant model.

KEYWORDS: energy, electricity, bass diffusion, sensitivity analysis, renewables

INTRODUCTION

In the year 2016, according to the World Bank, 87.35% of the world's population had access to electricity. The region where this access was most restricted is Sub-Saharan Africa (SSA), where only 42.81% of the population enjoyed this service. Considering Latin America and the Caribbean (LAC) as another poverty pole region, the database reports that 97.79% of LAC inhabitants had access to electricity. There was a significant difference between LAC and SSA, as the situation in LAC is comparatively much better. Using numbers from the 2016 census, we deduced that 14 million people in LAC did not have access to electricity, compared to 590 million people in SSA. Because there are definitively more urgent needs at SAA than electricity, this paper will focus on LAC and the implementation of new technologies for the generation and distribution of electricity.

If we focus on the poorest countries, in the year 2000, a little bit over 33% of the population had the chance of accessing electricity; based on these countries' needs companies were overproducing energy. As a result of this decision, losses in transmission and distribution averaged 25% of the total production, so that those firms involved in the electricity sector were operating mostly at significant losses (Kenny & Søreide, 2008).

Another factor affecting the progress in the electricity sector in the LAC was the popular idea, from the 1960's, that reinforced the state as requiring a monopolistic and preponderant role in everything related to energy provision and distribution. The LAC is now facing serious challenges, as it is creating competitive markets while modernizing old institutional structures and national standards and norms (Herrera, 2001). These changes have helped the penetration of energy generation and distribution in the LAC, with a high percentage of private participation in this sector. According to the World Bank database, in 2016 the LAC received 22.263 billion dollars of investments from private companies. This influx of capital into developing countries in the LAC is important for those economies and represents an important push towards

technologies that the public sector could not finance—in some cases due to money supply and technological advancement.

1.1 Global Trends on Generation and Sources

Using the secondary data available at the UN Database, we were able to analyze the sources of generation capacities and trends for the near future.
Combustible Fuels' energy is the generation process with the largest installed capacity and it is also the largest generator of electricity in the world; after the Tsunami in Japan, there was a push back on nuclear energy that is noticeable after 2011, but it has been stable ever since. Therefore, we do not expect all the fuel and nuclear capacity to be uninstalled suddenly, but it will rather continue to function.

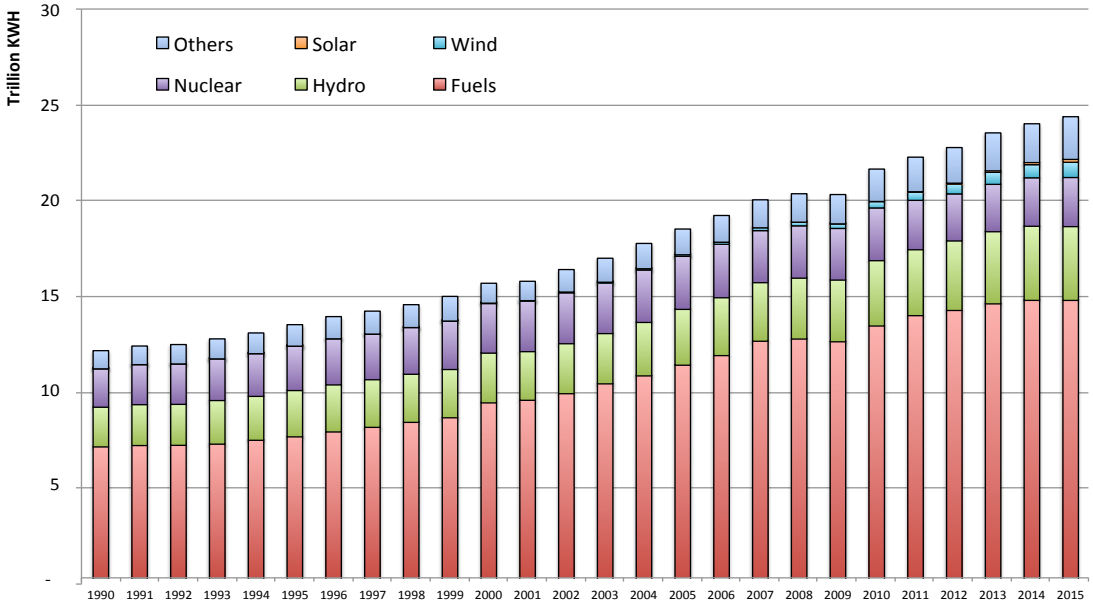
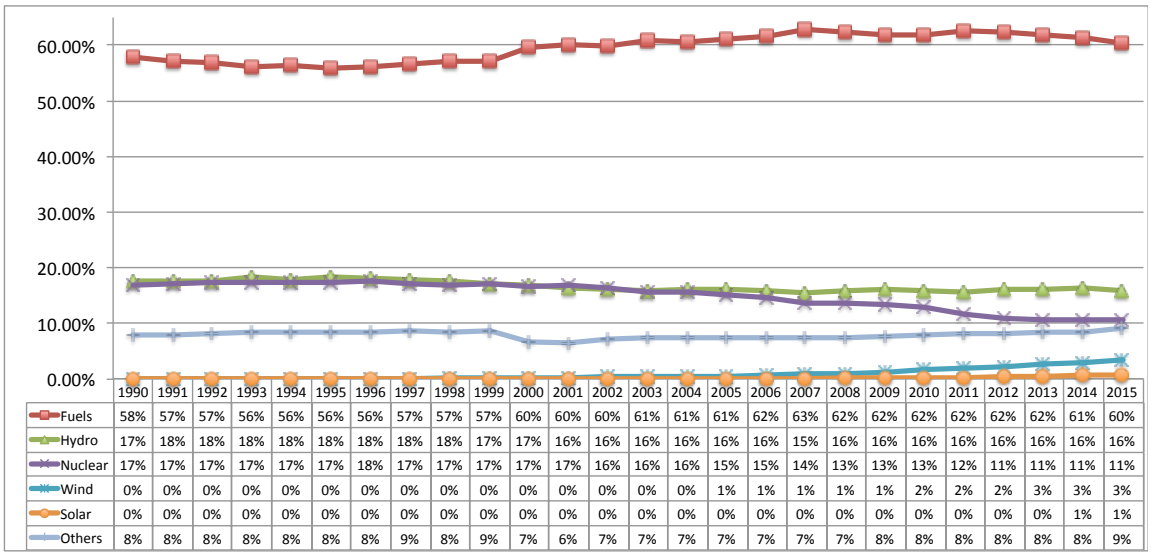


Figure 1: Growth of electricity capacity in KWH per year (source: UN data)

Breaking the production of electricity into the major source of generation, we found that there are some other sources that are not considered in the major categories that the UN database includes, so we added a group named "others".

The installed capacity of electricity generation has been growing way beyond the actual consumption of energy, but we are assuming a perfect world where we will have energy generated and consumed every hour of the whole year. The statistics show an important growth on solar and wind energy generation in the past ten years for the wind and in the last 2 years for the solar panels generation. We found some interesting facts. Namely, China did not report any solar generation until. The plan in China for photovoltaic is so aggressive that it is expected to generate over 1,800 MW by the year 2020, with a stretch goal of 10,000 MW or more (Shen & Wong, 2009).



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Fuels	58%	57%	57%	56%	56%	56%	56%	57%	57%	57%	60%	60%	60%	61%	61%	61%	62%	63%	62%	62%	62%	62%	62%	62%	61%	60%
Hydro	17%	18%	18%	18%	18%	18%	18%	18%	18%	17%	17%	16%	16%	16%	16%	16%	16%	15%	16%	16%	16%	16%	16%	16%	16%	16%
Nuclear	17%	17%	17%	17%	17%	17%	18%	17%	17%	17%	17%	17%	16%	16%	16%	15%	15%	14%	13%	13%	13%	12%	11%	11%	11%	11%
Wind	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	2%	2%	2%	3%	3%	3%
Solar	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%
Others	8%	8%	8%	8%	8%	8%	8%	9%	8%	9%	7%	6%	7%	7%	7%	7%	7%	7%	7%	8%	8%	8%	8%	8%	8%	9%

Figure 2: Percentage of Generated Electricity by Source (source: UN data)

1.2 Global Sources of Generation Capacity versus Production

The following tables show the comparison of contributions by country for the generation compared to the production of electricity. We shall be careful with the veracity of the data.

Table 1: Hydro capacity and Production in 2015 (KWh)

Country	Installed Capacity	Contribution	Production	Contribution
China	2,278,579,770,000	27.4%	1,130,270,000,000	29.2%
United States	702,381,930,000	8.5%	269,675,000,000	7.0%
Brazil	629,635,500,000	7.6%	338,673,000,000	8.7%
Canada	545,615,400,000	6.6%	349,664,000,000	9.0%
Russian Federation	350,356,260,000	4.2%	168,419,000,000	4.3%
Japan	343,733,580,000	4.1%	74,801,000,000	1.9%
India	277,087,710,000	3.3%	121,377,000,000	3.1%
Norway	215,525,640,000	2.6%	133,525,000,000	3.4%
Turkey	177,713,160,000	2.1%	67,146,000,000	1.7%
France	173,659,860,000	2.1%	58,801,000,000	1.5%
Italy	152,651,400,000	1.8%	46,361,000,000	1.2%
Spain	139,138,110,000	1.7%	30,620,000,000	0.8%
Sweden	112,180,230,000	1.4%	75,428,000,000	1.9%
Viet Nam	107,439,930,000	1.3%	57,174,000,000	1.5%
Others	2,095,863,285,180	25.2%	954,041,955,967	24.6%
Total	8,301,561,765,180	100.0%	3,875,975,955,967	100.0%

Table 2: Nuclear Capacity and Production in 2015 (KWh)

Country	Installed Capacity	Contribution	Production	Contribution
United States	677,876,640,000	25.7%	830,288,000,000	32.3%
France	433,703,100,000	16.4%	437,428,000,000	17.0%
Japan	288,869,760,000	10.9%	9,437,000,000	0.4%
China	186,657,900,000	7.1%	170,789,000,000	6.6%
Russian Federation	180,708,480,000	6.8%	195,470,000,000	7.6%
Korea, Republic of	149,188,920,000	5.7%	164,762,000,000	6.4%
Canada	96,406,710,000	3.7%	101,423,000,000	3.9%
Ukraine	95,046,450,000	3.6%	87,627,000,000	3.4%
Germany	74,189,130,000	2.8%	91,786,000,000	3.6%
Sweden	66,556,560,000	2.5%	56,348,000,000	2.2%
United Kingdom	65,175,690,000	2.5%	70,345,000,000	2.7%
Spain	50,831,130,000	1.9%	57,305,000,000	2.2%
Belgium	40,622,310,000	1.5%	26,103,000,000	1.0%
India	39,708,600,000	1.5%	37,414,000,000	1.5%
Others	193,562,250,000	7.3%	233,365,000,000	9.1%
Total	2,639,103,630,000	100.0%	2,569,890,000,000	100.0%

Table 3: Solar Capacity and Production in 2015 (KWh)

Country	Installed Capacity	Contribution	Production	Contribution
China	289,776,600,000	18.6%	38,776,000,000	22.2%
Germany	273,343,560,000	17.5%	38,726,000,000	22.2%
Japan	234,610,500,000	15.0%	99,000,000	0.1%
United States	161,046,540,000	10.3%	25,059,000,000	14.4%
Italy	129,788,040,000	8.3%	22,942,000,000	13.2%
United Kingdom	63,114,690,000	4.0%	1,405,000,000	0.8%
Spain	49,230,420,000	3.2%	13,829,000,000	7.9%
France	46,413,720,000	3.0%	3,525,000,000	2.0%
India	37,778,130,000	2.4%	6,763,000,000	3.9%
Australia	29,953,200,000	1.9%	86,000,000	0.0%
South Africa	26,250,270,000	1.7%	-	0.0%
Thailand	24,525,900,000	1.6%	315,000,000	0.2%
Korea, Republic of	24,278,580,000	1.6%	3,388,000,000	1.9%
Belgium	21,448,140,000	1.4%	4,000,000	0.0%
Others	147,939,130,287	9.5%	19,378,041,000	11.1%
Total	1,559,497,420,287	100.0%	174,295,041,000	100.0%

Table 4: Combustible Fuel Capacity and Production (KWh)

Country	Installed Capacity	Contribution	Production	Contribution
China	7,708,881,960,000	27.2%	3,936,740,000,000	26.8%
United States	5,301,798,840,000	18.7%	2,802,188,000,000	19.1%
India	1,445,654,100,000	5.1%	943,013,000,000	6.4%
Japan	1,335,260,070,000	4.7%	746,184,000,000	5.1%
Russian Federation	1,230,746,760,000	4.3%	630,719,000,000	4.3%
Germany	666,163,290,000	2.4%	361,482,000,000	2.5%
Saudi Arabia	560,612,610,000	2.0%	215,670,000,000	1.5%
Korea, Republic of	481,641,960,000	1.7%	345,891,000,000	2.4%
Indonesia	453,194,664,000	1.6%	142,227,000,000	1.0%
Italy	450,788,790,000	1.6%	173,249,000,000	1.2%
Iran (Islamic Rep. of	423,409,092,000	1.5%	256,953,000,000	1.8%
United Kingdom	396,653,190,000	1.4%	177,866,000,000	1.2%
Spain	387,124,500,000	1.4%	96,474,000,000	0.7%
Thailand	353,138,610,000	1.2%	136,324,000,000	0.9%
Others	7,144,172,246,880	25.2%	3,710,469,612,656	25.3%
Total	28,339,240,682,880	100.0%	14,675,449,612,656	100.0%

Table 5: Wind Capacity (KWh)

Country	Installed Capacity	Contribution	Production	Contribution
China	898,252,500,000	31.2%	185,766,000,000	23.3%
United States	498,576,510,000	17.3%	192,809,000,000	24.2%
Germany	306,882,900,000	10.6%	79,206,000,000	9.9%
India	172,354,560,000	6.0%	26,867,000,000	3.4%
Spain	157,645,890,000	5.5%	49,312,000,000	6.2%
United Kingdom	98,179,170,000	3.4%	33,257,000,000	4.2%
Canada	77,040,180,000	2.7%	26,060,000,000	3.3%
France	70,190,790,000	2.4%	19,795,000,000	2.5%
Italy	62,771,190,000	2.2%	14,844,000,000	1.9%
Brazil	52,438,710,000	1.8%	21,623,000,000	2.7%
Sweden	40,120,800,000	1.4%	16,268,000,000	2.0%
Denmark	34,865,250,000	1.2%	14,133,000,000	1.8%
Portugal	33,917,190,000	1.2%	11,607,000,000	1.5%
Poland	33,566,820,000	1.2%	10,858,000,000	1.4%
Others	346,341,040,410	12.0%	95,207,673,667	11.9%
Total	2,883,143,500,410	100.0%	797,612,673,667	100.0%

1.3 Diffusion of Renewable Generation

Figure 2 shows that there are no major trends in the generation of electricity. Wind and solar are going upwards, but their contribution is still minuscule to the total electricity generated nowadays. Focusing only on the renewable resources' generation, we are going to conduct Bass' diffusion analysis only for the wind and solar electricity generation processes by state using the data available at the UN Database.

1.3.1 Wind Generated Electricity

We are seeing Texas as the largest contributor for the electricity generated with wind, with Oklahoma following at a distance with more than one third of the Texas generation; but Oklahoma's growth is important with a very fast diffusion speed, eclipsed only by Illinois which is growing tremendously in a short period of time.

Table 6: Diffusion Indexes for Wind Electricity Generation in the US by States

Wind Energy	Cum. Level (Millions)	Maturity Level (Millions)	Innovation Index	Imitation Index	Diffusion Speed
USA	254.25	311.33	0.0064	0.2977	46
Texas	67.09	362.74	0.0028	0.1475	53
OK	24.40	131.96	0.0007	0.2590	362
IA	20.82	22.22	0.0046	0.4025	87
KS	18.50	40.79	0.0014	0.2981	206
CA	13.97	198.90	0.0039	0.0166	4
IL	11.30	11.30	0.0007	0.6450	969
ND	10.99	16.80	0.0053	0.2412	45
MN	10.88	12.90	0.0138	0.2658	19
CO	9.57	10.56	0.0058	0.3595	62
WA	7.48	7.77	0.0055	0.5115	93

California shows an imitation index of 0.016 which is the smallest one of all, which means that only innovators are implementing wind energy because the curve shows a flattened curve, as this state has been generating electricity using wind mills long before anyone else. Therefore, we do not see as a rapid growth in California as Washington and Minnesota, which will reach maturity much faster.

Table 7: t-test for top 10 States using Wind generated Electricity

Wind	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Lower	Upper
Cum_Level	1.86	10	0.092	40.8409	-8.0107	89.6926
Maturity	2.59	10	0.027	102.4791	14.1507	190.8074
Innov_Index	4.18	10	0.002	0.0046	0.0022	0.0071
Imit_Index	6.14	10	0	0.3131	0.1996	0.4267

Doing t-test for the states' cumulative level is below 10%, but maturity level, innovation and diffusion indexes were significantly below 2%. The top ten states show that the diffusion of wind generated energy will reach maturity around the year 2050, when some scholars are predicting that renewable energy will represent 50% of all electricity in the US (Lehr, 2013).

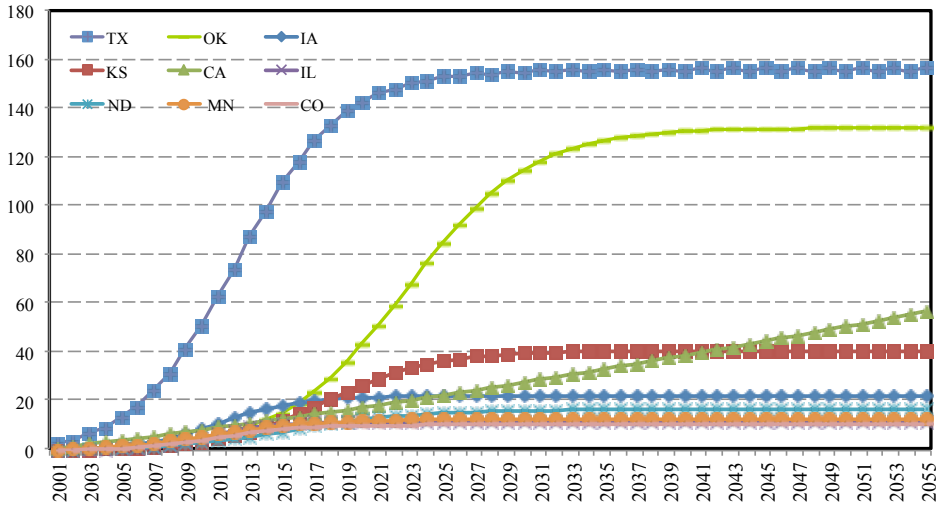


Figure 3: Diffusion of Wind Generation by State

1.3.2 Solar Generated Electricity in the US

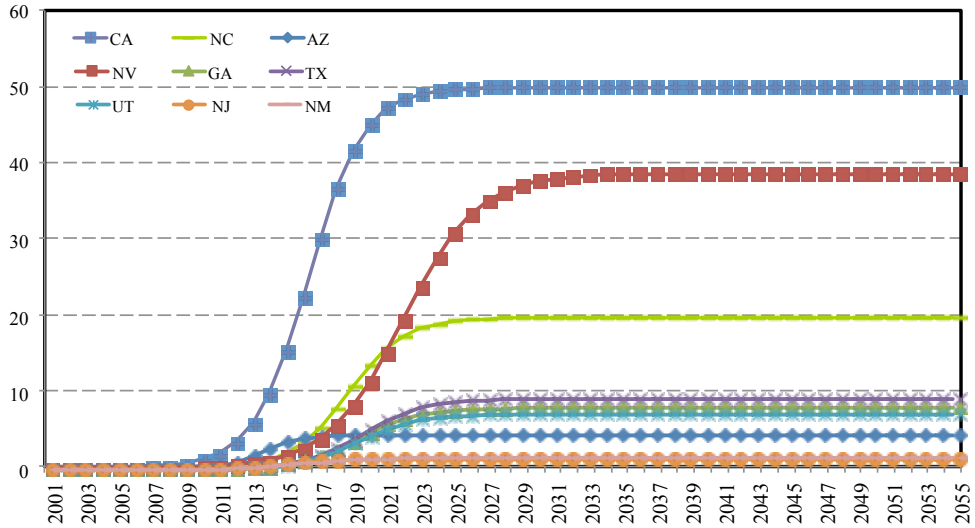


Figure 4: Diffusion of Solar Generation by State

For solar energy, California is undoubtedly the largest contributor with 43.62% of all solar electricity in the country. California has been a pioneer in renewable resources electricity, so we are also seeing an imitation index of zero. This means that the curve is flattened and all the growth is identified as innovator growth that will take much longer to mature. North Carolina is second on order, followed by Arizona and Nevada, but their growth is strongly driven by imitation, which means that they are reaching maturity soon. Nevada's growth is so impressive that the maturity level for this state is expected to be around 38.73 million of Megawatt-hours.

Table 8: Diffusion Indexes for Solar Electricity Generation in the US by States

Solar Energy	Cum. Level (Millions)	Maturity Level (Millions)	Innovation Index	Imitation Index	Diffusion Speed
USA	52.96	99.85	0.0000	0.5937	21,810
CA	23.10	28.46	0.0000	0.7473	74,729
NC	5.58	19.91	0.0000	0.5885	58,854
AZ	4.74	4.62	0.0000	0.8437	84,374
NV	3.83	38.73	0.0000	0.4459	18,024
GA	2.14	8.12	0.0000	0.5672	56,719
TX	2.12	9.33	0.0000	0.5573	55,672
UT	1.97	7.27	0.0000	0.5685	56,852
NJ	1.17	1.42	0.0001	0.6060	7,007
NM	1.11	1.64	0.0002	0.4800	1,930
MA	1.05	1.72	0.0000	0.6786	67,864

For solar generation, the t-tests results are significantly below 10%, with the exception of the innovation index which is the one driving the solar energy generation. The maturity level and the imitation index are the most significant, at below 5%, which demonstrates that the analysis is correct and there will be a quick diffusion process for solar energy in the US.

Table 9: t-test for top 10 States using Solar generated Electricity

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Cum_Level	1.896	10	0.087	9.07	-1.5912	19.7312
Maturity	2.291	10	0.045	20.09727	0.5473	39.6472
Innov_Index	1.399	10	0.192	2.73E-05	-0.000016	0.000071
Imitat_Index	17.726	10	0	0.606973	0.530677	0.683269

3.1.8 Global Prognosis

Coal and other combustible fuels are one of the major concerns in the world for the emission of CO_2 to the environment, as it contributes to the greenhouse effect— the process responsible for global warming. It is concerning to see the tremendous growth of energy generation with the use of coal in China, while in the United States coal use is decreasing, as shown in Figure 5.

Looking at the generation of electricity using hydropower, we see China growing tremendously. China is the number one producer of hydropower and it is still growing strong, while the other countries have remained in a steady state using these natural resources. We also see Brazil growing slowly in this area, after the investments referenced in the introduction, but with a trend down on the last three years.

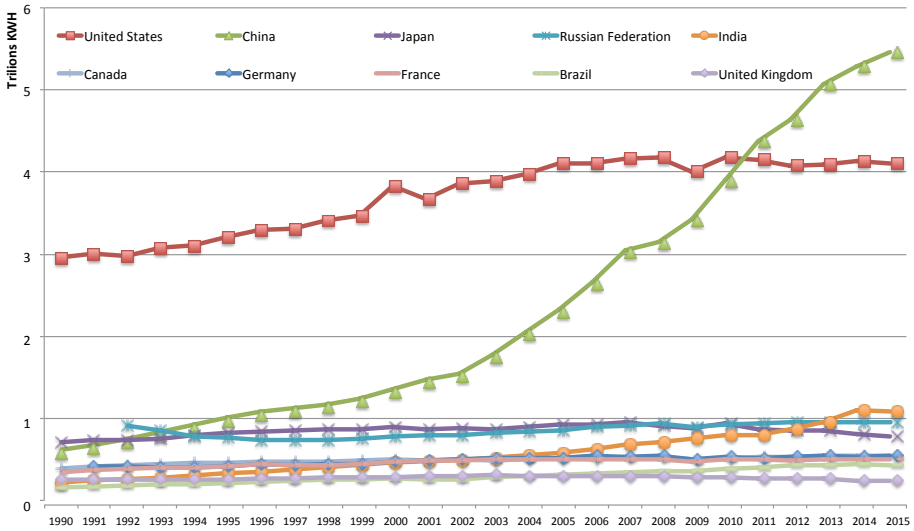


Figure 5: Energy generation burning fuels (source: UN Data)

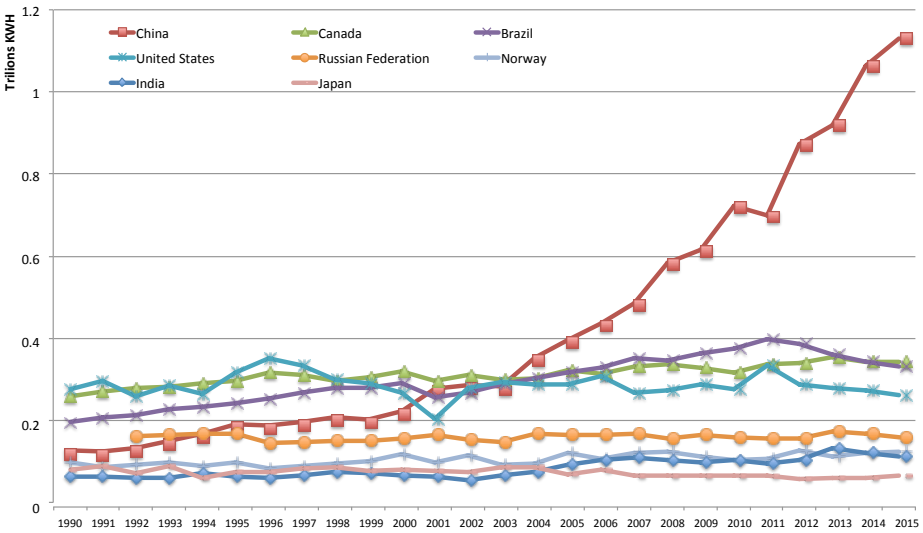


Figure 6: Electricity generated using hydro power (source: World Bank database)

Wind is a renewable resource and has been identified as one of the cleanest sources of energy, causing less harm to the environment; the US is the leader in its implementation. We can see that China is growing in second place and it is about to take the leadership position.

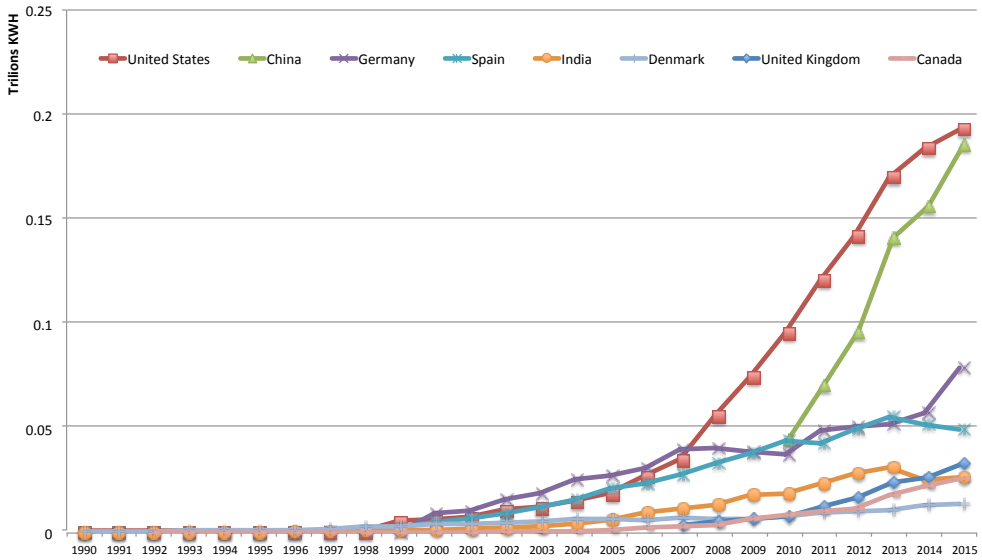


Figure 7: Electricity generated with Wind (source: UN Data)

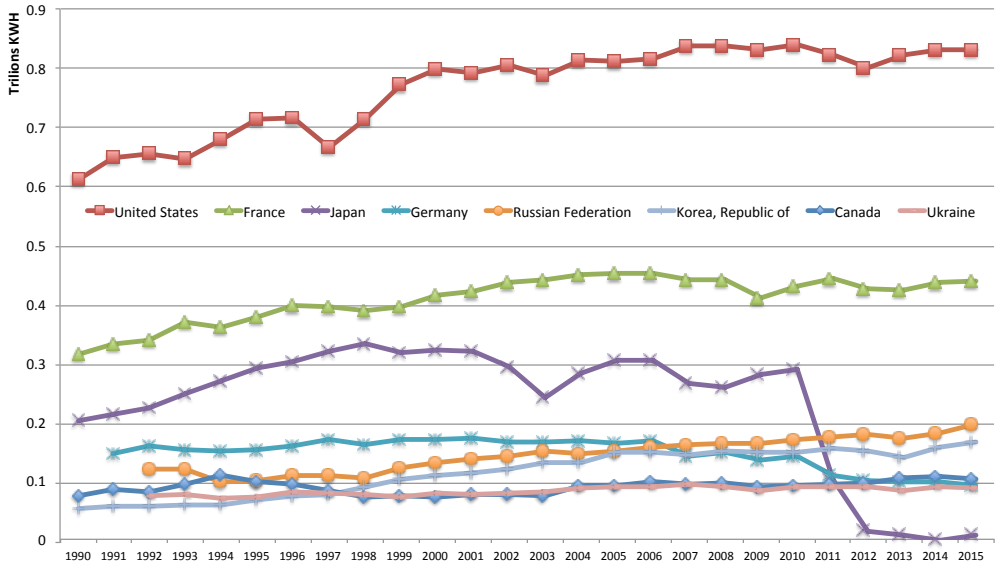


Figure 8: Electricity generated using nuclear plants (source: World Bank database)

Nuclear energy had been steadily growing throughout the world, but following the Fukushima incident there are some countries that are reversing their efforts toward nuclear energy until preventive measures can be implemented to prevent disasters. Japan is the clear example, as it has reduced its nuclear electricity generation to a minimum.

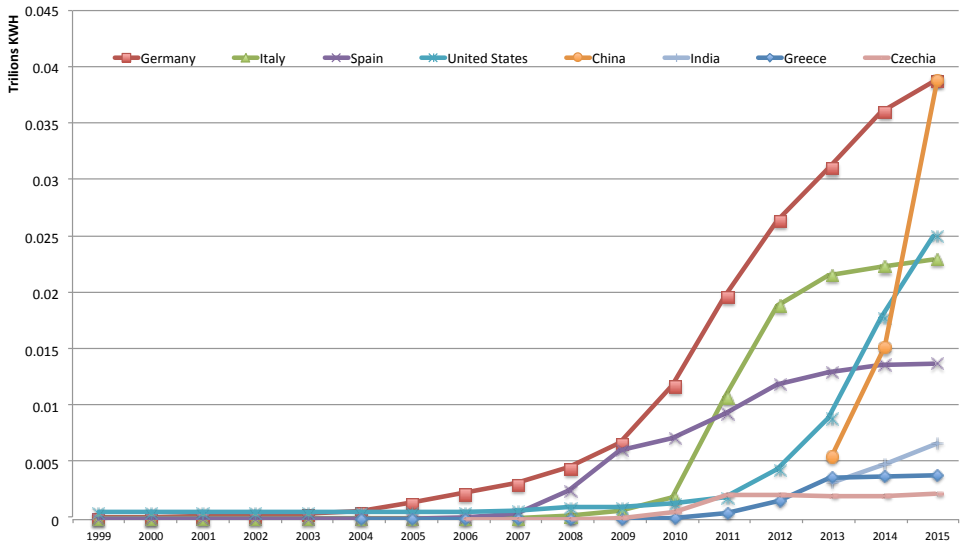


Figure 9: Electricity generated by Solar Energy (source: UN Data)

Another source of energy that it is growing rapidly is the solar energy generation, where Germany is the world leader, but not for long, as China I about to take the leadership position too after only three years of reporting generation of solar electricity. This is the latest of the renewable resources energy coming strong because the generation was almost zero until 1999 when solar energy really kicked in.

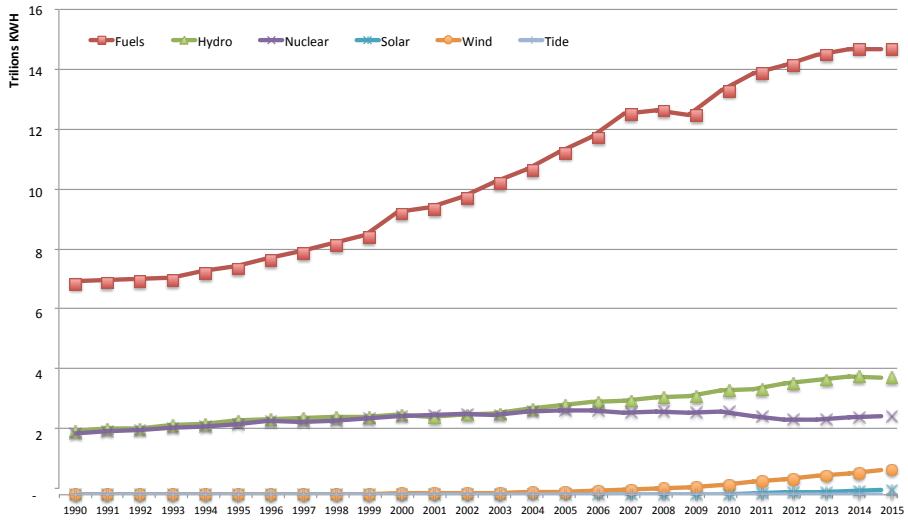


Figure 10: Global energy generation sources (source: World Bank database)

Looking at Figure 5, it is evident that the amount of energy produced using oil, coal and other combustible fuels has been drastically reduced. Figure 5 clearly shows that combustible fuels are the largest source used to generate electricity and will continue to be for a long time, until regulators begin inhibiting its growth. Hydro is clearly second and is also growing, with a big push from China. Nuclear energy will completely change its trend as more countries are prohibiting its use, and oil is also going down. Figure 11 shows that the leadership on electricity generation has changed from the United States to China after 2011 because of the Chinese exponential growth.

The potential of the Chinese market has not been fully understood, as the communist government is investing all necessary capital to electrify the country and allow foreign industries to be located there, while the nationals have access to utilities that can improve quality of life.

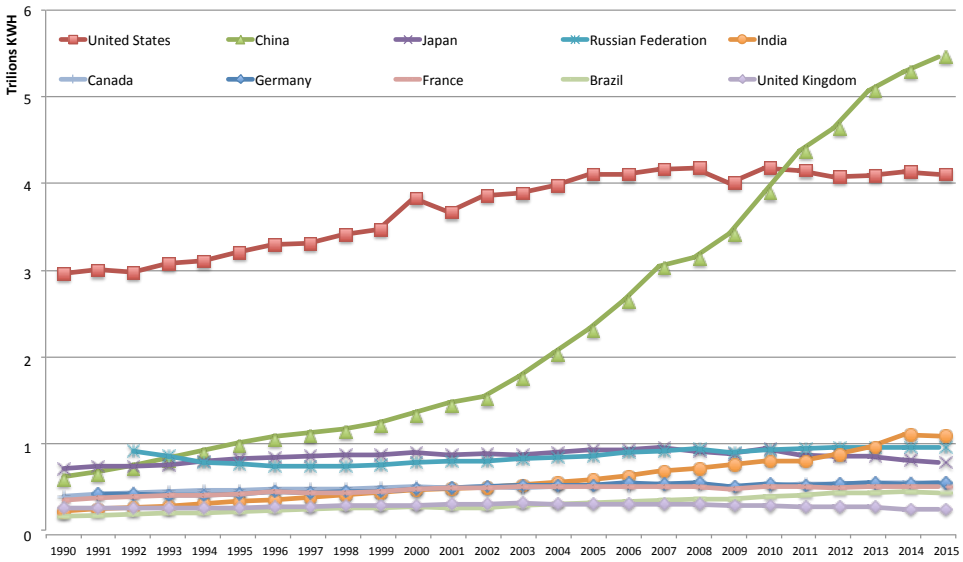


Figure 11: Worldwide top electricity generation producers

CONCLUSIONS

The results of the research present a challenging future for human society as consumption keeps growing and generation is mostly based on generation burning combustibles that emits large amounts of CO_2 to the atmosphere. Consumers, utility companies and governments that are shifting towards the use of renewable resources energy are taking some important actions that are showing exponential growth of wind and solar energy, while nuclear and fuels burning processes still growing but slowly. Unfortunately much of the investment continues to support macro-generation, when one of the possible solutions (distributed generation) is not being supported as much. Maybe solar cells' generation by consumers may also help to revert the trend of contamination and dependency on fuels.

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DECISION SCIENCES INSTITUTE

Drivers and Barriers to Sustainability Engagement among NY State SMEs

ABSTRACT

In the extant literature on SMEs' sustainability adoption, relatively fewer research has focused on the US compared to Europe. Our study consists of a larger number of firms (75), from a broader cross section of industries and geographical spreads, investigating major drivers and barriers to SMEs' sustainability. Findings show important internal and external drivers such as owners/managers' sense of moral obligation to reduce negative environmental impacts, lowering costs, market trends of customers who value socially responsible products and environmental audits. However, competitive advantage, regulatory compliance, or financial incentives were not deemed important influencers. Major barriers included cost and limited resources.

KEYWORDS:

Environmental Sustainability, Sustainability in Operations, Small and Medium-sized Enterprise, SMEs, Sustainability in SMEs, NY State SMEs

INTRODUCTION

Awareness of environmental impact is being increasingly studied and investigated at international, national and business levels. Paris Accord, succeeding Kyoto Protocol, has been the most recent effort to treat climate change at global and international levels (Christoff, 2016). In addition, majority of the large corporations have recently made significant efforts to demonstrate their corporate social responsibly and the environmental plans they are committed to through published annual or semi-annual sustainability reports (GRI Sustainability Reporting). Large corporations have been the focus of government policies, regulations and incentives more than Small and Medium-sized Enterprises (SMEs). However, SMEs collectively constitute a larger portion of the economy and are held responsible for a greater share (70%) of the environmental pollution (Parker et al., 2009). On the other hand, SMEs' operations and resources are usually much more limited compared to larger corporations, which leads to more constraints and difficulties for the adoption of sustainable solutions.

A lot of research has been done to explore how and why SMEs develop sustainability strategies and how they implement sustainable solutions. As shown by Parker et al. (2009) and Wiesner et al. (2017), majority of the published work on SMEs' sustainability is focused on Europe, particularly the UK and Germany, with few studies on other countries such as the Netherlands, Sweden, Austria, Australia, Canada, Hong Kong, Israel, Japan, New Zealand, S. Korea, Malaysia and the United States. Lehner and van Eyssen (2017) studied the barriers complicating the adoption of sustainability in businesses. They interviewed ecopreneurs' businesses in Sweden and demonstrated that market demand and partners, as external factors, play a more important role for ecopreneurs to be environmentally sustainable. Aghelie (2017) investigated the drivers

and barriers in SMEs' adoption of sustainability by interviewing businesses in Malaysia. Del Giudice et al. (2017) presented a comparative study of SMEs sustainability adoption between the UK and Italy. They interviewed 10 SMEs in those countries and showed how owner-managers' roles and their collaboration with employees and other stakeholders were different across countries and had key roles in sustainability engagement decisions made by SMEs.

Some sustainability studies have also been done on US SMEs (Theyel & Hofmann, 2012; Langwell & Heaton, 2016). Langwell and Heaton (2016), for example, present the impact of the human resources on SMEs' adoption of sustainability. However, the number of US studies compared to European countries is not adequate or proportional to the size of the SME sector in the US. The scope of studies on US SMEs is also limited in the number of dimensions investigated, the industry that SMEs come from, or in the small sample size of the SMEs studied. In this study, we take a comprehensive approach of investigating major drivers and barriers in SMEs' sustainability adoption through a large sample of SMEs (over 70) in the US. Our pool of SMEs come from small towns (e.g., Ithaca, NY) to big cities (e.g., New York City) and across different industries (manufacturing to services such as food, healthcare, etc.). The purpose of this study is to expand our knowledge of US SMEs' sustainability drivers and barriers. In addition to reviewing the literature during the early development of our study, to validate the potential contributions of our study, we also shared the focal points of our research with four sustainability experts who are very experienced and involved in business sustainability in NY State or at the regional level. These experts were not aware of any previous practice-oriented research similar to ours, which not only integrates several of these dimensions but also focuses on the experience of small businesses in this region. Given their response, we realized that our research could identify both successes and gaps in the sustainability efforts among small businesses in the NY State. These experts believed that our research would provide a baseline data that could benefit both the owners/managers of such businesses, which are the backbone of the local communities in sustaining employment growth and environmental efforts, as well as the state and local government agencies to identify resources and tools that these businesses need for sustainable development.

In the next section, we review the literature on sustainability in SMEs followed by the Methodology section where we describe how we selected SME participants, collected, and analyzed the data. In the Results and Discussion section, we report on and discuss some of our key findings and conclude the paper with a discussion on some of the implications and limitations of our study and suggest directions for future research.

LITERATURE REVIEW

Given the focal point of our study - the examination of drivers and barriers to SME sustainability adoption strategies - this section starts with review of the findings of the meta analyses of such research, followed by the latest published work. In the interest of representation, we have aimed to include studies from developed and developing countries.

In a qualitative investigation of the environmental literature with a focus on business survey evidence, Tilley (1999) identified the following forces that prevented firms from transforming their pro-environmental attitudes into pro-environmental forces: low standard of eco literacy, poor environmental awareness among owners/managers, economic barriers which made reduction of environmental impact costly, and low awareness about the environmental business programs and support offered by governments.

Walker et al. (2008) reviewed 351 publications with a primary emphasis on identifying the main barriers and drivers to environmental management among SMEs. They noted three barriers that prevented such firms from engaging in good environmental practices. First,

characteristics of the SMEs in general (heterogeneous industry nature, size, urban/rural divide, managers' varying educational and ethnic background/gender) which made targeted communication and coordination of technical assistance difficult. Second, resources availability (including financial, human and time) which made perceived cost the single biggest reason why SMEs did not engage in environmental management. Third, owners/managers' knowledge of, interest in, and motivation to adopt environmental management which may have prevented them from viewing environmental issues or the need to act responsibly as significant. Many times, these stemmed from the belief that their adverse environmental impact was small or insignificant.

Parker et al. (2009) reviewed nearly 50 journal articles published between 2003 and 2008 with a primary focus on developing environmental improvement intervention strategies that would be most effective for various subsets of SMEs. Drawn from the literature examined, they listed the following factors as the main drivers/barriers of SME environmental improvement: regulation, environmental commitment, business performance commitment, financial incentives, external demand, environmental knowledge, and assistance/education.

In their analysis of the role of SME suppliers in implementing sustainability, Meqdadi et al. (2012) provided an extensive listing of the literature on SME barriers and drivers in sustainability initiatives by organizing them for SMEs vs. their supply network. As for drivers of SMEs' sustainability, they list commitment and beliefs/values of top management, cost savings and benefits, existence of environmental awareness, availability of financial and technical resources and infrastructure complying with environmental standards and seeking competitive advantage, among others. Among the barriers, they cite lack of top management commitment, time and awareness, perception that their impact on environment is minimal, high cost of environmental programs, lack of financial resources, lack of skills, know-how and technical expertise, among others.

Drawing on 84 journal articles published between 1987 and 2010, Klewitz and Hansen (2014) found SMEs' strategic sustainability behavior to range from *resistant, reactive, anticipatory,* and *innovation based to sustainability-rooted* and identified innovation practices at *product, process,* and *organizational* levels. In their review of literature, they refer to most of the major factors listed by the studies noted above.

Johnson and Schaltegger (2015) reviewed 112 studies to identify the specific sustainability management tools designed for SMEs and reasons why they were implemented or not. All in all, they identified 26 sustainability management tools from the literature applicable to SMEs. They note the following as the normative considerations as to why SMEs should implement these methods: managing legal compliance and stakeholder relationships, performance improvement, organizational learning, and innovativeness. As for barriers to implementation, they divide them into internal and external. The internal barriers include the lack of awareness on sustainability issues, absence of perceived benefits, the lack of knowledge and expertise, and the lack of human and financial resources. The external barriers consist of insufficient external drivers and incentives, the unsuitability of formal management tools in informal SME structures, and the complexity of internationally designed standards and instruments for locally focused SMEs (Johnson & Schaltegger, 2015).

Agellie (2017) explored the drivers and barriers to SMEs sustainable green business practices and uncovered 21 drivers and 35 barriers. The drivers were in turn classified into seven categories among which "social influences" such as improving company's image, having long term relationship with consumers by earning and returning their trust were the most

important driver. “Training and knowledge” (e.g., availability of affordable comprehensive training and education courses) was the least important driver. The barriers, in turn, were divided into six groups among which “government and legislation” was found to be the most challenging barrier for SMEs to implement, that is to say, the absence of government support and enforcement or limited budget/financial incentives to support green sustainable projects. “Suppliers” was found to be the easiest barrier to overcome.

Among studies focused on developing countries, Agan et al. (2013) surveyed 500 Turkish manufacturing firms and found the most influential driver affecting environmental improvement to be the expected benefits resulting from enhancement in companies’ image, reputation, and brand. Chan (2011), surveyed 48 SME hotels in Hong Kong on barriers to the implementation of environmental management systems and found the following factors hindering such adoption: implementation and maintenance costs, lack of knowledge/skills, lack of the sense of urgency, ambiguity of standards, and lack of qualified consultants.

In an interesting twist of research, Chasse and Boiral (2017) explored how decision makers in SMEs explain their lack of commitment to sustainability by conducting 33 interviews in 9 Canadian companies. They grouped responding managers’ rationale for lack of commitment to sustainability into three main justifications. First, prioritization of economic survival, arguing that pursuit of sustainability would possibly lead to layoff, plant closure and risk of bankruptcy, among others. Second, looking for scapegoat, offering such arguments as having little control over suppliers, minimal pressure by consumers to improve their products, not having financial resources to be proactive, inadequate government policies and lack of financial assistance to support SMEs sustainability initiatives. Lastly, denial and minimization in such ways as reject having negative impact, discount sustainability issues and believe that they were in fact running sustainable operations.

METHODOLOGY

We selected the interview method as an exploratory approach in our study. Qualitative methods have been used in many studies of SMEs’ sustainability behavior (Langwell & Heaton, 2016; Aghelie, 2017; Del Giudice et al., 2017). As shown in the literature, many external and internal factors such as government regulations, consumer trends, and businesses’ culture and values are defined within countries, states, and regions. Therefore, studies should focus on certain geographical boundaries to be able to identify the drivers and barriers for SMEs in a region and develop guidelines that are effective for the corresponding areas. We focused on exploring SMEs’ sustainability behavior and strategies in NY State and conducted interviews with SMEs in this area. The interview instrument consisted of six open-ended questions, which were formally developed after reviewing existing literature along with preliminary discussions with several SME experts. Table 1 includes the categories of the questions as well as the questions themselves. Questions prompted interviewees to discuss topics including: their familiarity with sustainability and how they learned about it, their implementation of sustainable business practices (e.g. renewable energy, recycling, local sourcing, etc.), their motivations for being sustainable (e.g. values, regulations, incentives, consumer behavior, competitors, etc.), barriers preventing sustainability in their business (e.g. awareness, cost, etc.), potential future sustainability plans as well as any other relevant information they may have liked to share.

Table 1. *Interview Questionnaire*

Category	**Question**
Familiarity	1. Are you familiar with environmentally sustainable solutions in small businesses (such as energy conservation, reuse and recycling, local resources, etc.)? How did you learn about them?
Solutions	2. Have you implemented any environmental solutions in your business? If yes, please explain exactly what you have done.
Drivers *(Internal)*	3. What have been your motivations in implementing those solutions?
External	a. Have regulations and policies encouraged you in your efforts?
External	i. Did tax incentives help?
External	ii. Did fine or complying with regulation influence your decision?
External	iii. Did your trade/industry association influence your choices?
External	b. Has your consumers' behavior of shopping sustainable product/service influenced your adoption of sustainability?
External	c. Has your competitors' adoption of sustainability motivated you to do the same?
Internal	d. Have you had any business sustainability goal regardless of the external of factors of government policies and consumers' trend?
External or Internal	e. Have you been encouraged by any other factors than the ones discussed above?
Performance	f. Has your investment of adopting sustainable solutions paid off?
Barriers	4. If you have not implemented any sustainable solution, why have you made that decision?
Internal	a. Have you been aware of such solutions?
Internal	b. Have you been concerned with the cost of the adoption of sustainable solutions?
Future Plans	5. Do you have any future plan to start or expand your sustainability efforts?
Other	6. Is there anything else you would like to share with us in this regard?

Interviews were conducted over the phone, in person or through video conference and were up to an hour in length depending on how much information the interviewee wanted to or

was able to share, based on their awareness or knowledge of sustainability or on the amount of sustainable solutions implemented by their business. Prior to the interviews, interviewees were provided a brief overview of the study, the interview questionnaire and the informed consent forms so that they could acknowledge their understanding of the purpose and the voluntary nature of the participation in our research. Utilizing the interview guidelines that detailed potential responses and follow-up questions, interviews were conducted by researchers.

Data Collection

Data was collected via semi-structured interviews with managers and owners of 75 SMEs operating in the NY State. SMEs were defined as small to medium-sized enterprises with 250 or fewer full-time employees. As shown in Table 2, participating SMEs were from the metropolitan areas such as Ithaca (25), New York City (11), Syracuse (9), and Buffalo (9). Of these, 86% were for-profit businesses. To improve generalizability, the interviewed businesses varied across industries, including manufacturing, retail, farming, restaurant, and health.

Table 2. *List of participant locations in NY State*

Location	Number of Participating SMEs
Ithaca	25
Other	21
New York City	11
Syracuse	9
Buffalo	9

Businesses were primarily chosen through referrals or by the researchers' own familiarity with them. Many businesses were also contacted using information provided by the Chamber of Commerce or online business directories and listings, including *the Small Business Administration's Dynamic Small Business Search* database. The SBA's database produced a randomized selection of small business contact information based on location criteria specified by researchers.

Content Analysis

After interviews were conducted, content analysis of the interview transcripts was completed by the researchers. This was done by thoroughly reading through the transcripts and coding the interviewees' responses to each question, which were coded into a spreadsheet, organized into columns for each of the open-ended questions and sub-questions asked in the interviews.

Using the Grounded theory approach, researchers identified several categories in the data as they emerged in the interviews themselves in order to create coded terms (Strauss &

Corbin, 1990; Williamson et al., 2006). When researchers discovered a response within a transcript that did not fit any of the already defined terms, they added a new term to describe the response. Each new term and its definition was recorded in a shared list between researchers to improve the inter-rater reliability of the researchers' coding. Researchers also identified categories and terms by reviewing the terminology used in prior research regarding business sustainability (Robinson & Stubberud, 2013; Wiesner et al., 2017). For instance, the term "feel good" was adopted in the current study to describe sustainable solutions that had paid off for businesses through intrinsic and personal benefits (Robinson & Stubberud, 2013).

Initially, 115 terms were defined to identify recurring concepts within the interviews such as "Family Influence", "Cost", and "Limited Resources". Recognizing the overlap in the definitions of some of the terms, the researchers grouped the related terms into categories, reducing the total number of terms to 86.

FINDINGS & DISCUSSION

As noted in the review of literature section, a variety of internal and external factors such as education, businesses' self-motivation and regulations are among the major drivers behind small businesses' decisions to implement sustainability (Tilley, 1999; Walker et al., 2008; Parker et al. 2009; Johnson and Schaltegger, 2015). At the same time, studies have shown several barriers such as the cost of implementing sustainable solution and resource limitations prevent SMEs from utilizing such solutions. Below we discuss the key findings of this study with respect to the prominent drivers and barriers identified by NY State SMEs against the backdrop of the extant literature.

Drivers

Environmental Awareness

When first considering implementing sustainable solutions in business operations, it is necessary for small business owners or managers to have some level of knowledge, awareness, or understanding as to how. Gadenne et al. (2008) and Giri et al. (2015) demonstrated how environmental awareness, for instance, had influenced SMEs' decision to adopt sustainable solutions. As with typical knowledge-gaining activities, individuals turn towards formal or informal educational outlets such as colleges and journal articles as well as their peers to obtain knowledge. This was evident across several respondents' comments such as the following:

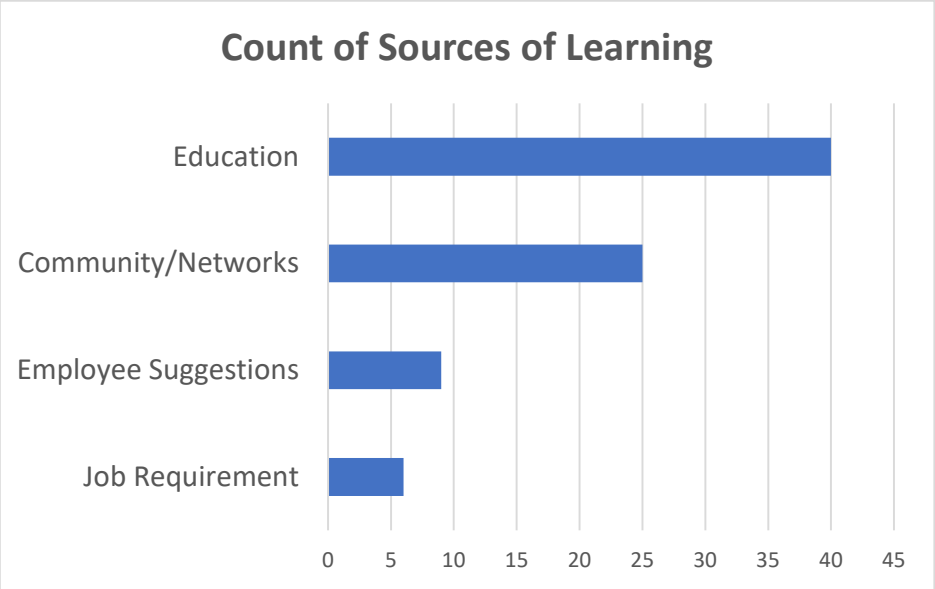
> "I learned about sustainability in class"

> "Because you're subjected to a community of conversation that supports that modality *[sustainability]*, it makes it a lot easier…... We are highly suggestive creatures, and you have to conform with your community."

According to our analysis (Fig. 1), 50% of the respondents noted that education, whether formal or informal (e.g., professional seminars, schooling, journal articles), contributed to their decision to implement sustainable solutions. This aligns with the rise of sustainability-related

courses and educational opportunities offered at colleges and universities around the US, which exposes business owners and managers to the subject (Christensen et al., 2007). In addition to education, 31% of the respondents also noted that their communities or networks allowed them to learn about adopting sustainable solutions. As these social sources have been linked to opportunity recognition, to remain competitive with larger firms, it is plausible to conclude that learned opportunities such as reducing costs or improving customer relations impacted SMEs' business owners/managers' decisions to implement sustainable solutions (Ozgen et al., 2007). Our finding here is in concert with several previous studies which found the extent to which SME owners/managers or employees' knowledge about how to engage in environment improvement was one of the key motivators for adoption of sustainability solutions (Tilley, 1999; Walker et al., 2008; Parker et al., 2009; Meqdadi et al., 2012).

Figure 1. *Sources of learning about sustainability by SME managers / owners*



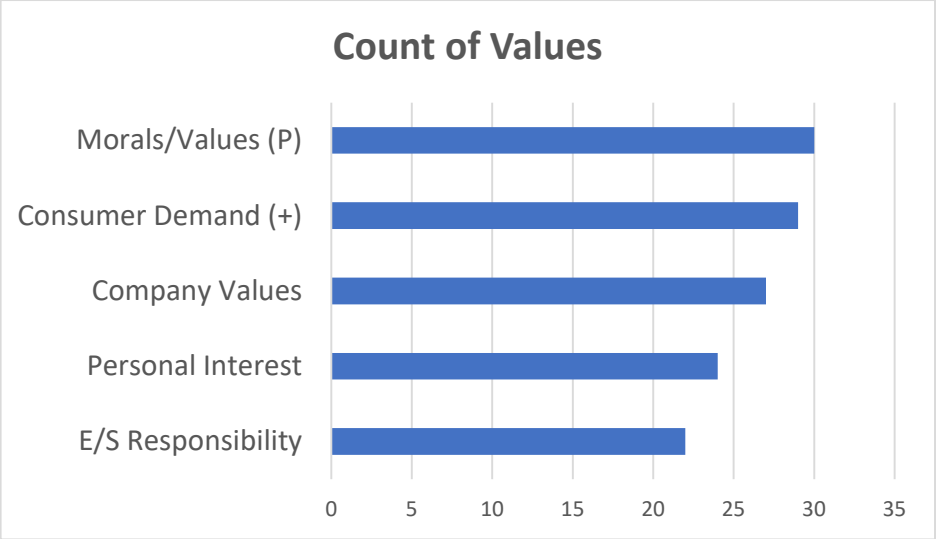
Values

Although businesses may differ in their motivations depending on industry or market segment, their underlying motivations to engage in sustainability are similar. Lozano (2013) notes that SMEs can be motivated by a variety of factors such as internal leadership, customer expectations, and regulations. NY State SMEs appear to be driven by the belief that businesses and individuals hold an obligation to reduce their negative impact on the environment and society. Additionally, SMEs feel as though engaging in such activities will allow them to improve their bottom line in the long term. This can be surmised from transcript excerpts such as the following:

> "I worked with our board of directors to come up with our mission statement which is our triple bottom line mission to enhance community, economy, and environment, through reuse. We saw our core activity to keep stuff out of the landfill, and that it also had other positive impacts."

As per our analysis (Fig. 2), the most common motivators encompassed personal morals or values, general company values and the idea of corporate responsibility, in that order. As the competitive landscape broadens and consumers obtain greater power in influencing business decisions, it has become essential for firms wishing to remain competitive to engage in corporate social responsibility activities such as giving back to the community, sourcing from sustainable suppliers, or providing adequate living wages (Juščius et al., 2008). Coupled with a continuous growth in the environmental movement since the mid 1900's, business owners and managers have become more aware of the necessity of intertwining their operations with sustainability to both limit negative impact while maximizing their operations (Dunlap et al., 2014).

Figure 2. *Values impacting SME sustainable solution implementation*



As it relates to management values, earlier studies have noted both dismissive predisposition by some who do not see environmental issues or the need to act responsibly as significant for their business believing that their impact is small or insignificant, as well as managers who believe they have a responsibility to engage in environmental improvement, proactively undertake such actions and view their business having an environmental impact (Walker et al., 2008; Parker et al., 2009).

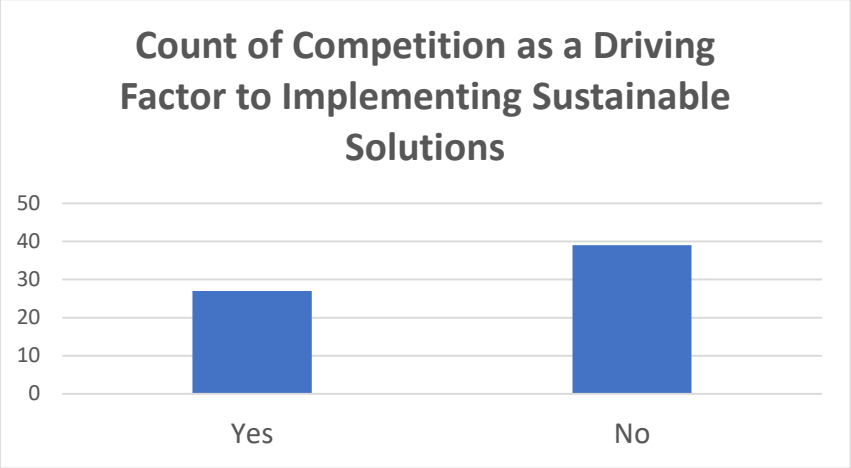
Competitive Advantage

With over 28.8 million SMEs in the United States, individual businesses operate in a vastly competitive environment (SBA Office of Advocacy, 2016). As a result, staying competitive or diversifying one's product line or services is a top priority for business owners and managers. In relation to this research, it does not appear that sustainable solution adoption is impacted heavily by competition, but rather that sustainable solutions are used to inspire the competition. This can be seen through various excerpts such as:

> "No [our competitors' adoption of sustainability has not motivated us], I actually look at it like I hope we motivate other people to start doing more."

According to our results (Fig. 3), of the 66 respondents referring to this factor, 59% noted that competition had no impact on their decisions to adopt sustainable solutions, whereas 41% stated that it did. Although it may appear that the actions of competitors in terms of sustainability does not impact SMEs' decisions to implement sustainable solutions, the concept of maintaining competitive advantage may still apply. As it has been noted, engaging in effective sustainable efforts that help reduce costs, and optimize business operations have led to strong competitive advantages (Meqdadi et al., 2012; Laszlo, 2017). Over the past decade, these advantages have included desirable cultures, improved customer loyalty, improve company's image, reduced operating costs, increased innovation / creativity, improved risk management, and additional value for stakeholders (Fink, 2016; Agellie, 2017).

Figure 3. *Impact of competition on SMEs implementing sustainable solutions*



Regulations, Taxes, and Compliance

Government intervention and involvement in business practices has been prevalent in the US for quite some time. Graafland et al. (2017) argues that direct government regulations and involvement, although helping to improve environmental performance, should be used in conjunction with other factors such as social license pressures to be effective. Although municipal, state, or federal compliance, regulations, or support can impact a business's operations, it appears that it does not have a major impact on NY State SMEs in terms of implementing sustainable solutions. This becomes evident from excerpts like the following:

> "Not at all, I haven't received any kind of specific notice as to plans I should follow or things I can change about my sustainability from the government."

Over the past few decades, there has been an increase in government assistance provided to businesses not only for general economic growth purposes, but also for sustainability activities such as climate investments (Stiglitz, 2016). According to our results, government regulations and incentives did not greatly impact the decision of SMEs to engage in sustainability. Of the 57 owners/managers who responded to this question, about 39% noted government regulations as having an impact on their decision, and 41% of the 59 interviewees who commented on government incentives viewed it as an inducement. In terms of compliance, a resounding 81% of the 54 owners/managers who spoke about compliance stated that it had no impact as well. Overall, it appears that government programs, hold little to no effect on sustainable adoption rates (Table 3).

Table 3. *Government Regulations, Taxes, and Compliance Breakdown*

	Yes	**No**
Government regulations impact on SMEs	39% (22)	61% (35)
Government incentives impact on SMEs	41% (24)	59% (35)
Regulatory compliance impact on SMEs	19% (10)	81% (44)

Findings of the earlier studies on the role of government regulations, compliance and incentives in companies' sustainability decisions have been mixed. For example, in their meta-analysis, Parker et al. (2009) found the extent to which regulations existed and were extensive enough to force SMEs to engage in environmental improvement and the extent to which financial support or incentives were provided to offset the costs or whether taxes/charges/fines were imposed to discourage negative environmental impact to be all impactful on companies' sustainability decisions. Johnson and Schaltegger's meta-analysis (2016) and Agellie's (2017), on the other hand, found that the absence of government support or limited financial incentives offered to support green sustainable projects were among the major barriers to the firms' adoption of sustainability.

Barriers to Implementation

Aside from the various motivations that encourage SMEs to implement sustainable solutions, there also exists barriers that inhibit implementation. Luthra et al. (2015) identified 28 barriers to sustainability for SMEs across seven core dimensions including economical and financial, market, awareness and information, technical, ecological and geographical, cultural and behavioral, and political and government issues. These barriers, though unique to each organization based on size and industry, primarily included costs due to the capital intensity of sustainable solutions such as solar panels, and a general lack of resources such as space or employees for NY State SMEs. This is based on such excerpts as follows:

> "Yes, entirely, it [adopting sustainable practices] is more time consuming and way more expensive, it's often not practical for a small business."

According to our analysis (Fig. 4), among the responding firms, cost rises to the top among barriers to implementation, with 73% noted it as a major concern (Fig. 5). Although still dependent on the financial success of the organization, cost has been noted as one of the leading inhibitors of sustainable solutions in the United States (Meath, 2016). Limited resources was noted as the next barrier to reduce or defer their implementations.

Figure 4. *Barriers impacting SME sustainable solution implementation*

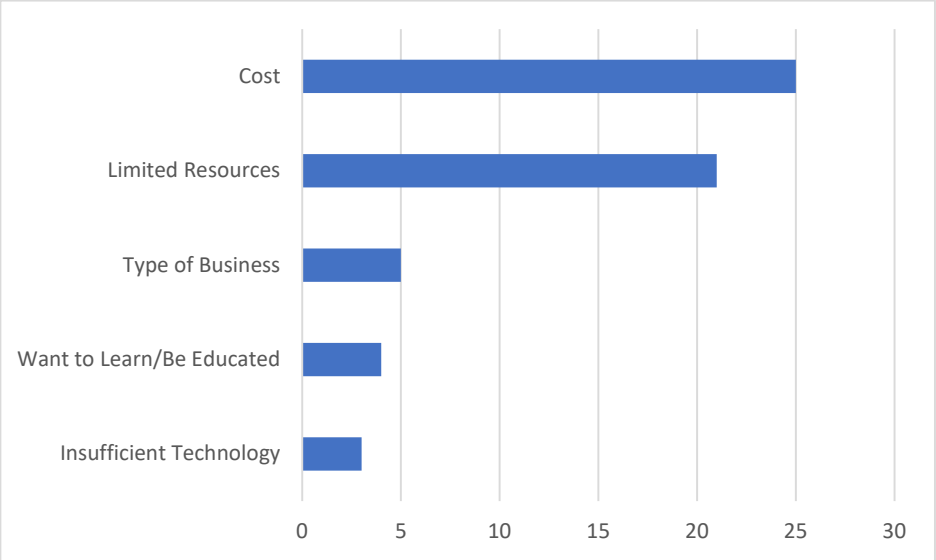
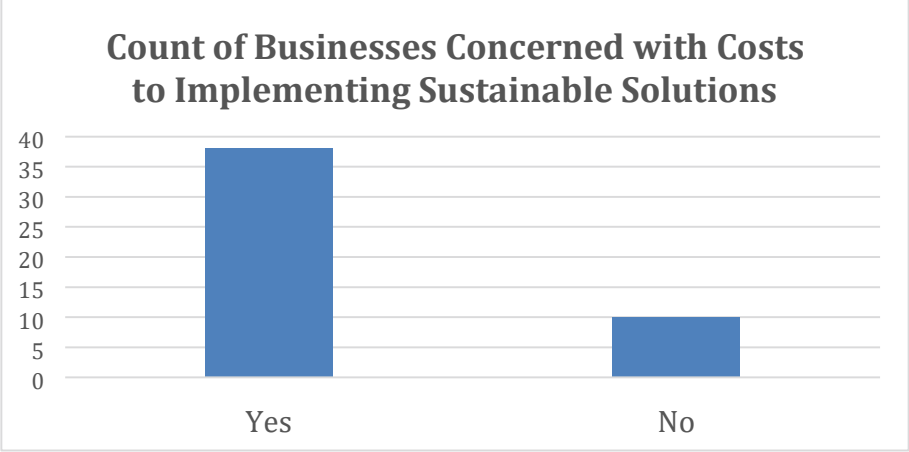


Figure 5. *SMEs concerned with the cost of sustainable implementation*



The high cost of environmental programs and lack of financial resources have been among the most frequently cited barriers to the adoption of sustainability programs, particularly among the SMEs making such investment unaffordable and/or highly risky (Tilley,1999; Walker

et al.,2008; Chan, 2011; Meqdadi et al., 2012; Johnson and Schaltegger,2016; Agellie's, 2017; Chasse and Boiral, 2017).

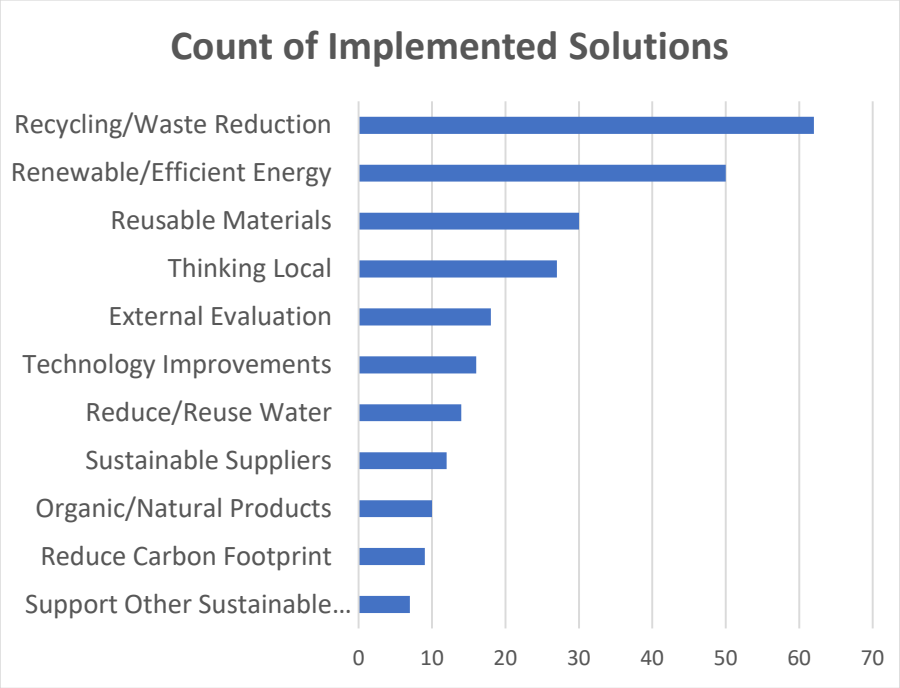
Implemented Solutions

In terms of sustainable solutions that NY State SMEs implemented (Fig. 6), the most prominent was recycling /waste reduction. In total, 78% of respondents (62) engaged in "recycling efforts or took initiatives to reduce waste generation." Ithaca, having the highest number of respondents, held a 96% engagement rate for this solution making it above average for this activity.

The second most prevalent solution was Renewable / Efficient Energy. In total, 63% of respondents (50) noted "utilizing efficient energy technologies such as LEDs, reducing energy consumption, or implementing renewable energy technologies." New York State, excluding Ithaca and New York City, were above average in this category with a 74% (29) engagement rate.

Some other notable sustainable solutions that participants engaged in included Reusable Materials ("using materials or products that can be reused") at 38% of respondents, Thinking Local ("Working to improve local community, sourcing from local suppliers, or supporting local economy") at 34%, and Utilizing External Evaluations ("Utilizing third-party sustainability audits or achieving sustainability-related accreditations") at 23%. Other solutions included such activities as Technology Improvements, Reducing / Reusing Water, Incorporating Sustainable Suppliers into the Supply Chain, and Switching to Organic / Natural Products (Fig. 6).

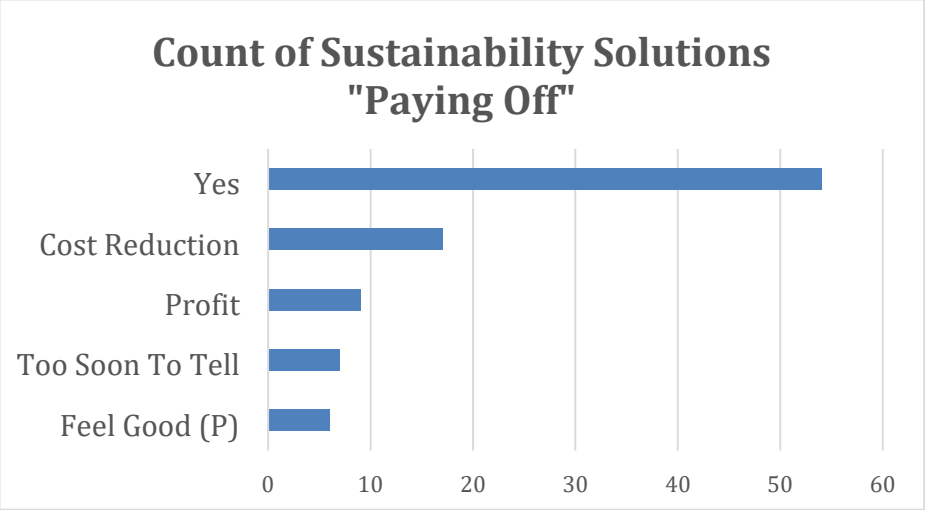
Figure 6. *List of Implemented Solutions for NY State SMEs*



Pay Off

In terms of implemented solutions paying off, 68% of participants noted that their sustainable solution adoption had paid off for their respective businesses (Fig. 7). In some cases, interviewees even went as far as to note that their sustainable initiatives had resulted in reduced costs or increased profitability. However, it was not clear from this preliminary research to what extent this pay off occurred through increasing profits, improving customer relations, or other aspects of business.

Figure 7. *SMEs that have stated their sustainable solutions have paid off*



Relative to other areas (i.e., drivers and barriers to sustainability adoption) fewer research has examined whether such solutions have paid off. Meqdadi et al. (2012) found cost savings and benefits to be one of the motivators among the Canadian firms they studied.

CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

The results of our research identified important internal and external drivers of the sustainability adoption in NYS SMEs. Internal drivers such as a sense of duty or moral obligation to reduce negative environmental impacts, lower costs and potential future liabilities (cleanup costs), or the possibility of lower long-term operation costs, like the cost of gas or electricity were all positively influencing adoption decision of SMEs. Among external drivers, majority of the participating SMEs did not consider competitive advantage, government regulations and regulatory compliances, or financial incentives as important influencers of sustainability adoption strategies. Further analysis of this finding can help policy makers to either extend the government regulations or make them more effective for SMEs implementation. Social trends, however, such as customers who value socially responsible products are considered important factors. In addition, any formal or facilitated education such

as workshops, seminars, conferences, or environmental audits, as external factors, played a positive role. This result again has implications for planning and developing more formal education at colleges or informal ones at places such as chambers of commerce that can strengthen SMEs' ability to adopt sustainable solutions. Our study also identified the barriers such as cost and limited resources that prevent SMEs adoption of sustainability.

The generalizability of our study is limited due to the methodology and the sample size used. We conducted a qualitative research to explore and understand important factors influencing NYS SMEs' sustainability behavior. Our results are based on analytical and not statistical inference. The results of our study will be the basis for our future research in which we are going to develop an online survey and collect data from hundreds of SMEs across NY State. The online survey obtains more objective and structured data and allows us to conduct statistical analysis of the importance of various factors and their relationships that lead to gaining deeper insights on SMEs sustainability behavior.

Acknowledgements

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Abstract

Despite the growing number of studies on coopetition, research still lacks knowledge about the antecedents and the conditions of inter-organizational coopetition, and this study aims to fill this gap. The results indicate that the interdependence between partners is positively related to inter-firm coopetition, and that this relationship is contingent on the joint occurrence of opportunism (a behavioral condition) and technology uncertainty (a contextual condition). Specifically, highly interdependent firms are more likely to be involved in a coopetitive relationships when both opportunism and technology uncertainty are high. Interestingly, our data also show that opportunism or technology uncertainty alone may not be adequate in moderating the interdependence – coopetition relationship.

DECISION SCIENCES INSTITUTE
Effect of perceived risk in moderating the relationship of PPD and website related to product return

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ABSTRACT

In recent years, product returns in internet retailing have shown to be increasing. Among these product returns, large proportions are false failure returns that are not due to functional defects. While it has identified that product return decision influenced by post-purchase dissonance (PPD) among other factors, little information known about which factors in online retailing are responsible for forming the post-purchase dissonance. In the current study, we seek to address this issue of factors influencing post-purchase dissonance. We use a large data set of customers who experienced returns to identify which process attributes influence post-purchase dissonance related to product returns.

KEYWORDS: website information; post-purchase dissonance; attractiveness of alternatives; perceived risk; purchase involvement

INTRODUCTION

Given the liberal return policy in online shopping provided by the new consumer rights protection law in China created the environment for large number of product returns (Ferguson, et al., 2006; Huang, et al., 2011). This happens even before consumers have had enough time to experience the product's performance or evaluate its overall quality (D'Innocenzio, 2011). This high percentage of return rates indicate there must be some factors in E-retail business that make the products' return highly susceptible. In spite of this large occurrence of returns in E-retail, there is very limited extant research on this subject matter within the Operations Management (OM), Supply Chain Management (SCM), and Marketing literatures; specifically, there is a lack in theory-driven investigation (Mollenkopf et al., 2011). According to some recent studies (Powers and Jack, 2013; Lee, 2015), post-purchase dissonance (PPD) is found to be an important driving force for customers to return the purchased products. As a commonly used theory in social psychology, cognitive dissonance has been widely applied to explore consumer behavior. Festinger's (1957) early research suggests that cognitive dissonance could potentially be affecting consumers' attitude towards their purchase decisionAccording to cognitive dissonance theory, customers are motivated to alleviate the anxiety and uncertainty caused by dissonance by taking some actions, which leads to the recovery of psychological balance (Brehm, 1956; Festinger, 1957).

Many researchers are exploring which actions consumers would take to alleviate their negative psychological position. Changing cognition would be a core method to gain the recovery of psychological balance when consumers lack confidence in the success of their actions. Korgaonkar & Moschis (1982) observed that reversibility of purchasing decision has a great influence on consumer's dissonance-reduction process. Therefore, to make the purchase decision undone, the return of purchased product is an efficient dissonance-reduction strategy. In the context of sustainable supply chain Tangpong, Hung, & Li (2014) suggest that human agents need to adapt to the environment in order to reduce the cognitive dissonance to function more effectively. Since cognitive dissonance theory has been widely adopted by researchers to explain the psychological consequences of a purchase decision, it has recently become the theoretical backbone for consumers' post-purchase dissonance (Lee, 2015; Keng and Liao, 2013). With the introduction of the concept of post-purchase dissonance in consumer research, researchers have directed to explore the negative consequences of post-purchase dissonance. If the negative psychological situation could not be alleviated in time, post-purchase dissonance will lead to customer dissatisfaction, which may result in negative behavior that may be harmful to the enterprises, such as negative word of mouth (Grandey et al., 2013) and thus negative publicity.

As a necessary medium for online shopping, E-retailers transfer information about products and services to customers through websites, which helps to attract and guide consumers' purchase (Collier & Bienstock 2006). Therefore, website information provides a strong signal about the product and service quality and widely used in the online market (Hsieh & Tsao, 2013). Online vendors can provide detailed product descriptions in the website, such as product materials, size and function (Park & Stoel, 2005), and can use the image interaction technology to simulate customers' product experience (Kim et al., 2007). Customers can understand the demand of products and other customers' consumption experience by involving themselves on the process and focusing on online customer reviews (Babić et al., 2016), which will help customers to reduce the pre-purchase perceived risk (Ho-Dac et al., 2013). In addition, the availability of attractive alternatives is essential for making choices in product return or buying another product, this will result in cost reduction in switching, which may also have added benefit of decrease in customer's cognitive dissonance during the post-purchase process (Harris and Daunt, 2011; Powers and Jack, 2013). While post-purchase dissonance, website information, perceived risk, attractiveness of alternatives, and purchase involvement have received some attention in the literature separately as discussed earlier, moderating effect of some of these attributes on the core relationship have remained relatively unexplored.

Thus, we direct our attention for the most part on the process attributes of post-purchase dissonance to show that website information is the key predictor of post-purchase dissonance, and that attractiveness of alternatives and perceived risks are influential attributes in their relationship that shows the main functional mechanism of product return system in online retailing. Thus, we integrate the theories of cognitive dissonance along with perceived risk to propose a theory that the association between website information and post-purchase dissonance, although negative, can be strengthen further when customers experience lack of attractive alternatives, but higher purchase involvement. Our results show that post-purchase dissonance, in which attractiveness of alternatives are lower, is impacted more by website information than in which attractiveness of alternatives are higher. Similar results, also observed with perceived risk. While prior research has observed that website information has strong effect on post-purchase dissonance, our findings suggest that the magnitude of this effect is also conditional on the level of other attributes, such as, perceived risk.

LITERATURE REVIEW

PPD is defined as psychologically uncomfortable state following a purchase selected from a set of alternatives, each of which has some desirable attributes (Nadeem, 2007). In general, PPD refers to negative emotions experienced by the consumers, such as doubts, uncertainty, anxiety, regret, etc.; which are results of cognitive confliction shortly after purchase decision (Lee, 2015). Those rejected alternatives can be simulated as a counterfactual in the mind of consumer (McConnell et al., 2000), which would then amplify the existing dissonance (Walchli & Landman, 2003). This may result in product returns for it to help customer to alleviate the uncomfortable state of mind formed by the purchase choice (Gilovich and Medvec, 1995; Zeelenberg et al., 1996). PPD can be influenced by various factors, such as consumer's purchase experience, importance of the purchase decision, customer support service, competitors' product information, the number of alternatives available, consumer's involvement with the purchase, risk perception by consumer, and personality traits (Hawkins, 1972; Murray & Schlacter 1990; Olsen, 2008; Stone, 2003; Lii, 2001; George and Edward, 2009; George and Yaoyuneyong, 2010). Kassarjian and Cohen (1965) noted that comparing the negative attributes of the chosen product, a consumer with decision making difficulty reflects the positive attributes of rejected alternatives, which gives rise to a logical inconsistency between cognitions (Festinger 1957). Hawkins, Best and Coney (2001) measured the PPD's stimulation in terms of purchase decision difficulty. Murray and Schlacter (1990) highlights the association between pre-purchase uncertainty and PPD. Some studies indicate that PPD negatively related to consumer self-confidence (Hennig-Thurau et al., 2002; Nandan, 2005; Szymanski & Henard, 2001) and positively related to consumer anxiety (Keng & Liao, 2009; Liao & Chen, 2008; Soutar & Sweeney, 2003; Sweeney et al., 2000).

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ABSTRACT

This research study discusses the Business Intelligence and Analytics (BI&A) evolution, applications, frameworks and emerging trends with the aim to provide a summary of core concepts, a succinct description of the key applications and frameworks, and an account of main recommendations for addressing the Big Data challenges and opportunities. It develops an integrated and organized view on the BI&A evolution process and presents an integrated BI&A application framework to help organizations adopt or develop the appropriate BI&A solutions to derive the desired impact in the Big Data era. The implications for theory and practice are discussed for competitive advantage in the dynamic global business environment in the Big Data era.

KEYWORDS: Big Data, Business Intelligence, Analytics, BI&A Application Framework, Mobile and Sensor-based Content

INTRODUCTION

Welcome to the Age of Big Data and data-drive decision making! Undoubtedly, Big Data represents a new era in data exploration, utilization, and decision making. According to McKinsey Global Institute, Big Data refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyze (Manyika, 2011). Recent studies show that a majority of employers in the market believe that their organization's need for Big Data skills and support tools will rise in the future (Wixom et al., 2013). With the prominent value proposition, Big Data also brought big challenges for businesses and decision makers across all walks of life. More than often businesses are collecting more data than they know what to do with. Just as the saying goes "*You can't manage what you don't measure*". Successful decision makers must be able to work with the data, make sense of it, and understand the big picture approach to using Big Data to gain insights (Willwhite, 2014; Asllani, 2015).

To put it simply, because of Big Data, business executives and managers can measure, and hence know, radically more about their businesses, and directly translate that knowledge into improved decision making and performance (McAfee & Brynjolfsson, 2012). Modern business analytics has become their weapon of choice. Business intelligence and analytics (BI&A), for instance, have experienced significant growth over the past two decades and have been identified as one of the four major technology trends in the 2010s (IBM Tech Trends Report, 2011). Indeed, organizations have become more competitive through the use

of business intelligence and modern analytics in this Big Data era (Asllani, 2015). Motivated by the emerging opportunities and challenges as well as lack of practical transference of applying BI&A in the Big Data era, we conduct an integrated and selective review (Glass et al., 2004; Webster & Watson, 2002) on the BI&A evolution, applications, frameworks and emerging trends with the aim to provide a summary of core concepts, a succinct but valuable description of main applications and frameworks, and an account of main recommendations for addressing the Big Data challenges and opportunities. The results of this research can help BI&A researchers to count with an updated and integrative summarization of the evolution of the BI&A, and to executives and managers to count with a set of updated recommendations for coping with Big Data challenges and opportunities.

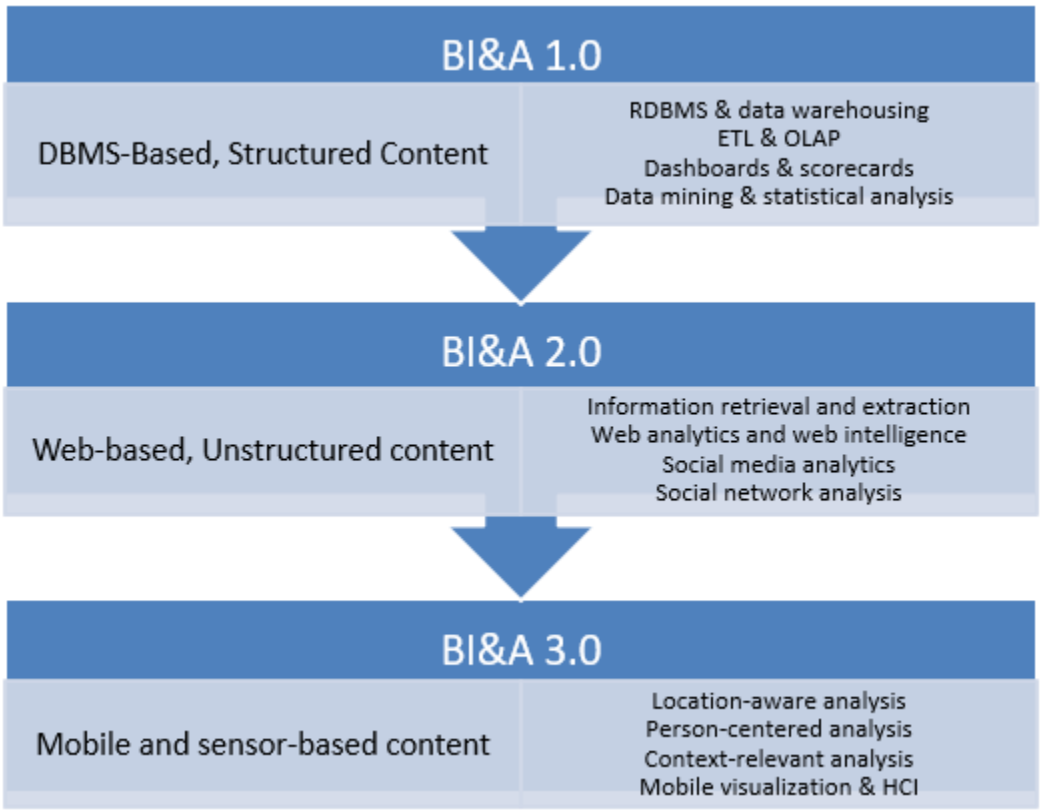
The remainder of this paper is structured as follows: section 2 reports the review of BI&A evolution phases and their key characteristics from core studies; section 3 presents an overview of the Big Data challenges and opportunities for BI&A; section 4 explains an investigation of BI&A applications and framework in the Big Data era; section 5 discusses the implications and insights for addressing the Big Data challenges for BI&A researchers and practitioners; and finally, this paper concludes with the research limitations and recommendations for future studies.

THE EVOLUTION OF BI&A

The term “intelligence” has been used by scholars in the field of artificial intelligence (AI) since the 1950s. Only two decades ago, “business intelligence” (BI) was recognized as a popular trend in the management information systems (MIS) field. Later with the advent and rapid advancement of Internet technologies, business analytics (BA) was introduced within the BI domain and simply defined as “using data for better decision making” (Winston, 2013). More recently, the rise of Internet of Things (IoT) or the Industrial Internet together with improved access to large amount of data is also fueling the Big Data trend. The automation of business processes with information technology has led to the automatic capture of massive data (Asllani, 2015). Accordingly, Big Data and Big Data analytics, considered in this paper as a sub-set of business analytics that offers new directions for BI&A, have been used to describe the unique and advanced analytical techniques that can handle the high volume, variety, value, and velocity of Big Data in business applications.

As a data centric approach that relies heavily on data collection, extraction, and analysis technologies, BI&A has its theoretical roots in the longstanding data management field (Chen, Chiang & Storey, 2012). According to Chen et al (2012), BI&A evolution process can be classified into phases 1.0 (DBMS-based), 2.0 (Web-based), and 3.0 (mobile and sensor-based). More specifically, BI&A 1.0 refers to the BI&A technologies and applications currently adopted in industry, where data are mostly structured, collected by companies through various legacy systems, and often stored in commercial relational database management systems (RDBMS). In the 2000s, Web 2.0-based systems and analytical technologies have led to the exciting era of BI&A 2.0 research, which was centered on text and web analytics for unstructured web contents. Whereas web-based BI&A 2.0 has attracted active research so far, mobile devices and their complete ecosystems of downloadable applications are transforming different facets of society leading to the emerging BI&A 3.0 systems in support of highly mobile, location-aware, person-centered, and context-relevant analysis. Figure 1 below depicts the BI&A evaluation phases and key characteristics.

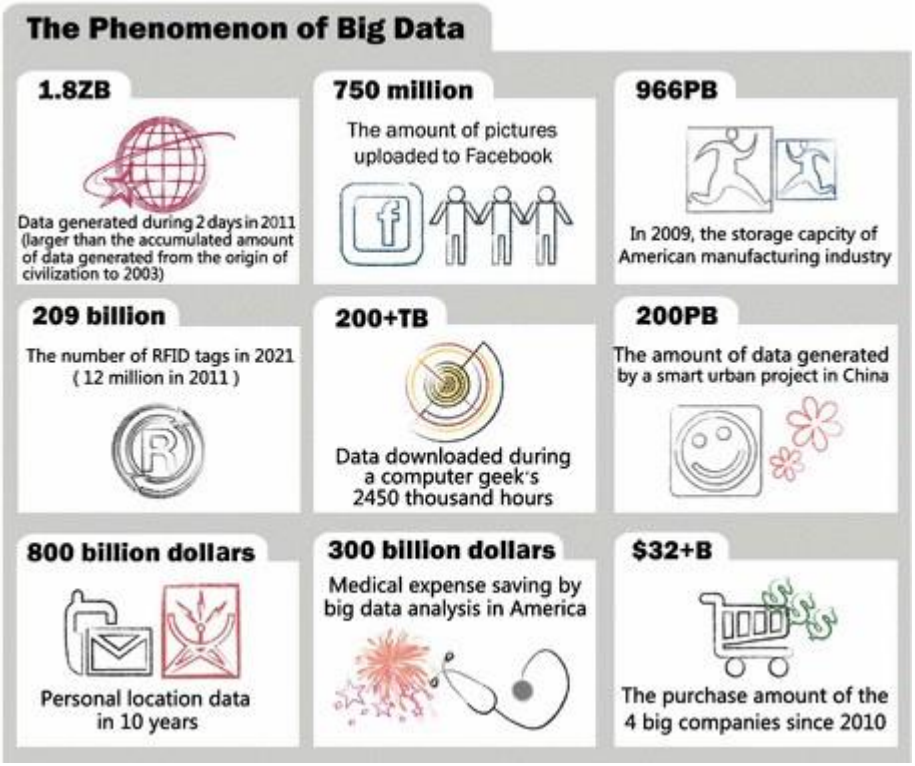
Figure 1: BI&A Evolution Phases and Key Characteristics (adapted from Chen et al. 2012)



THE BIG DATA CHALLENGE & OPPORTUNITY

Modern businesses are now entering the new paradigm of Big Data. In 2010, the total amount of data on earth exceeded one zettabyte (Ackerman & Guizzo, 2011). By end of 2011, the number grew up to 1.8 zettabyte (Reed et al., 2012). Further, it is expected that this number will reach 35 zettabyte by 2020, according to the recent release of 2011 Digital Universe study sponsored by EMC. In 15 of the US economy's 17 sectors, business organizations with more than 1,000 employees, on average, store over 235 terabytes of data—more data than is contained in the US Library of Congress (Brown et al., 2011). Figure 2 below illustrates the phenomenon of Big Data worldwide.

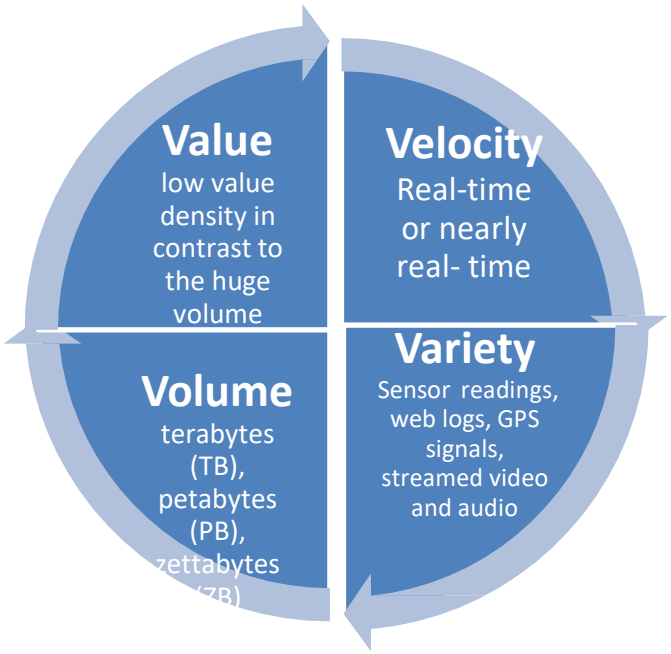
Figure 2: The boom of the global data volume (adapted from Chen et al., 2014)



What is Big Data? Big Data is an abstract concept that refers to massive data sets having large, more varied and complex structure with the difficulties of storing, analyzing and visualizing for further processes or results (Sagiroglu& Sinanc, 2013). Although there are variations about the exact definition, Big Data is typically characterized by three Vs: volume, velocity, and variety. Volume refers to the large size of the data such as terabytes (TB), petabytes (PB), zettabytes (ZB), etc. The volume of Big Data is larger than the volume processed by conventional relational databases in legacy systems. Velocity means how frequently the data is generated and flows into an organization. Real-time or nearly real-time information makes it possible for a company to be much more agile than its competitors (McAfee & Brynjolfsson, 2012). Accordingly, variety refers to the sources, types and formats of data. Different from structured data sets, Big data takes a variety of forms ranging from RFID sensor readings, unstructured social networking messages and web logs, GPS signals from cell phones, streamed video and audio, and more. More recently, many researchers and practitioners proposed one additional key characteristic, namely, the 4^{th} V of Big Data, value (Gantz & Reinsel, 2011; Hashem et al., 2015), which refers to the low value density incontrast to the huge volume of the large data set. It poses big challenges in discovering

huge hidden values from large datasets with various types and rapid generation. Figure 3 below summarizes and depicts the four Vs of Big Data.

Figure 3: The Four Vs Characteristics of Big Data



One of the challenges in the era of Big Data is the increased difficulty of mining enormous amounts of data and information to identify the relevant pieces for effective decision making (Asllani, 2015). The Big Data expansion, similar to the preceding analytics movement, seeks to glean intelligence from data and translate that into business competitiveness. However, to fully realize its potential, Big Data demands new techniques with many of these approaches still in the developmental stages. Asllani (2015) succinctly captures this transformation: "*acquiring the new tools requires a radical change in underlying beliefs or theory: they require a new way of thinking*" (pp. 6). Some of the inherited challenges in Big Data are finding capable ways to capture, store, analyze, and virtualize it in order to support more effective and efficient decision making. More specifically, the volume generally improves the quality and accuracy of BI&A models and solutions. Furthermore, according to Asllani (2015), robust BI&A models can accelerate the flow of information by offering quicker decisions and improving operational business intelligence. Variety, however, presents serious challenges in implementation of BI&A techniques for Big Data. With the right technological framework of the BI&A solution, the negative impact of variety can be mitigated (Asllani, 2015).

Similar to many other technology innovations, Big Data's power does not eliminate the need for human insight or vision. In fact, the managerial challenges are greater than the technical challenges of using BI&A in the Big Data era and reaping the full benefits of the transition (McAfee & Brynjolfsson, 2012).

BI&A APPLICATIONS & FRAMEWORK FOR BIG DATA

In addition to being data driven, BI&A is highly applied and can leverage challenges and opportunities presented by Big Data and domain-specific analytics needed in many high-impact application areas (Chen et al., 2012). In this section, we identified four particular domains to examine the current and potential value BI&A solutions can derive in the Big Data era, including health care in the United States, public sector administration in the European Union, retail in the United States, and global manufacturing. Together these four domains represented close to 40 percent of global GDP in 2010 (Manyika et al., 2011). The data and analytics characteristics, potential impacts, and illustrative case studies within each domain are discussed. By carefully analyzing the application and data characteristics, we can present an integrated BI&A application framework that can facilitate the BI&A researchers and practitioners to adopt or develop the appropriate analytical techniques to derive the intended impact in the Big Data era (Manyika et al., 2011; Chen et al., 2012).

Healthcare

Historically the healthcare industry has generated large amounts of data from numerous patient care points of contact, sophisticated medical instruments, and web-based health communities, driven by record keeping, compliance and regulatory requirements, and patient care (Raghupathi & Raghupathi, 2014). Unfortunately, BI&A for Big Data in health care generally lags well behind BI&A applications in other sectors such as Retail and Manufacturing because it has rarely taken advantage of scalable analytical methods or computational platforms (Miller, 2012). By discovering associations and understanding patterns and trends within the Health care Big Data, BI&A can take advantage of the explosion in data to extract new and actionable knowledge for making better informed decisions (Raghupathi & Raghupathi, 2014).

As Miller (2012) purported, current researchers "*are doing clinical trials using vast troves of observational health care data, analyzing pharmacy and insurance claims data together to identify adverse drug events, delving into molecular-level data to discover biomarkers that help classify patients based on their response to existing treatments, and pushing their results out to physicians in novel and creative ways*". As such, BI&A has the potential to improve the care quality, enable deeper understanding of patient disease patterns, save patient lives, and lower costs in the healthcare delivery system (Miller, 2012; Raghupathi & Raghupathi, 2014). To accomplish so, the current BI&A solutions need to be equipped with advanced techniques targeted at the Big Data challenges, such as machine-learning for pattern recognition, segmentation and predictive modeling, hypothesis-free probabilistic causal approaches (e.g. Bayesian network analysis), symptom–disease–treatment (SDT) association rule mining and clustering, and so on. However, as argued by Manyika et al. (2011), deploying BI&A for Big Data in this sector would need to be accompanied by a range of enablers beyond technology innovation, some of which would require a substantial rethinking of the way health care is provided and funded.

Public sector administration

Similar to healthcare, the public sector is another large sector facing tremendous pressure to improve its efficiency and productivity. In general, governments have access to vast amounts of digital data but rarely take advantage of the powerful strategies in which they could use this information to improve performance and transparency (Manyika et al., 2011). Proper integration and extension of BI&A strategy and technologies that complement the Big Data management would be necessary, such as massive parallel-processing (MPP)

databases, distributed file systems, cloud computing technologies, criminal association rule mining and clustering, criminal network analysis spatial-temporal analysis and visualization, and multilingual text analytics to mention a few.

Successful applications of BI&A in this sector include homeland and cyber security informatics (Chen et al., 2012), in which security agencies are gathering, processing and analyzing large amounts of security-related data (e.g., criminal records of terrorism incidents and cyber security threats); public transportation (Zaslavsky et al., 2013), in which transportation agencies make use of sensor roadways in order to monitor traffic in real-time to optimum traffic management; tax collections or benefit payments auditing (Brown et al., 2011), in which tax agencies apply automated algorithms that perform systematic, multilevel checks on tax returns and automatically flag returns that require further examination or auditing; and construction and public safety (Zaslavsky et al., 2013), in which public safety agencies utilize embedded sensors with monitoring systems to collect variety of different measurements such as a change in temperature and the concrete reaction to that change for further safety analysis.

Retail

In contrast to the first two domains, retail is an advanced, progressive sector where the revolution of Big Data first emerged. The retail sector retail has been leveraging BI&A strategies and techniques for decades. More recently, businesses have been using vast amounts of data for segmenting customers, identifying emerging trends, improving business decision making, driving more sales, and developing new revenue-making strategies. These data are pulled from the web, such as online searches, posts and messages, as well as from local stores, such as customer movement in the store and fitting rooms. Unlike traditional sales transaction records collected from various legacy systems of the 1980s, the Big Data that businesses today collect from various sources are less structured and often contain rich customer opinion and behavioral information (Chen et al., 2012). Along the process, various analytical techniques have been developed for social media customer opinion analysis and customized recommender systems, such as text analysis and sentiment analysis, association rule mining, database segmentation and clustering, anomaly detection, and graph mining (Adomavicius & Tuzhilin 2005; Pang & Lee 2008).

For example, retail giant Walmart, the largest retailer in the world with more than two million employees and annual sales of around $450 billion, has been a data-driven company since the 1990s. The company uses innovative BI&A techniques that allowed the retailer to peer into its massive databases of previous transactions to identify customer buying patterns and predict future buying trends (Mayer-Schönberger & Cukier, 2013). Major Internet firms, such as Amazon, Google, and Facebook, also continue to lead the development of web analytics, cloud computing, and social media platforms that offer substantial opportunities for researchers and practitioners to “listen” to the voice of the market from a vast number of business constituents (Chen et al., 2012). Nevertheless, there is still tremendous potential across the industry for businesses to expand and improve their use of BI&A for Big Data, particularly given the increasing ease with which they can collect information on their consumers, suppliers, and inventories (Brown et al., 2011).

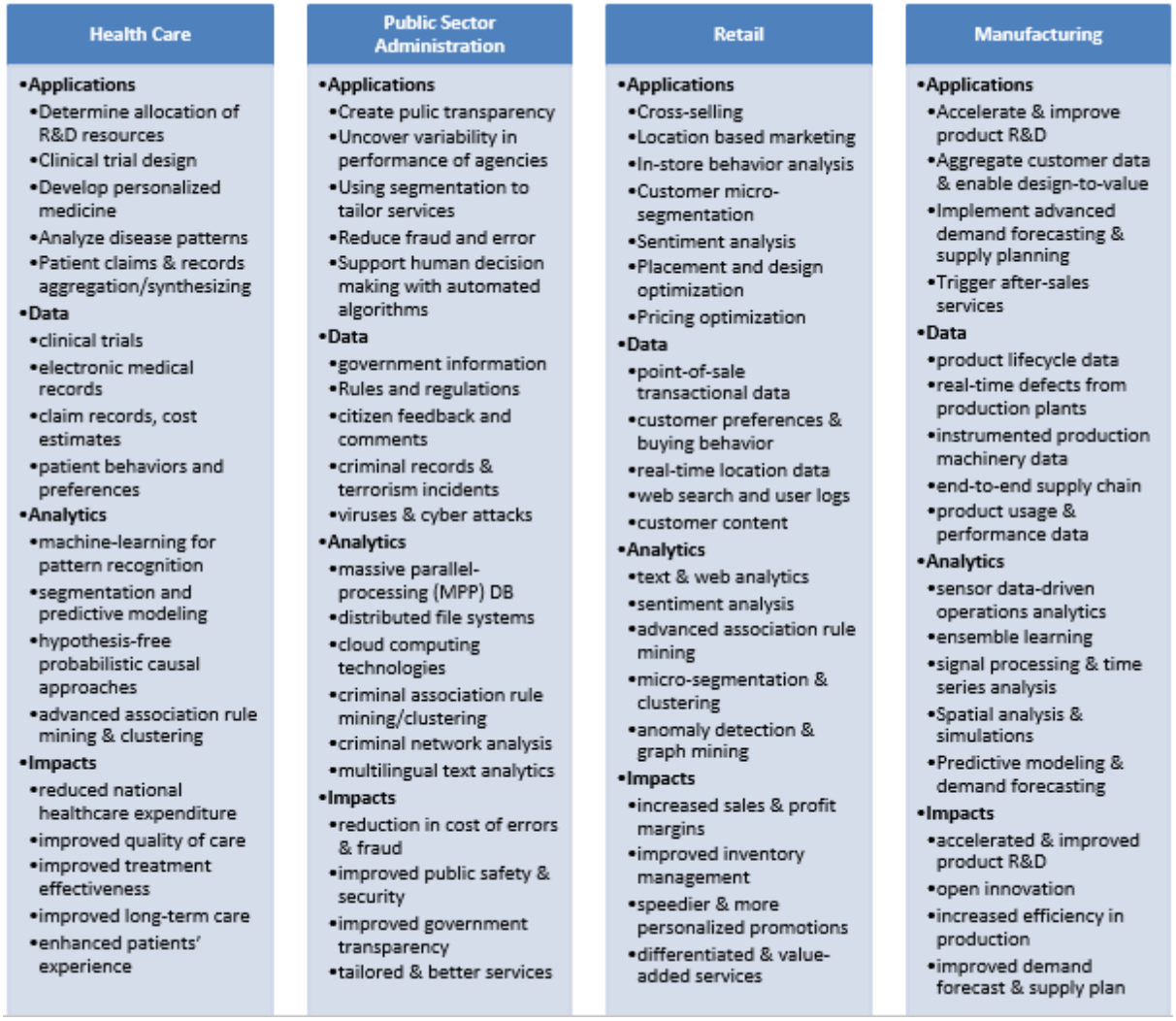
Manufacturing

Increasingly global and fragmented manufacturing value chains have created new challenges that manufacturers worldwide must overcome to sustain productivity growth (Manyika et al., 2011; Lee et al., 2013). As Manyika et al. (2011) purported, manufacturers will need to leverage a significant amount of digital data to drive efficiency across the extended enterprise and to design and market higher quality products in order to continue achieving increased levels of productivity growth. This sector generates the most datasets, more data than in any other sector, from a multitude of sources including instrumented production machinery for process control, supply chain management systems, monitoring systems that observe the performance of products in action (Manyika et al., 2011). Indeed, the amount of data generated will continue to grow exponentially in this sector.

Using a Boeing jet for example, it generates 10 terabytes (TB) of data per engine every 30 minutes and a single six hour flight would generate 240 terabyte (TB) of data (Zaslavsky et al., 2013). In addition, there are about 28537 commercial flights in the sky in United States on any given day. According to Manyika et al. (2011), BI&A for Big data has the potential to enable seven performance improvement areas for manufacturers, affecting the entire value chain: 1) offer further opportunities to accelerate product development and improve product design, through concrete customer input and open innovation; 2) aggregate customer data and make them widely available and enable design-to-value; 3) share data through virtual collaboration sites (idea marketplaces to enable crowd sourcing); 4) implement advanced demand forecasting and supply planning across suppliers; 5) implement lean manufacturing and model production virtually (digital factory) to create process transparency; 6) implement sensor data-driven operations analytics to improve throughput and enable mass customization; and 7) collect after-sales data from sensors and feedback in real time to trigger after-sales services. In short, manufacturers around the globe have tremendous potential to generate value from the use of BI&A with Big Data, integrating data across the extended enterprise and applying advanced analytical techniques to raise their productivity both by increasing efficiency and improving the quality of their products (Brown et al., 2011; Lee et al., 2013).

Figure 4 below summarizes the promising and high-impact BI&A applications to address the challenges and opportunities brought on by the Big Data era in four main domains, namely, healthcare, public sector administration, retail, and manufacturing. This integrated BI&A application framework can facilitate the BI&A researchers and practitioners to adopt or develop the appropriate analytical techniques in each specific domain to derive the intended impact and value in this Big Data era (Manyika et al., 2011; Chen et al., 2012).

Figure 4: BI&A Application Framework for Big Data in Four Main Domains

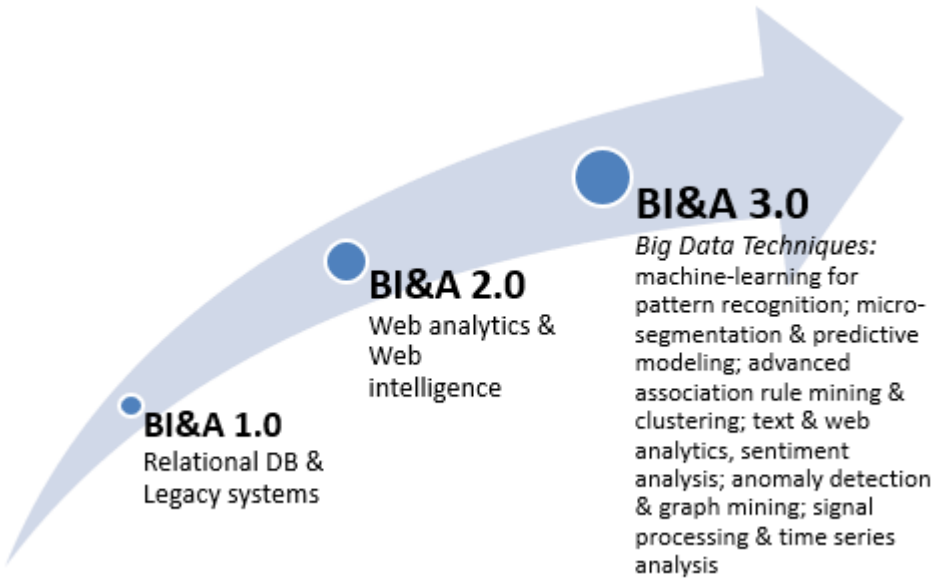


DISCUSSIONS AND INSIGHTS ON BI&A FOR BIG DATA

In this Big Data era, data is not only becoming more available but also more understandable. Recent studies show that a majority of employers in the market believe that their organization's need for Big Data skills and support tools will rise in the future (Wixom et al., 2013). With the prominent value proposition, Big Data has also created new challenges for businesses and decision makers across many different industries and jobs. Businesses are collecting vast amounts of data more frequently yet they are still not grasping the potential of all the data.They do not know what to do with all this data. Consequently, decision makers face the challenge to work with huge datasets from multiple and varied sources, make sense of this data, and process the data with adequate tools to gain insights toward an efficient and effective decision making process. Thus, Big Data needs adequate methods and tools for such an aim (Willwhite, 2014; Asllani, 2015).

The key value promise of Big Data for business executives and managers is to know radically more about their businesses and directly translate that knowledge into efficient and effective decision making processes leading to better organizational performance (McAfee & Brynjolfsson, 2012). For this aim, the Business Intelligence and Analytics (BI&A) methods and tools has become their processing strategy of choice. BI&A evolution process can be classified into phases 1.0 (DBMS-based), 2.0 (Web-based), and 3.0 (mobile and sensor- based). According to some researchers, BI&A 3.0 applied to Big Data has enabled some important international organizations to be more competitive in the global environment (Asllani, 2015). To accomplish this goal, the current BI&A 3.0 solutions need to be equipped with advanced techniques targeted at the Big Data challenges, such as machine-learning for pattern recognition; micro-segmentation and predictive modeling; advanced association rule mining and clustering; text and web analytics; sentiment analysis; anomaly detection and graph mining; and signal processing and time series analysis. Figure 5 below depicts the BI&A evolution process with phase 3.0 techniques highlighted to address the Big Data challenges and opportunities. Figure 6 presents an overview of the Big Data characteristics and corresponding BI&A technology as well as methodology solutions to mitigate the challenges.

Figure 5: BI&A Evolution & phase 3.0 techniques to address Big Data Challenges



From an application perspective, executives and leaders of global organizations are facing these new challenges of effective decision making in the Big Data era and they desire practical BI&A solutions that can help them convert the Big Data into strategic insights and impacts. This integrative review presented in this paper adds to this body of knowledge and helps facilitate additional research and practical endeavors. A logical evolution of the origins and techniques of BI&A for Big Data were identified and presented. Based on the richness and variety of BI&A application and research findings, we present the following recommendations and cautions to executives and leaders interested in such productive yet challenging investments:

- All industry sectors face the challenges of effective and efficient decision making in the Big Data era and the current **BI&A 3.0 solutions can help them become competitive data-driven companies**.
- To effectively address the Big Data challenges, the current **BI&A 3.0 solutions need to be equipped with advanced techniques** depending on the involved data types, sources, structures, and other organizational characteristics.
- Practitioners across different industries can utilize **the presented integrated BI&A application framework** to adopt or develop the appropriate BI&A techniques and solutions to derive the intended impact in the Big Data era.
- BI&A for Big Data brings **a new culture and way of decision making**. Besides technical challenges, managerial challenges of using BI&A in the Big Data era must be addressed to reap the full benefits of that transition.

Figure 6: Big Data challenges and corresponding BI&A solutions (adapted from Asllani, 2015)

Big Data dimension	Challenges to BI&A	Technology-based Solutions	Methodology-based Solutions
Volume	Managing large and rapidly increasing data sources	• Advanced software programs able to process large number of constraints and decision variables	• Standardize the ETL processes to automatically capture and process input parameters • Encourage system-driven versus user-driven optimization programs
Variety	Dealing with heterogeneity of data sources Dealing with incomplete data sets	• Relational database systems and declarative query language to retrieve data input for optimization models • ETL toward specialized optimization driven Data Marts	• Add data structuring prior to analysis • Implement data cleaning and imputation techniques
Velocity	Managing large and rapidly changing data sets Reaching on-time optimal solutions for operational business intelligence	• Advanced optimization software with the capability to reach optimal solutions within a feasible amount of time • Use optimization packages that directly connect to operational data bases	• Consider a trade-off between less than optimal but time feasible and practical solution and optimal but complex and often delayed solutions
Value	Discovering hidden value from large volume data sets Filtering noises and searching for hidden patterns and knowledge through powerful processing	• Advanced cloud computing to address the challenge of processing demand • Scalable implementation of computerized machine-learning for pattern recognition	• Clean and filter noises prior to performing analytics • Adopt scalable solution for data acquisition and analysis through two-phase process, crawling and processing

This study reveals that the BI&A evolution process has experienced drastic changes in its execution by organizations, its theoretical conceptualization by researchers, and its practical implications in the Big Data era. The main shift on the BI&A evolution process can be stated as an evolution from traditional analytical and statistical techniques with structureddata sets in highly predictable and cooperative business environment, to data-driven discovery and highly proactive and creative decision-making utilizing advanced analytical techniques with unstructured and massive data sources to cope with a highly dynamic global business environment in the Big Data era.

CONCLUDING REMARKS

The wealth of Big Data, in turn, accelerates advances in data-driven decision making with advanced BI&A tools and applications. With an aggressive push towards Web 2.0 and Internet of Things (IoT) or the Industrial Internet, data has become more accessible and ubiquitous in the global environment. This Big Data phenomenon and trend necessitates the appropriate techniques and solutions to convert massive data into useful and actionable information. It is a simple formula: Using BI&A for Big Data leads to better predictions, and better predictions yield better decisions (McAfee & Brynjolfsson, 2012). In this paper, we have reviewed the BI&A evolution phases and key characteristics, the Big Data challenges and opportunities for BI&A, and illustrative BI&A applications to address the Big Data challenges and opportunities. Along the process, we have developed an integrated and organized view on the BI&A evolution process and presented an integrated BI&A application framework to help organizations adopt or develop the appropriate BI&A solutions to derive the desired impact in the Big Data era.

On an application level, this paper also elicits a set of practical recommendations to executives and leaders in organizations worldwide for interpreting the BI&A literature and applying the rich body of knowledge for IT practitioners. Given the importance and complexity of BI&A and Big Data phenomenon, we encourage and anticipate continued research efforts to investigate and establish advanced and updated conceptualizations and frameworks to cope with this complex yet critical subject.

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Efficient Class of Estimators for the Population Variance Using Quartiles of Auxiliary Variable

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ABSTRACT

The focus of this research is to explore a variance estimation for a given population based on quartiles and some other functions of quartiles of the auxiliary variable. The optimum value of the characterizing constant has been obtained ensuring the least amount of MSE of the suggested estimator. Also, we compare the estimator with the competing estimators through the numerical example within the theoretical assumptions. The results of the study show that the proposed estimator yielded the lowest value of MSE among all competing estimators.

KEYWORDS: Population Variance, Estimators, Quartiles, Bias, Mean Squared Error (MSE).

INTRODUCTION

According to natural law, it is well established that no two things are precisely similar. Thus, we can infer that variation is a natural phenomenon, and observed in daily life. For example, a physician is in need to have a complete knowledge of measures and possible variations in pulse rate of human beings, temperature and blood pressure as well for a suitable prescription. An agriculturist will have to have an appropriate understanding of changes in climate factors to have an idea for the planning about when, how and where to plant his crop (Singh et al., 2013). Therefore, it is important to understand the variance or variation of the population to make the optimal decisions.

Sampling is used where it is difficult to collect data on the entire population and to estimate the parameters. The most apparent estimator for a given parameter is the corresponding statistic. Although the sample variance is unbiased for population variance, unfortunately, it can be significantly different from the actual results of variance for another samples. Thus, we search for even a biased estimator with a smallest possible MSE. This goal is achieved by applying the concept of the auxiliary variable. The auxiliary variable is defined as a variable that has either negative or positive correlation with the study variable. Many authors utilized auxiliary information or variable in the form of known parameters for enhancing the precision of

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population variance estimation. There are several latest research work that have used the similar approach (Khan and Shabbir, 2013; Maqbool et al., 2016; Maqbool and Javaid, 2017).

In this study, an estimator has been proposed for the precise population variance estimation integrating auxiliary information in the form of quartiles and some functions of quartiles at the stage of estimation.

LITERATURE REVIEW

Over the years, several estimators such as sample variance estimator and various improved ratio estimators have been proposed for refining the estimation process of population variance. A summary of recent research work related to estimators is presented in Table 1.

Table 1: Summary of Literature Review of Existing Estimators

YEAR	REFERENCES	JOURNAL
2017	Maqbool and Javaid	American Journal of Biological and Environmental Statistics
2016	Maqbool, Raja and Javaid	Int. Journal of Agricultural and Statistical Sciences
2013	Singh and Solanki	Communications in Statistics -Theory and Methods
2013	Yadav and Kadilar	Hacettepe Journal of Mathematics and Statistics
2012	Tailor and Sharma	Statistics in Transition New Series
2012	Nayak and Sahoo	Revista Colombiana de Estadistica
2012	Subramani and Kumarapandiyan	Int. Journal of Probability and Statistics
2008	Singh and Vishvakarma	Journal of Statistical Theory and Practice

PROPOSED ESTIMATOR

The study proposes an improved array of ratio-based estimators using quartiles and some functions of quartiles of auxiliary variable for improved population variance estimation as,

$$t_{p_i}^{*} = \kappa_i \, s_y^2 \left[\frac{S_x^2 + \alpha L_i^2}{s_x^2 + \alpha L_i^2} \right], \ (i = 1,2,3)$$

Where κ_i $(i = 1,2,3)$ are characterizing constants that are determined based on the MSE of $t_{p_i}^{*}$ is the lowest.

The properties of the $t_{p_i}^{*}$ are studied using assumptions given below,

$s_y^2 = S_y^2(1+\varepsilon_0)$ and $s_x^2 = S_x^2(1+\varepsilon_1)$ where $E(\varepsilon_i) = 0$ for $(i = 0,1)$ and up to degree one of the approximation which is ignoring finite population correction factor, defined as,

$E(\varepsilon_0^2) = n^{-1}(\lambda_{40} - 1)$, $E(\varepsilon_1^2) = n^{-1}(\lambda_{04} - 1)$, $E(\varepsilon_0 \varepsilon_1) = n^{-1}(\lambda_{22} - 1)$.

The members of the suggested array of estimators, respective biases and MSEs for the optimum values of the characterizing constants, up to the first order of approximation are presented in Table 2.

Table 2: Proposed estimators, biases and MSEs

Estimator	Bias	MSE
$t_{p_1}^* = \kappa_1 s_y^2 (S_x^2 + \alpha L_1^2 / s_x^2 + \alpha L_1^2)$	$(\kappa_1 - 1)S_y^2 + \Phi \kappa_1 \theta_1^* (\theta_1^* - c)$	$S_y^4[1-(A_1^2/B_1)]$
$t_{p_2}^* = \kappa_2 s_y^2 (S_x^2 + \alpha L_2^2 / s_x^2 + \alpha L_2^2)$	$(\kappa_2 - 1)S_y^2 + \Phi \kappa_2 \theta_2^* (\theta_2^* - c)$	$S_y^4[1-(A_2^2/B_2)]$
$t_{p_3}^* = \kappa_3 s_y^2 (S_x^2 + \alpha L_3^2 / s_x^2 + \alpha L_3^2)$	$(\kappa_3 - 1)S_y^2 + \Phi \kappa_3 \theta_3^* (\theta_3^* - c)$	$S_y^4[1-(A_3^2/B_3)]$

Thus, the biases and the MSEs of the suggested estimators are defined as follows,

$B(t_{p_i}^*) = (\kappa_i - 1)S_y^2 + \Phi \kappa_i \theta_i^* (\theta_i^* - c)$, $(i = 1,2,3)$

$MSE(t_{p_i}^*) = S_y^4[1-(A_i^2/B_i)]$

Where the optimum values of the characterizing scalars are,

$\kappa_i^{(opt)} = \dfrac{A_i}{B_i}$ with $A_i = [1 + n^{-1}\{\theta_i^{*2}(\lambda_{04} - 1) - \theta_i^*(\lambda_{22} - 1)\}]$ and

$B_i = [1 + n^{-1}\{(\lambda_{40} - 1) + 3\theta_i^{*2}(\lambda_{04} - 1) - 4\theta_i^*(\lambda_{22} - 1)\}]$

EFFICIENCY COMPARISON

We present the theoretical efficiency of the suggested estimator demonstrating the enhancement in comparisons with competing estimators and the assumptions where suggested estimator is better than the competing estimators are as follows:

$V(t_0) - MSE(t_{p_i}^*) > 0$, or $\gamma(\lambda_{40} - 1) - S_y^4[1-(A_i^2/B_i)] > 0$, $(i = 1,2,3)$

$MSE(t_R) - MSE(t_{p_i}^*) > 0$, or $\gamma[(\lambda_{40} - 1) + (\lambda_{04} - 1)(1 - 2c)] - S_y^4[1-(A_i^2/B_i)] > 0$, $(i = 1,2,3)$

$MSE(t_i) - MSE(t_{p_i}^*) > 0$, or $\gamma[(\lambda_{40} - 1) + \theta_i(\lambda_{04} - 1)(\theta_i - 2c)] - S_y^4[1-(A_i^2/B_i)] > 0$, $(i = 1,2,3)$

$MSE(t_i^*) - MSE(t_{p_i}^*) > 0$, or $\gamma[(\lambda_{40} - 1) + \theta_i^*(\lambda_{04} - 1)(\theta_i^* - 2c)] - S_y^4[1-(A_i^2/B_i)] > 0$, $(i = 1,2,3)$

NUMERICAL STUDY

We analyzed the efficiency of suggested and competing estimators for the population variance. Data was taken from the study of Singh and Chaudhary (1986) on page 108. The population parameters have been presented in the following Table 3.

Table 3: Parameters of the population

N	70	C_y	0.6254	Q_1	80.1500
n	25	S_x	140.8572	Q_2	160.3000
$\bar{Y}$	96.7000	C_x	0.8037	Q_3	225.0250
$\bar{X}$	175.2671	λ_{04}	7.0952	Q_r	144.8750
ρ	0.7293	λ_{40}	4.7596	Q_d	72.4375
S_y	60.7140	λ_{22}	4.6038	Q_a	152.5875

Where $\theta_1 = 1.00404$, $\theta_2 = 1.008079$ and $\theta_3 = 1.011342$ for above population.

Table 4: Constants θ_i^* for different values of α

α	θ_1^*	θ_2^*	θ_3^*
0.0	1.000	1.000	1.000
0.1	0.969	0.885	0.797
0.2	0.939	0.794	0.662
0.3	0.911	0.720	0.566
0.4	0.885	0.659	0.495
0.5	0.861	0.607	0.439
0.6	0.837	0.563	0.395
0.7	0.815	0.524	0.359
0.8	0.794	0.491	0.329
0.9	0.774	0.462	0.303
1.0	0.755	0.436	0.282

The MSEs of different estimators along with the variance of the sample variance estimator for above population are,

$t_0 = 2043417.072$, $t_R = 1438805.637$, $t_1 = 1449800.126$, $t_2 = 1460902.739$, $t_3 = 1469947.550$
$t_4 = 1458757.621$, $t_5 = 1448737.470$, $t_6 = 1459829.679$

The MSEs of various estimators t_i^* ($i = 1,2,3$) suggested by Singh et al. (2013) and the proposed estimators for different values of characterizing constant α are presented in Tables 5 and 6.

Table 5: MSE of various estimators for different value of α

Value of α	MSE of Estimator		
	t_1^*	t_2^*	t_3^*
0.0	1438805.64	1438805.64	1438805.6
0.1	1358033.53	1171169.43	1025550.5
0.2	1285929.52	1021490.64	901891.57
0.3	1224012.52	940223.872	**887422.34**
0.4	1171169.43	900515.115	916001.75
0.5	1126366.62	**886131.403**	962104.33
0.6	1085380.23	887954.099	1012904.40
0.7	1051161.99	900293.404	1064009.10
0.8	1021490.64	918605.715	1113155.80
0.9	995948.760	940654.878	1160573.20
1.0	**974138.802**	965160.485	1202141.60

Table 6: MSE of various proposed estimators for different value of α

Value of α	MSE of Estimator		
	$t_{p_1}^*$	$t_{p_2}^*$	$t_{p_3}^*$
0.0	998972.5	998972.5	998972.5
0.1	977617.2	920547.1	868791.4
0.2	956890.8	867281.0	**826395.7**
0.3	937798.7	837478.7	838348.2
0.4	920547.1	**826167.0**	875488.9
0.5	905240.1	828187.7	923216.3
0.6	890720.8	839406.3	972323.3
0.7	878266.4	857223.9	1019993.0
0.8	867281.0	878350.9	1064714.0
0.9	857757.5	901611.8	1107006.0
1.0	**849659.8**	926240.6	1143461.0

RESULTS AND DISCUSSION

From Table 5, it can be seen that the variance of sample variance is 2043417.072 and the MSE of rest estimators are lying in the interval 1438805.637-1469947.550. The MSE of estimators in Table 5 is ranging in the interval 1438805.64-885369.73. The MSE of proposed estimators in Table 6 is lying in the interval 998972.5-825861.6. Results show that the suggested estimators are best among other population variance estimators.

CONCLUSION

In this study, we suggested an enhanced array of estimators of the population variance utilizing information on auxiliary variable in the form of quartiles and some functions of quartiles. We derived bias and the MSE of the suggested array. The suggested array is compared with the competing estimators. The assumptions for which suggested array is more efficient than competing estimators have been derived. Finally, the theoretical findings have been verified through the numerical study and shown improvement over competing estimators.

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(A complete list of references is available upon request)

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Empirical Evaluation of Firms' Business Analytics Task Orientation: Text Mining Analysis

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ABSTRACT

Businesses focus on developing business analytics to help gain competitive advantage. Yet skilled individuals are required to perform the analysis. This research project focuses on determining the various stages of task orientation by understanding job postings. The job postings are empirically analyzed using text-mining tools. Using the results of the text-mining analysis, cluster analysis algorithms are used to classify the various types of task orientations. Finally, the relationships among several business characteristics, the tools acquired by businesses, and the identified task orientations are analyzed and then insights into the level of analytic capability of the business are provided.

KEYWORDS: Analytics Tools, Business Characteristics, Cluster Analysis Task Orientation, Text-Mining

INTRODUCTION

Businesses have pursued implementing business analytics to translate real-time insights into competitive advantage, to provide various stakeholders with valuable information for improved problem-solving and decision-making, and to evaluate the massive amounts of unfiltered and unstructured data available for insight generation (Ertemel, 2015; Popovič et al, 2012). Competitive advantage may be achieved by simply using the competencies of analysts performing the insight generation tasks (Trieu, 2017). Yet exploiting the vast quantity of available data becomes a tremendous challenge. Ideally, the insights discovered by the analyst forms the basis for generating actionable insights (Doumpos & Zopounidis, 2016).

Previous research has reported that when businesses are operating in highly competitive markets, the impact from the insights generated on problem-solving and decision-making, produce positive results (Popovič et al, 2012). Yet, the specific analytic competencies required to generate those insights are not well understood and remains an ongoing area for investigation as limited knowledge has been presented in the literature regarding what and how analysts utilize business analytics. Thus, researchers continually question the value of these analytics systems since the academic literature lacks an overarching framework to provide guidance (Agarwal & Dhar, 2014).

Therefore, the focus of this research project is to examine what specific analytics tasks are performed thus providing a contribution to the literature. This research project evaluates the skills required of analysts and the tools used to perform insight generation. In addition, this research project investigates whether the nature of business analytic tasks vary by size and industry type of the business. To accomplish these objectives, a taxonomy containing business analytics task orientations is adopted. Then, this research project empirically validates the different business analytics task orientations using cluster analysis algorithms on job posting data. Finally, the relationships among characteristics, task orientation, and adopted analytics tools are assessed. The results highlight the determinants and nature of analytic tasks performed as well as the adopted tools.

LITERATURE REVIEW

The use of analytics is important as analytics are used to generate insights thus leading to more informed actions. Since many research studies use various analytic terms interchangeably (Bayrak, 2015), it is important to define "business analytics". Davenport and Harris (2007) define this term as "the focus on the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive actions." Watson (2009) views it as "a broad category of applications, technologies, and processes for gathering, storing, accessing, and analyzing data to help analysts". Pape (2016) explicates it as "a set of methods that transform data into action by generating insights used for decision-making". Recently, Wang et al. (2018) incorporates terminology associated with "big data" by including "a combination of skills, technologies, applications, and processes that enables firms to analyze an immense volume, variety, and velocity of data across a wide range of networks to support informed decision-making, and action-taking".

In defining analytics, it is important to recognize the integration of business intelligence and big data terminology along with the focus on analysis, data, models, and an evidenced-based culture. Big data contributes massive volumes of data from various sources which can be used to support different types of actions over varying time-periods. Model creation primarily focuses on providing an explanatory context for business orientation tasks (Goes, 2014). Further, another aspect of analytics involves the analytic culture of the business. The analytics need to be related to the processes used for problem-solving and decision-making (Baesens et al, 2016). It is important that the analytics used for fact-based decision-making and generated insights from the various explanatory, predictive, and prescriptive models are relevant for decision problems (Vidgen et al, 2017).

Conceptual Framework

The conceptual framework that was developed for this research project involves the use of business characteristics, task orientation, and usage of analytics tools. There are a variety of adoption models proposed for integrating business analytics into the problem-solving/decision-making processes. These models include the Healthcare Analytic Adoption Model, task orientation model, the PAIR model, and the simplified taxonomy of big data analytics (Goes, 2014; Sanders, 2012). The task orientation model is adopted for use in this research project.

This research project hypothesizes that business analytics tasks may have four distinct task orientations with differing outcomes. In performing business analytics, four different task orientations that include situation-sensing, making predictions, making evaluations, and making decisions can be used. While these orientations can be used separately or in combination, it is

expected that the business will primarily focus on a certain task orientation while performing analytics tasks. It is also hypothesized that task orientation is influenced by the characteristics of size and industry type. In addition, it is conceptualized that the primary task orientation will have an impact on the specific analytics tools adopted.

Task Orientation

To generate insights demanded by businesses, this study postulates that the analytics tasks being performed may have different task orientations focused on what is to be accomplished by the analytics effort. The task orientation taxonomy indicates that the firm can use one of four specific orientations labeled situation-sensing, making predictions, making evaluations, and making decisions. While firms can adopt any combination of these orientations, it is expected that they will primarily focus on a specific orientation while performing business analytics tasks.

Antecedents: Business Characteristics

It has been argued that business size, skilled personnel, and culture contribute to the successful use of business analytics (Trieu, 2017). Further, a business needs to possess a unique blend of cultural, financial, and human capital to create a business analytic capability which competitors will find difficult to replicate (Gupta & George 2016). To create this essential capability, a business needs to either improve the analyst's business analytic skills or search for individuals who have these skills. Ideally, analysts with required competencies will provide improved insight generation (Ayyagari et al, 2011). To achieve this goal requires that the business has a clear understanding of both the business analytics task and the connection between the expected outcome and the required skills.

It is postulated that size affects the ability of the business to convert business intelligence assets into business analytical impacts (Trieu, 2017). Since larger businesses have the capability of mobilizing greater resources, it is believed that larger businesses are more likely to exploit business intelligence potential. Engaging in business analytics is an expensive, multi-year investment requiring a wide range of skills (Ramamurthy et al, 2008). Yet, small and medium-sized businesses often lack the resources and expertise needed to take advantage of analytical tools (Doumpos & Zopounidis, 2016). Thus, larger businesses may employ the more sophisticated task orientations. Yet, not every business embraces a data-driven culture as businesses in certain industries are more data-driven and may have adopted more advanced business analytics tools leading to different task orientations.

Consequences: Tools

There exists strong connection between the business analytic tool sophistication and the quality of insights generated. Further, Wang & Byrd (2017) report that the effective use of business analytics tools indirectly influences problem-solving and decision-making efficiency and effectiveness. Therefore, it is important to acquire the capabilities of the tools that can facilitate specific business analytics task orientations.

Gartner has classified the business analytic tool platform capabilities into categories labeled analytic, decision, and information. The analytic capabilities contain a collection of various analysis methods, data transformations, and tools including ad-hoc query, content analytics, dashboards, speech analytics, and visualizations. The decision capabilities encompass applications such as scenario modeling and simulation to help analysts learn, share, and

understand the data. The information capabilities focus on the technology infrastructure that ensures proper interfaces thus permitting the exchange of data, documents and other content.

Businesses may combine tool capabilities by establishing a proactive use of the information environment in which insight generation is based on rationality. Analysts with analytical research styles will adopt and use the tools to a greater extent than analysts with conceptual research styles. Hence, a business analytics task orientation with the right analytics culture can help with overcoming the trade-off between reach and richness of the tools.

METHODS

By extracting job postings for business analytics positions, business analytics task descriptions were developed. Then, in late 2017, online job search sites were used to collect business analytics postings. Those posts containing business analytics job titles were selected for this research project. To identify size and industry type, business names of the potential employer in the posting were used. For the identified size, businesses were classified using the 2017 Fortune 500 list. If the business was in the Fortune 500 list, they were classified as Fortune 500 whereas the remaining businesses were classified as non-Fortune 500. By identifying the SIC code and the primary market served, businesses were further classified into consumer products, financial services, healthcare services industrial products, or retail.

Text-Mining Process

Business analytics task descriptions were gathered as the first step in the text-mining process. Over a two-month period in 2017, business analytics postings that were highly relevant were gathered. For the second step in the text-mining process, text-refining and text pre-processing were performed on the collected postings. This was accomplished by clearing the formatting as well as implementing tokenization and stemming for text reduction. The third step in the text-mining process was to perform text-mining analysis using the refined and pre-processed texts. The text-mining analysis process generated intermediate output that contained relevant term concepts related to the four business analytics task orientations. The final step was to perform clustering analysis using the previously generated document-based output. The clustering algorithms created clusters associated with the identified business analytics task orientations.

RESULTS

The k-means clustering procedure was used. The clustering algorithm generated four unique clusters utilizing 27 relevant word-concept terms. These word-concept terms are related to the four task orientations. By examining the cluster centroids, the resulting clusters were classified thus allowing for the interpretation of each cluster grouping.

Cluster 1, consisting of 39 businesses, represented the decision orientation cluster. The word-concept term list showing values greater than .20 include the following nineteen terms: action, analytics, analyze, communicate, decide, define, effect, improve, inform, insight, monitor, problem, report, revenue, solution, strategy, translate, understand, and visualize. Cluster 1 shows large centroid values for concepts relevant to decision as well as prediction, evaluation, and sensing orientation. This suggests that the decision orientation task is a more advanced and sophisticated task orientation driven by the combination of all four task orientations. Cluster 2 consists of 99 businesses and represents prediction task orientation. The word-concept term list showing values greater than .20 include the following fourteen term concepts: action,

analytics, analyze, decide, improve, inform, insight, performance, predict, problem, report, solution, strategy, and understand. These concepts are primarily relevant for prediction task orientation with some overlap with the decision and evaluation task orientation. Cluster 3 consists of 58 firms and represents the evaluation task orientation. The word-concept term list showing values greater than .20 include the following ten term concepts: analytics, analyze, decide, determine, inform, intelligence, performance, report, solution, and visualize. These concepts are primarily related to evaluation orientation task with some decision and evaluation orientation tasks. Cluster 4, consisting of 291 businesses, represents the situation-sensing orientation cluster. The word-concept term list showing values greater than .20 include the following eight terms: analytics, analyze, improve, insight, performance, report, strategy, and understand. These concepts are related to sensing task orientation along with the other three task orientations in a very superficial way. Relatively small centroid values for most of the term concepts characterize this cluster.

According to these results, the largest number of businesses are classified into the situation-sensing task orientation followed by approximately 20 percent of the businesses focused on the prediction task orientation. The remaining 20 percent of businesses were either the make decision or making evaluation task orientation.

Cross-tabulation

This research project evaluated the relationship between business analytics task orientation and business characteristics. Chi-square statistics for cross-tabulations were used to test these relationships. The chi-square test indicates a significant relationship between business analytics task orientation and industry type. The results show that businesses in consumer product, industrial products, and financial services sectors tend to belong to cluster 2 and cluster 4. These two clusters focus on make prediction and situation-sensing business analytics orientation tasks. Businesses in the healthcare services and retail sector more often focus on the situation-sensing business analytics orientation task. The chi-square test is not significant for the relationship between business analytics task orientation and business size. The chi-square test indicates a non-significant relationship between business analytics task orientation and tools used. The selected businesses reported a total of 62 analytics tools in their job posts. Twenty-two analytic tools show reported frequency of 10 or higher. The results show that businesses are using a diverse set of business analytics tools.

DISCUSSION AND CONCLUSIONS

This research project tested a conceptual model that captured the relationships among task orientation, business characteristics, and analytics tool adoption. Text-mining analysis of relevant job postings together with cluster analysis provide insights into the nature of business analytics orientation tasks and adopted tools. Evaluating job postings provides a leading indicator view of the future direction for the business. Each word-concept term used in the job posting belongs, to a certain degree, to a specific cluster. Yet, with cluster analysis, the word-concept terms overlap other clusters as the clustering algorithm optimizes for cluster centers. Thus, cluster analysis partitions the word-concept terms into segments which can then be used to better understand the relationships among the business task orientations.

Using the task orientation model, four types of business analytics task orientation were empirically validated. Text-mining analysis was performed to identify the relevant concepts used to describe the required business analytics tasks. Text-mining output was further

analyzed using clustering algorithms to classify tasks into four unique categories. The cluster analysis results show that the largest cluster containing about half of the businesses focused on the situation-sensing orientation task. The next largest clusters were the prediction and evaluation-oriented clusters with 20.3% and 11.9% of the businesses respectively. The smallest cluster was the decision-orientation cluster which contained 7.8% of the businesses. These results suggest that businesses are using business analytics primarily for sensing tasks, although prediction and evaluation tasks are also important. Yet, the utilization of business analytics for making decisions has not been fully integrated into the business culture. However, the movement toward business analytics is impacting processes, rebalancing the decision-making relationship dynamics, and altering the scope and scale of optimization challenges.

This research project also evaluated antecedents and consequence of analytics task orientation. Two antecedents, size and industry type, were assessed to determine if they were related to task orientation. The results show that task orientation is related to industry type as there exist significant differences in selection of the task orientation for the type of industry. As certain industries require different orientation tasks, unique competencies need to be developed for businesses to remain competitive. The results show no significant relationship between orientation and tools. Interestingly, the results show that there are no dominant business analytics tools used supporting Columbus' (2016) report that the top 10 business analytic providers comprised less than 60% of the market. Yet, by 2026, the demand that drives these business analytics tools is expected to surge with a forecasted 23 percent compounded annual growth rate. These tools are viewed as containing volumes of high quality information in well-designed data stores, user-friendly tools providing timely access, effective analysis, and intuitive presentation thus enabling analysts to develop actions to understand problems and make decisions. These findings are consistent to the reported statistics suggesting that the business analytics tool market is highly fragmented.

These findings provide important implications regarding training as no specific tools are dominantly used thus tool independent training may be required for analytics tasks. Therefore, training should focus on the basic mechanisms of business analytics rather than tool specific skills. The cluster analysis results suggest that business analytics tasks are primarily focusing on the situation-sensing orientation task, followed by the make prediction and make evaluation orientation tasks. These findings shed light on the nature and content of business analytics knowledge and training required. Given that the United States faces a critical shortage of individuals with analytical skills to analyze the volumes of available data and make recommendations based on their findings, the barrier for businesses to incorporate analytics into their processes is the inability to acquire talented individuals. As this research project uses posts from businesses in the United States, managers can gain valuable insights. Yet, given the preliminary nature of this project and the limitations of the sample, the findings may not be generalizable. Future research efforts are required to confirm the results of this project.

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DECISION SCIENCES INSTITUTE
Endangered Species International Trade Analysis using Power BI Analytics Tool

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ABSTRACT

This paper demonstrates the descriptive analytics method for revealing instant meaningful insights from endangered species international trade using the Power BI analytical tool. The endangered species international trade dataset is analyzed by creating Power BI visualizations that display revelations at a glance. Results display instant plots depicting the levels of exported and imported quantities of endangered wild fauna and flora with respect to several aspects such as their family, class, source, purpose and exporter/importer countries. Use of Power BI visualizations can display faster analysis results and uncover relevant trade insights to benefit the trade volume assessment and restriction monitoring process.

KEYWORDS: Endangered species, Power BI, Visualizations, Insights

INTRODUCTION

International trade analysis for endangered species has been a critical step in regulating the buying and selling of the 'near extinct' wild fauna and flora. Several researchers have been involved in exploring analytical procedures to better investigate the exploitation practices of the endangered species (Bhammar et al. 2016); Clifton, Rastogi, 2016; Jones, 2018). It has been a need of the law enforcement agencies and organizations to employ appropriate tools to analyze the huge amounts of the trade data stored on electronic platforms such as transnational databases (Jones, 2018).

In this research the powerful analytical tool Power BI is used to perform descriptive analytics and produce valuable insights on the endangered species international trade data stored in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) database (CITES, 2013). This paper is written in sections starting with the literature review explaining the background on the endangered species international trade followed by description of the Power BI analytical tool. The methods section explains the procedure followed in this research starting from data acquisition to creating visualizations. Results and discussion section displays screen shots of the Power BI visualizations and discuss the insights obtained followed by the final closing statements in the conclusion section.

LITERATURE REVIEW

Endangered Species International Trade

Endangered species are the wild fauna and flora that are on the verge of becoming extinct mainly due to reasons such as habitat loss, disease, geographic range, climate change and illegal trade. International wildlife trade has adversely affected the populations of the most iconic fauna and flora such as elephants, rhinos, orchids and many more thereby threatening their survival (Pambo et al., 2016; Jones, 2018). On the other hand, the trade also generates

significant profits for all the consumers thriving in countries throughout the world for example United States has been reported as the largest wildlife trader in the estimated $300 billion international trade (Sheikh & Corn 2016). The presence of a thriving international market for wildlife import and export leads to the necessity of monitoring and regulation of the trade to avoid increase in endangered species.

In 1973, due to the growing global concern over increase in the number of endangered wildlife species, 21 nations united and signed an international agreement called the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in Washington DC. Since then the main objective of CITES has been to provide a framework to monitor and regulate the trade levels (Sheikh & Corn 2016). CITES follows the procedure of first identifying the species as needing protection and then assessing the risk posed on their survival due to the trade. CITES maintains a database (Oracle RDBMS) that currently holds over 13 million international records of wildlife trade (CITES, 2013). Annual reports are produced from this database and are used for monitoring the trade levels and identify major anomalies in the reporting of imports and exports. In order to analyze a large database like CITES it becomes beneficial to employ a powerful and easy to use analysis tool that can provide instant insights.

Power BI Analytics Tool

Power BI (Business Intelligence) is a user friendly analytical tool created by Microsoft and first released to public in July 24, 2015 (Microsoft, 2015). This tool is built on advanced algorithms and has the ability and power to transform large amounts of data into insightful data visualizations. A visualization is a graphical representation displaying various patterns or trends of the input data thereby helping in the decision-making process.

Ever since its release several researchers have been using Power BI to uncover fast, meaningful visualizations to provide business solutions. It has also been noted that over 200,000 organizations from 205 countries are using Power BI successfully as a platform for data analysis (Krishnan et al, 2017). Power BI can provide results in the form of reports or dashboards which is a combination of more than one visualizations and provides at a glance 360 degree view of the data. There are variety of graphical representations to choose from the Visualization menu where each of them can show further customized view using filtering of the data fields. The uniqueness of the dashboards is their interactive feature where clicking on one visualization displays the related data on all other visualizations along with appearance of tooltips with data displays when mouse is hovered on them.

Researchers have compared Power BI with other tools available and have recommended it to be one of the preferred tools in terms of affordability and adaptability with variety of input sources (Barbulescu et al, 2016; Krishnan et al, 2017; Gowthami & Kumar, 2017).

METHODS

Dataset Acquisition

The dataset used in this analysis was acquired in form of a CSV file from the CITES database (CITES, 2013). It contains 67008 records on the international wildlife trade (import or export) of animal or plant species reported during the year 2016. The columns are as shown in the Figure 1 represent the following: Year column represents the year in which trade occurred; the next column is Taxon denotes the scientific name of animal or plant concerned; Class, Family and

Genus indicate the Taxonomic rank of the species; Importer and Exporter represent the respective country codes that are involved in the trade; Import and Export quantity columns represent the quantity of specimens reported as imports or exports; Term denotes the description of specimens traded; Unit represents the quantity unit in Kilograms (Kg) or Grams (g); Purpose codes represent the intention for the imports/exports such as B-breeding, H-hunting, T-commercial, S-scientific, P-personal etc.; Source column codes represents the original source of the species such as A-plants artificially propagated, C-animals bred in captivity etc. The full form for all the codes is available in the CITES Trade Database Guide (CITES, 2013).

Figure 1: International wildlife trade dataset (sample shown) of animal and plant endangered species exported or imported during 2016

Year	Taxon	Class	Family	Genus	Importer	Exporter	Importer quantity	Exporter quantity	Term	Unit	Purpose	Source
2016	Aquila heliaca	Aves	Accipitridae	Aquila	TR	NL		1	bodies		T	C
2016	Aquila heliaca	Aves	Accipitridae	Aquila	XV	RS		1	bodies		Q	O
2016	Haliaeetus albicilla	Aves	Accipitridae	Haliaeetus	BE	NO		43	feathers		S	W
2016	Haliaeetus albicilla	Aves	Accipitridae	Haliaeetus	BE	NO		43	specimens		S	W
2016	Haliaeetus albicilla	Aves	Accipitridae	Haliaeetus	DK	IS	700		specimens		S	W
2016	Haliaeetus albicilla	Aves	Accipitridae	Haliaeetus	XV	RS		1	bodies		Q	O
2016	Harpia harpyja	Aves	Accipitridae	Harpia	BR	FR		12	feathers		S	C
2016	Harpia harpyja	Aves	Accipitridae	Harpia	BR	FR		4	feathers		S	U
2016	Harpia harpyja	Aves	Accipitridae	Harpia	BR	FR		2	feathers		S	W
2016	Acipenser brevirostrum	Actinopteri	Acipenseridae	Acipenser	CH	DE		4	live		T	C
2016	Acipenser sturio	Actinopteri	Acipenseridae	Acipenser	US	IR	100		caviar	g	P	I
2016	Ailurus fulgens	Mammalia	Ailuridae	Ailurus	AU	NZ		2	live		Z	C
2016	Ailurus fulgens	Mammalia	Ailuridae	Ailurus	CA	US		1	live		Z	F
2016	Ailurus fulgens	Mammalia	Ailuridae	Ailurus	IL	DE		2	live		Z	C
2016	Ailurus fulgens	Mammalia	Ailuridae	Ailurus	JP	US	1		live		B	C
2016	Ailurus fulgens	Mammalia	Ailuridae	Ailurus	JP	US		1	live		Z	C

Import to Power BI

The dataset CSV file was converted into Excel (table) format and then imported into Power BI using the intuitive process of using the web buttons ‘Get data’ followed by ‘Import Excel data into Power BI’. Although any CSV file can be directly imported into Power BI but Excel conversion was done to view the data and clean up any unwanted columns such as serial number.

Visualization Creation

Power BI offers a whole range of visualization designs such as pie charts, scatter charts, line charts, stacked bar/column charts, tree maps, filled maps, funnel maps, gauge maps, multi-row cards (Microsoft, 2015). These options along with extensive page formatting tools, such as shapes and images were used to create visualizations revealing meaningful insights of the endangered species trade.

Procedure to create a visualization included the following:

- Identification of the central question/objective for each visualization
- Selection of data fields that correspond to the central question/objective
- Selection of the appropriate graphical representation. Several visualizations were tried and the ones that produced meaningful revelations were selected

- Further, filtering and drilling down using filtering tools on each visualization to eliminate any unwanted data category selections
- Formatting of each visualization to project results in standout colors and easy readable font style and sizes.

RESULTS AND DISCUSSION

Meaningful insights about the international trade of endangered species were revealed for the following central questions/objectives through Power BI visualizations (screen shots shown in the following figures).

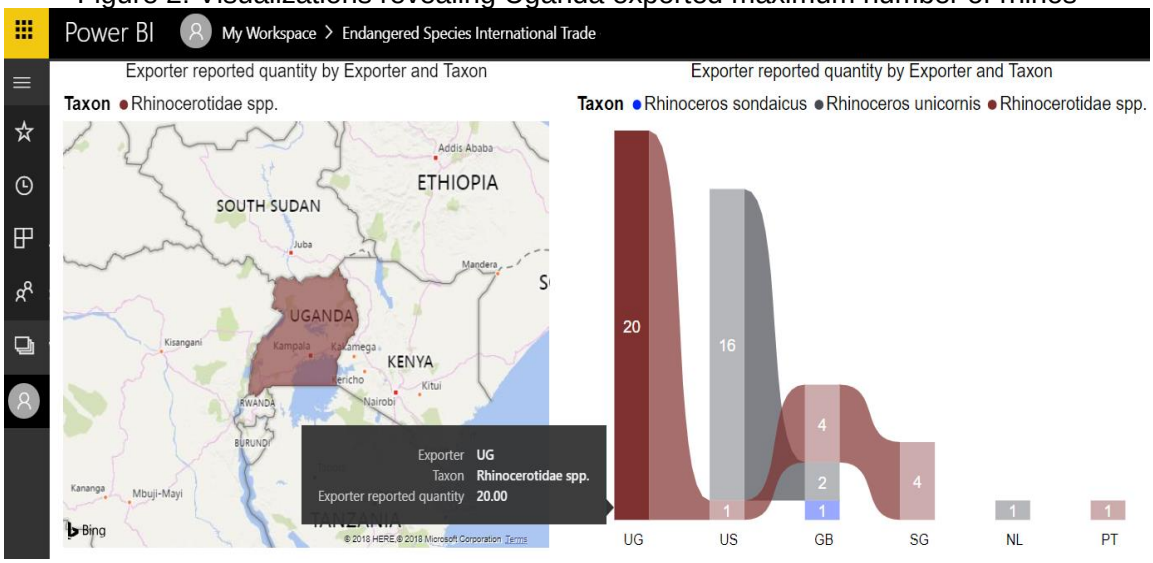
Country that Exported Maximum Number of Rhinos

Figure 2 shows two separate visualizations. The first one (left side) is a 'filled map' visualization displaying the number of species exported categorized by the exporter country and the species taxon. Initially it displayed the whole world map with color markings for each of the species taxon. The second one (right side) was created using the 'ribbon chart' representing the number of rhinos exported categorized by the exporter country and all the taxon representing rhinoceros. The objective was to determine the country that exported maximum number of rhinos. In order to see the exact country geospatially the taxon showing the maximum number was clicked on the right-side visualization and instantly the left visualization automatically zoomed in and displayed Uganda as the respective country.

- The visualizations clearly displayed that Uganda (country code – UG) exported the maximum number that is 20 rhinos followed by USA (US) which exported 16 rhinos and others such as UK (GB), Singapore (SG), Netherlands (NL), Portugal (PT) exported less than 5 rhinos

- The Rhinocerotidae spp. taxon was the maximum exported compared to the other taxon for rhinos.

Figure 2: Visualizations revealing Uganda exported maximum number of rhinos

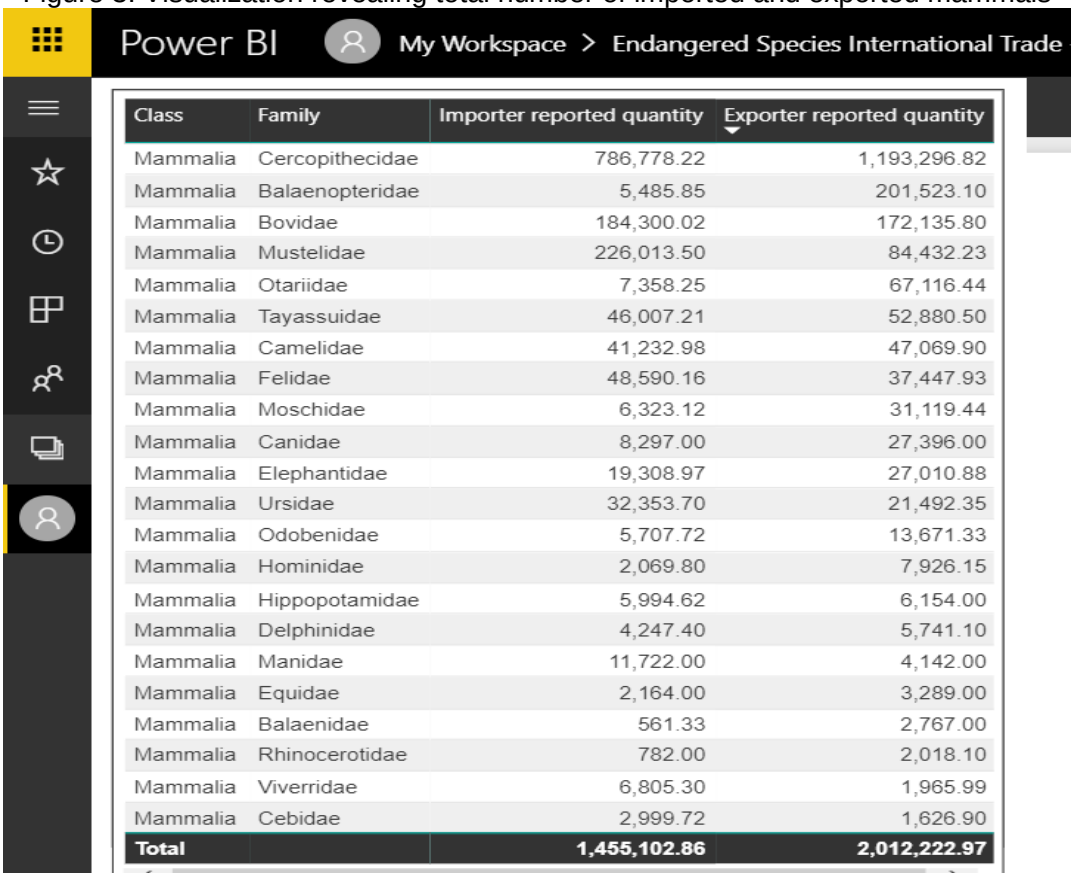


Total Number of Imported and Exported Mammals per Family

Figure 3 displays the 'table' visualization for total number of imported and exported mammals categorized by family.

- It is seen that Cercopithecidae family also known as the old world monkeys are the maximum number of mammals that were imported and exported
- The other species such as Bovidae (bison, African buffalo, water buffalo, antelopes, wildebeest, impala, gazelles, sheep, goats etc) and Mustelidae (carnivorous mammals, including weasels, badgers, otters, martens, mink, and wolverines) are the second highest to be imported and exported
- Rhinocerotidae (rhinos) and Hippopotamidae (hippos) import and export numbers are not as high compared to Elephantidae (elephants).

Figure 3: Visualization revealing total number of imported and exported mammals

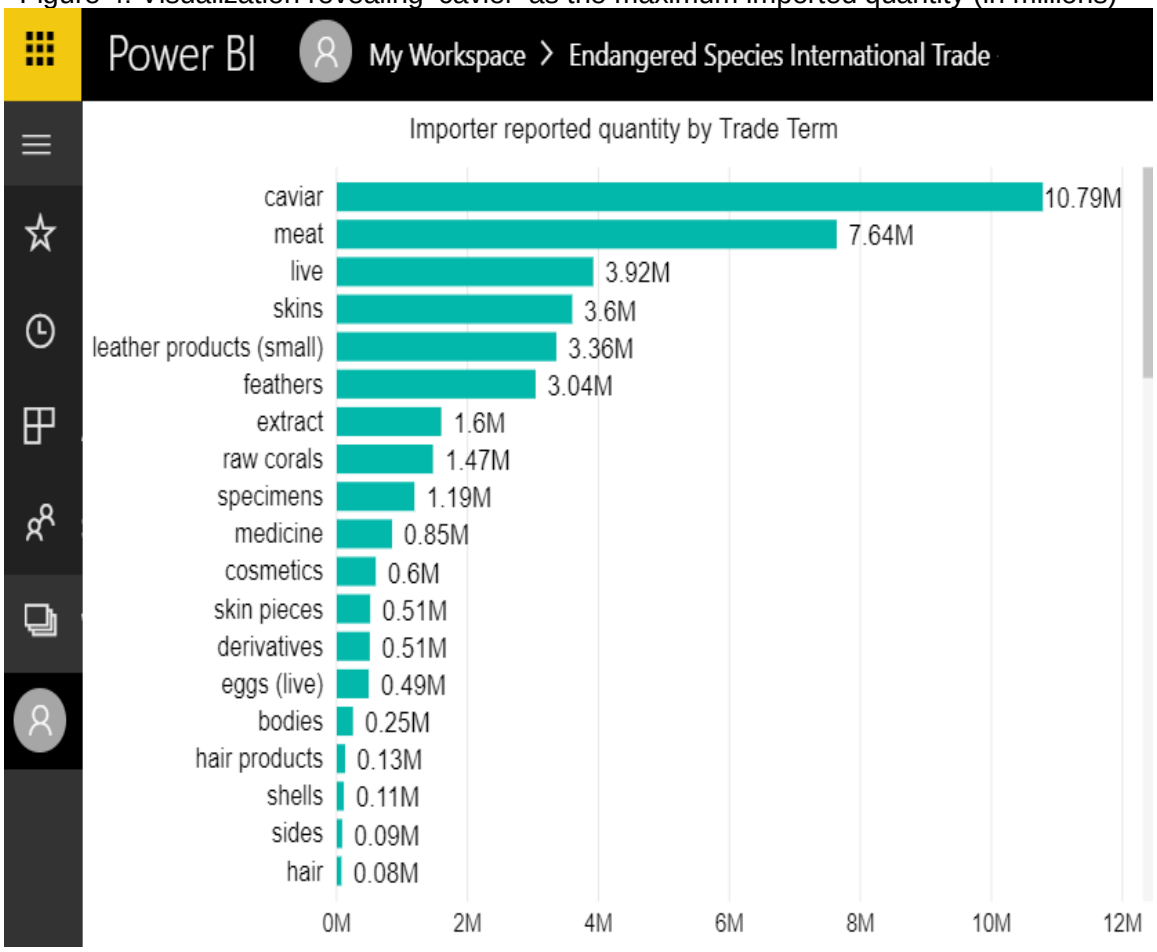


Class	Family	Importer reported quantity	Exporter reported quantity
Mammalia	Cercopithecidae	786,778.22	1,193,296.82
Mammalia	Balaenopteridae	5,485.85	201,523.10
Mammalia	Bovidae	184,300.02	172,135.80
Mammalia	Mustelidae	226,013.50	84,432.23
Mammalia	Otariidae	7,358.25	67,116.44
Mammalia	Tayassuidae	46,007.21	52,880.50
Mammalia	Camelidae	41,232.98	47,069.90
Mammalia	Felidae	48,590.16	37,447.93
Mammalia	Moschidae	6,323.12	31,119.44
Mammalia	Canidae	8,297.00	27,396.00
Mammalia	Elephantidae	19,308.97	27,010.88
Mammalia	Ursidae	32,353.70	21,492.35
Mammalia	Odobenidae	5,707.72	13,671.33
Mammalia	Hominidae	2,069.80	7,926.15
Mammalia	Hippopotamidae	5,994.62	6,154.00
Mammalia	Delphinidae	4,247.40	5,741.10
Mammalia	Manidae	11,722.00	4,142.00
Mammalia	Equidae	2,164.00	3,289.00
Mammalia	Balaenidae	561.33	2,767.00
Mammalia	Rhinocerotidae	782.00	2,018.10
Mammalia	Viverridae	6,805.30	1,965.99
Mammalia	Cebidae	2,999.72	1,626.90
Total		**1,455,102.86**	**2,012,222.97**

Quantities of Endangered Species Specimens Imported

Figure 4 shows the 'clustered bar chart' representation by the Term (description of specimens traded) revealing cavier (internal ovary eggs from wild sturgeon in the Caspian Sea and Black Sea (Davidson & Jane, 2006)) as the maximum imported quantity (10.79 million) followed by meat as the second largest imported quantity (7.64 million).

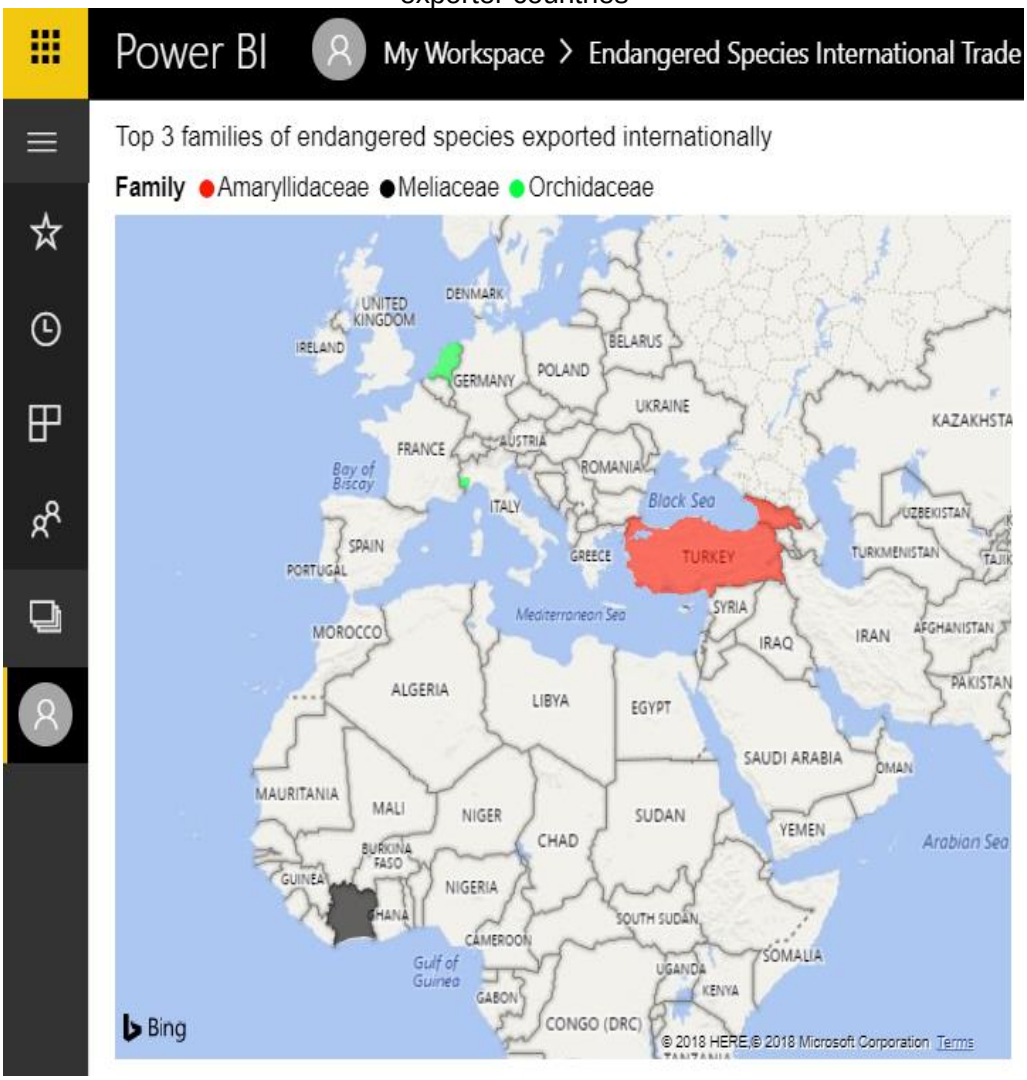
Figure 4: Visualization revealing ‘cavier’ as the maximum imported quantity (in millions)



Top 3 Maximum Exported Endangered Species Family

The ‘filled map’ visualization in Figure 5 reveals the top 3 maximum exported endangered species to be from the family of Amaryllidaceae (perennial flowering plants), Meliaceae (mahogany family flowering plant) and Orchidaceae (Orchids). Further upon hovering over the visualization it displayed the export quantity of approx. 26 million of Amaryllidaceae family plants being exported from Turkey. The second largest were approx. 9 million Orchids exported from Netherlands and third largest were approx. 8 million of mahogany family plants exported from Cote D’Ivoire (West African country). The revelation of the top 3 maximum exported families of species being from the family of flowering plants indicated regulation in the trade of animal species.

Figure 5: Visualizations revealing the top 3 maximum exported species families and their exporter countries



Top 5 Maximum Exported Endangered Species Class

Figure 6(a) shows the countries exporting the top 5 maximum exported species by class. United States was seen to be the largest exporter of Actinopteri (fish) with export quantity of 64,994 and almost all of India was seen to be exporter of 19,424 reptiles.

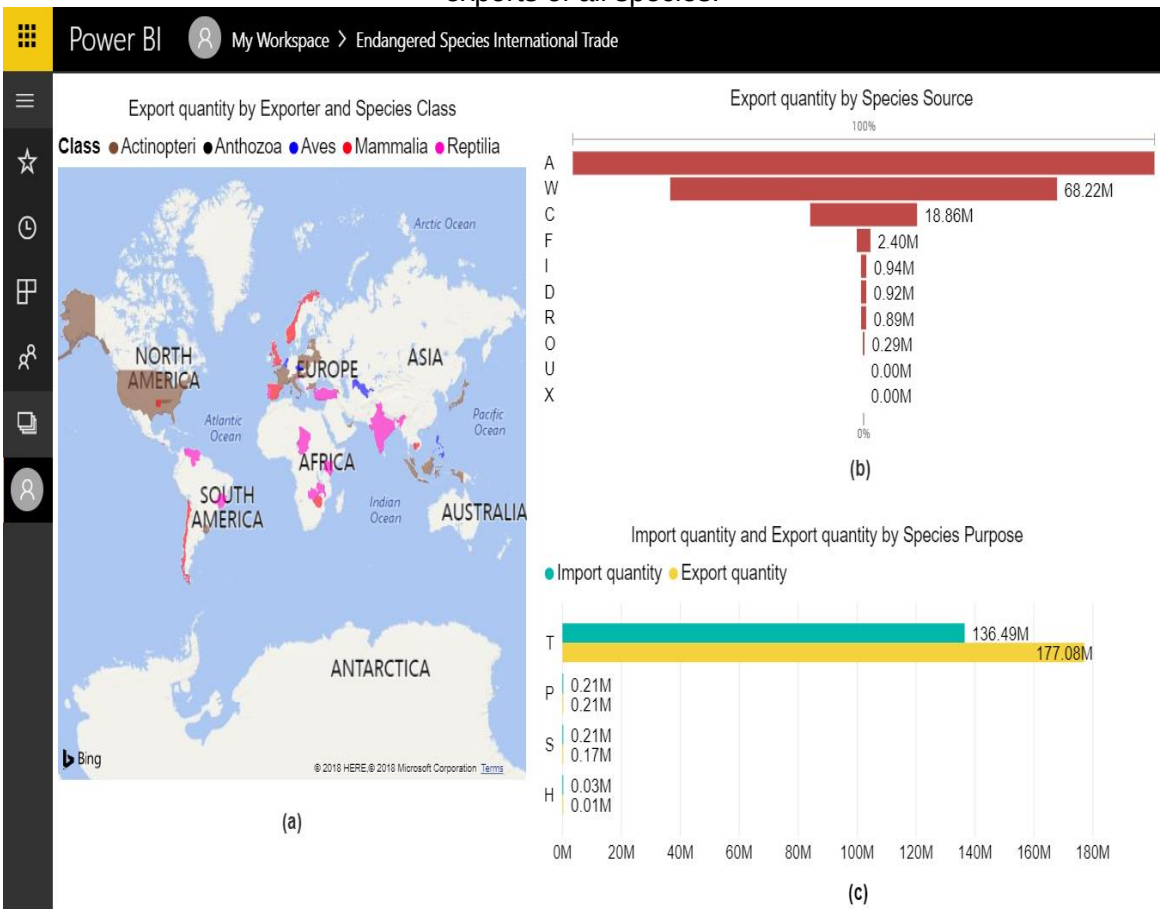
Source of the Maximum Species Exported

Figure 6(b) reveals that approximately 102 million species exported were from the source code A that refers to the plants that are artificially propagated followed by 68.22 million species for source code W referring to taken from the wild. It also reveals that export of animals bred and born in captivity source code C and F respectively are much less than the ones from the wild.

Purpose for the Maximum Species Imported and Exported

Figure 6(c) displays the commercial use (code T) as the purpose for maximum trade occurred. It also shows that number of exported species (177.08 million) were more than imported species (136.49 million) used for commercial purpose. The remaining purposes such as code P (personal), S (Scientific), H (Hunting) had much less trade quantities confirming trade regulation and restriction on the trade purposes.

Figure 6: Dashboard revealing the export quantity; a) Displays the countries exporting the top 5 maximum exported species by class; b) Displays quantity of species exported by their source; c) Reveals the commercial use (code T) as the purpose for maximum number of imports and exports of all species.



CONCLUSIONS

The method of descriptive analytics using visualizations provided instant exploration of the endangered species data and revealed meaningful insights on the international trade that occurred in 2016. It can be concluded that use of analytical tools such as Power BI can be very powerful and faster in analyzing the voluminous data from the endangered species international trade database such as CITES. Visualizations created can reveal meaningful insights and thereby benefit the trade restriction monitoring and import/export volume assessment process.

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Evaluating Performance Issues in Local Government
Using the PPP Model

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ABSTRACT

Performance evaluation in local governments has proven to be a difficult challenge. This paper focuses on county government performance using the "Profitability = Productivity + Price Recovery" (PPP) model. It describes the application, evaluation of performance, and the challenges in finding solutions to systemic problems.

KEYWORDS: Local government, productivity, profitability, public administration, performance evaluation

INTRODUCTION

Performance measurement is defined as the process of collecting and reporting data which can be used to summarize and assess program implementations (Berenson, 2016). In government, it can simply be interpreted as the achievements made at various levels of government and how the quality of these achievements can promote future projects. Many establishments are using performance measurements to manage and improve programs; as well as ensure desired results are produced. Today, federal government agencies are held to higher standards concerning how information is generated internally and also how this information is revealed to the public (Pollanen, 2011). States and local governments are also recognized for advanced practices related to result-oriented systems (Ralph and Rusdi, 2012). Local governments include cities and counties in which the representing members were elected by the community. During the budget process, governments forecast revenues and expenditures which focus on variability, seasonality, and sensitivity to economic factors (Williams and Kavanagh, 2016). This budgeting process not only helps to prepare the next fiscal year revenues and expenditures, it also assists in visualizing the trends of both revenues and expenditures in order to make appropriate decisions that will fit the organization's goals. Property taxes are the primary source of revenue for the county observed in this study. A significant portion of the revenue from property taxes is allocated to the General Fund, which is then distributed to other funds as needed; for example, the Airport and Parks and Recreation funds. Long-term sustainability of county operations depends on the proper use of property taxes and limited resources. Studying and monitoring how these funds are being used year after year, and the way that they trend, is very important because it allows for a continuity of fiscal efficiency to be seen by the community (Melitski & Manoharan, 2014). Performance issues and inefficiencies may come to light, requiring managerial attention and action. This study focuses on performance measurement using the PPP (model. The rest of the paper is organized as follows: Literature review, data collection/model setup, results/analysis, and conclusion.

There are many performance measurement models such as comprehensive models like the Balanced Scorecard (BSC) which allows managers to look perspectives from; Financial, Internal Business, Innovation & Learning, and Customer in order to understand overall performance.

The other types of performance models are more narrowly focused on single factor productivity that measures efficiency or productivity of labor, for instance, producing a single output. Total-factor measurement models are more appropriate for measuring performance at the organization level. Sometimes they are called multi-factor measurement models. Some of these models link productivity to profitability. One such model is the PPP model (Miller, 1984; Miller and Rao, 1989).

The PPP model is used in revenue-generating organizations. County governments typically do not sell products or services to generate revenue. Although it may manage some properties such as parks and airports, the clear majority of services include public works, law enforcement, and other offices which charges are not levied. Most of the revenues come from property taxes. So, there is no direct relationship between tax collection and major services provided such as the law enforcement service. That is one of the primary difficulties of performance measurement in county governments or governments at any level. County governments use tax funds as the major resource to provide all the services. So, the taxes would be inputs and the services would be outputs. On the other hand, if the services are not provided well, the taxes would dry up. For instance, deterioration in law enforcement and crumbling roads may lead to lower property values and lower tax revenues. In this sense, tax revenues are dependent on the service provided. So, tax revenues could be treated as revenues and the costs associated with providing services as inputs. In this paper, this is how the PPP application is developed for a county in Texas. The main purpose is to uncover and identify performance problem areas so that the administration can take action for a better performance.

DATA COLLECTION AND MODEL SETUP

The application of the PPP model requires quantities, prices and values of inputs and outputs. If two of the three (i.e., quantities, prices and values) are present, the third can be calculated by simple arithmetic. The data is collected, and the application is developed in a spreadsheet. The data is collected from the county's Comprehensive Annual Financial Reports for fiscal years 2011 through 2015. Although the data is public record, it is not easy to acquire, especially because the results may show some unpleasant truths about how the resources are being used. The county government should be commended for providing this data for this research study, and the study's intent is not to embarrass the administration in identifying the problem areas. Moreover, this application does not go into the underlying causes why a specific area may appear to have problems. It may be due to external factors or something that is not in control of the administration. So, the county goes nameless and the data is modified without affecting the major results. The value of the study is (1) to show the readers and researchers how this model and application can be used in identifying problem areas in local governments, and (2) for the county or local government administrators to apply this model internally to discover the problem areas and take timely action, which would be beneficial to the government and the tax payers.

Table 1 shows the county data for five fiscal years. It is important to mention that this study analyzes the data for the General Fund which is the main financial source in the county. Also, expenditures are just those related to the county's operation. The main revenues are property taxes and are calculated based on the tax rate shown in the table. Expenditures are classified into labor, operation, maintenance, energy, telephone and miscellaneous. It is important to mention that the analysis of the data is at the General Fund level; not at the whole government level. The other financial sources are not used in this study, because the purpose is to analyze revenues and expenditures excluding any other extraordinary or non-current transactions like

gain or loss on sale of assets, a premium or discount on bond issues, etc. Note, inter-fund transfers in and out are excluded since these transactions are between funds.

Table 1. Basic data: quantities, prices and values of inputs and outputs

	QUANTITY					PRICE					VALUE				
	Period-1	Period-2	Period-3	Period-4	Period-5	Period-1	Period-2	Period-3	Period-4	Period-5	Period-1	Period-2	Period-3	Period-4	Period-5
	Q1	Q2	Q3	Q4	Q5	P1	P2	P3	P4	P5	V1	V2	V3	V4	V5
Property taxes	225,909,286	226,183,593	234,366,960	258,566,909	245,407,818	$0.36	$0.36	$0.36	$0.35	$0.34	80256307	80353757	83260972	89253936	82243522
TOTAL Revenues											**80256307**	**80353757**	**83260972**	**89253936**	**82243522**
Salaries-Department Head	19	19	19	19	19	$62,220	$63,193	$66,913	$68,106	$69,311	$1,163,508	$1,181,706	$1,251,271	$1,273,589	$1,296,114
Salaries-Official	32	32	32	32	32	$58,751	$58,606	$59,431	$62,429	$63,507	$1,897,644	$1,892,958	$1,919,611	$2,016,455	$2,051,267
Salaries-Regular	1,012	1,012	1,022	1,035	1,052	$24,048	$23,886	$24,024	$23,913	$24,589	$24,325,002	$24,160,579	$24,545,142	$24,757,423	$25,875,260
Salaries-Overtime	1,012	1,012	1,022	1,035	1,052	$997	$983	$1,202	$1,469	$1,848	$1,008,418	$994,274	$1,227,708	$1,520,445	$1,944,398
Salaries-Court Reporters	15	15	15	15	15	$48	$0	$0	$0	$67	$728	$1	$1	$1	$1,023
Salaries-Temporary Employees	43	43	43	43	43	$9,604	$8,867	$9,095	$9,054	$8,503	$408,167	$376,842	$386,531	$384,799	$361,356
Salaries-Longevity Pay	238	238	238	238	238	$878	$884	$861	$830	$830	$208,962	$210,377	$204,868	$197,585	$197,590
Salaries-Supplemental Pay	82	82	82	82	82	$6,607	$7,453	$7,039	$7,249	$7,185	$539,168	$608,157	$574,343	$591,524	$586,284
Employee Benefits	1,012	1,012	1,022	1,035	1,052	$8,552	$8,754	$9,060	$9,320	$9,664	$8,650,775	$8,855,081	$9,256,103	$9,649,162	$10,169,622
Other Personnel Expense	1,012	1,012	1,022	1,035	1,052	$383	$313	$297	$324	$233	$387,018	$316,967	$303,939	$335,141	$244,718
Labor											$38,589,388	$38,596,943	$39,669,517	$40,726,124	$42,727,632
Office expense (per personnel)	1,026	1,026	1,026	1,026	453	$1,036	$1,032	$1,015	$1,126	$2,417	$1,063,399	$1,059,030	$1,041,814	$1,156,134	$1,095,945
Food & Kitchen	908	908	908	908	908	$1,725	$1,636	$1,728	$1,655	$1,684	$1,565,585	$1,485,461	$1,568,270	$1,502,195	$1,528,474
Professional services	47	47	47	47	47	$22,321	$20,762	$20,856	$23,421	$28,215	$1,043,504	$970,614	$975,026	$1,094,926	$1,319,066
Special Personnel	139	140	142	141	146	$29,247	$26,602	$25,325	$28,530	$29,291	$4,052,232	$3,730,968	$3,594,829	$4,025,554	$4,282,356
Capital Outlay	4	4	4	4	4	$110,000	$110,000	$110,000	$170,000	$110,000	$467,500	$467,500	$467,500	$722,500	$467,500
Travel	1,026	1,026	1,026	1,026	1,027	$159	$170	$164	$165	$195	$162,952	$174,263	$168,479	$169,488	$200,468
Operation											$8,355,173	$7,887,836	$7,815,917	$8,670,797	$8,893,809
Maint & repairs buildings	73	73	72	72	76	$29,968	$22,098	$25,400	$26,969	$25,223	$2,190,640	$1,615,340	$1,835,141	$1,948,487	$1,908,089
Maint & repairs vehicles	183	209	204	207	207	$7,991	$5,150	$5,997	$6,289	$6,159	$1,460,426	$1,076,894	$1,223,428	$1,298,991	$1,272,060
Maintenance											$3,651,066	$2,692,234	$3,058,569	$3,247,478	$3,180,149
Contractual Services (kwt/hour)	833,000	833,000	833,000	833,000	833,000	$2	$2	$2	$2	$2	$1,332,800	$1,332,800	$1,332,800	$1,332,800	$1,332,800
Energy											$1,332,800	$1,332,800	$1,332,800	$1,332,800	$1,332,800
Telephone	1,012	1,012	1,022	1,035	1,052	$400	$400	$400	$400	$400	$404,600	$404,600	$408,680	$414,120	$420,920
Internet	1,012	1,012	1,022	1,035	1,052	$200	$200	$200	$200	$200	$202,300	$202,300	$204,340	$207,060	$210,460
Telephone											$606,900	$606,900	$613,020	$621,180	$631,380
Other Services & Charges (debt service	5	5	5	5	5	$946,953	$1,075,639	$1,007,451	$1,137,255	$1,019,755	$4,829,460	$5,485,761	$5,138,000	$5,800,000	$5,200,753
Other Expenses	850	850	850	850	850	$300	$300	$300	$300	$300	$255,000	$255,000	$255,000	$255,000	$255,000
Miscellaneous											5084460	5740761	5393000	6055000	5455753
TOTAL											**57,619,787**	**56,857,474**	**57,882,823**	**60,653,379**	**62,221,523**
Profits											**22,636,520**	**23,496,284**	**25,378,149**	**28,600,556**	**20,021,999**

The attraction of the PPP model to the business community is that it uses readily available accounting data and provides performance results in dollars as opposed to abstract indexes (Rao 2000). In the PPP model, current period performance is measured against the actual performances of the previous periods. This paper describes a multi-period implementation of the PPP model for a county government. This application can help many revenue-generating organizations – both public and private – to develop their own applications for performance evaluation.

Once the data is setup for all previous periods until the most current period, we use the information provided by prices to “normalize” the values. The ratio of price-weighted sum of quantities of any input in two consecutive periods provides a deflator that helps “normalize” the dollar value. Table 2 shows all the important calculations thereafter summarized as follows.

1. Determine the dollar value of each input and output in the period prices,
2. Determine implied and “composite” deflator for each input for all periods,
3. Determine input and output profit margins and deflated profit margins,
4. Determine profitability, productivity, and price recovery indices.

An actual multi-period application of the PPP model in Microsoft Excel for a county government is described next. These contributions from the top level, through category level and down to the resource level are plotted so that the trends are easily identified, and the management can zero in on the problem areas.

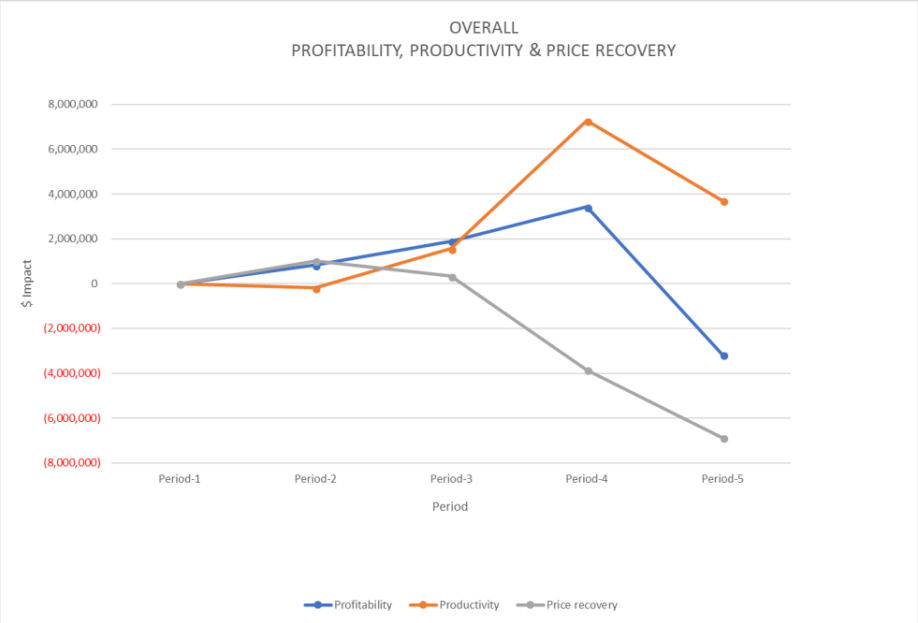
RESULTS AND ANALYSIS

Figure 1 shows the county’s overall profitability, productivity, and price recovery. Productivity contribution shows the performance without any effect of price changes in inputs and outputs.

Basically, it removes any inflationary factors. Price recovery reflects the price changes in inputs and outputs. Profitability is the sum of productivity and price recovery contributions.

In Figure 1, overall profitability of the county looks great until period 4. Apparently, this positive trend is primarily due to productivity. Overall price recovery seems to be a problem. It took a major dive in period 4 and continued in period 5. A negative price recovery contribution of $3.8 million in period 4 and $6.8 million in period 5 is a major problem. This requires drill down into categories and actual resources causing this problem.

Figure 1. County Overall Performance



Like the overall performance chart shown in Figure 1, one could generate charts for each category and each resource. Major problem category seems to be Labor. Figure 2 shows labor performance. In period 5, the overall price recovery contribution was -$6.8 million of which -$5.1 million from labor. This is a serious problem and requires further drill down into resources causing the problem.

CONCLUSIONS

Performance measurement helps organizations perform better. It is important that counties measure performance, identify problem areas and take timely action to improve performance. One model that could be used to develop an application to identify problem areas is the PPP model. This paper described the model setup, the data used, and the results obtained. The analysis has identified that the labor category is a serious problem in terms of price recovery contribution. That is the average expense of labor has been going up relative to average tax rates. Employee overtime, retirement and benefits also seem to be problem areas. The county administration needs to look at these areas and find ways to solve the issues.

REFERENCES

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Evaluation of UAV Technology for Search-and-Rescue of Persons with Autism: A Case Study

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ABSTRACT

Children with autism spectrum disorder wander away from care facilities with many reported critical "close calls." This case study presents an evaluation of unmanned aerial vehicle (UAV) and related technologies to help law enforcement develop effective search-and-rescue operations. The study found that deploying these technologies has advantages over traditional operations.

KEYWORDS: Unmanned Aerial Vehicle (UAV), Technology Evaluation, Search-and-Rescue, Case Study

INTRODUCTION

Among children with autism spectrum disorder (ASD), nearly 50% wander away from care facilities, while 32% of the parents report a critical "close call." As the prevalence of ASD rises at an alarming rate to an estimated 1 in 68 children in 2012 from 1 in 150 children just a decade ago, the risks of serious consequence of such incidents have increased significantly. Florida's geography, in particular, poses an elevated threat to children with ASD, due to the pervasive presence of natural and man-made bodies of water—91% of all deaths among wandering and eloping children with autism involve drowning. In addition to prevention, effective search-and-rescue operations, often conducted by law enforcement agencies, are a critical component of the safety of children with autism.

When law enforcement receives a call about a missing person with a mental or developmental disability (which is specified during the initial call and then marked with a special code), the action is swift and extensive. In the case of Palm Beach Sheriff's Office (PBSO), when the initial call is dispatched, it commonly takes 15 minutes for the first officers to arrive. Two or three officers will search the home (or care facility) first to ensure that child is not hiding out, unless an eye witness already reports seeing the missing child outside of the home. If the missing child is not found at home (or care facility), a full search-and-rescue operation is then initiated. A detective will be assigned to the missing child case and, within 20 minutes, four to six additional deputies and a sergeant (for day shift; two to three deputies plus sergeant for night shift) will arrive on scene to join the operation. Depending on the location and terrain, canine (bloodhound), helicopter, and other units may also be called. Altogether, there can be

up to 15 PBSO deputies and detectives, two canines, and a helicopter on one case at any given time. The search can continue for hours until the child is located and positively identified. It is worth noting that Palm Beach County is highly representative for such a pilot project, with a large area and large population of 1.4 million people living in an array of urban, suburban, and rural settings.

In the areas serviced by PBSO, there were 11 reported cases of missing person with autism and/or Asperger syndrome in 2015, and 14 such cases in 2016. When locating eloping children with autism, such search-and-rescue operations have proved to be effective. Even so, as with all operations, there are always limitations to current mode that can see improvements, for instance:

- When the search area is uncertain, a large number of deputies (up to 15 in some cases) is required to fully cover the possible elopement area. To reduce the requirement on PBSO resources, it would be advantageous to limit the perimeter of the search area by either obtaining the latest location of the eloping child (instead of the last seen location reported sometimes hours ago) or having a general direction of search, or both.
- Helicopter use is a critical part of the search team because it greatly expands the search area. However, the altitude and the required motion pattern of helicopters are limiting factors. Also, helicopter deployment may be restricted by weather conditions. In addition, deploying a helicopter is expensive, as it costs $1,000 per hour to operate (with additional personnel cost). It would be advantageous to have another “eye in the sky” that can replace or supplement the helicopter unit in a search-and-rescue operation.

Based on the requirements set forth in *Missing Persons with Special Needs Bill*, a joint pilot study between the authors’ University and PBSO is conducted, seeking to test and evaluate current, latest technologies that can aid the search for missing person with special needs, in particular eloping children with autism.

This project focuses on (1) wearable personal devices, attached to children with ASD that are at risk of elopement, that can track the motion and location of the wearer, and (2) unmanned aerial vehicles (UAVs), commonly known as drones, which can locate or aid the search of an eloping child. The evaluation criteria, which will be discussed fully later in this report, will aim to not only improve on both cost and effectiveness over current search-and-rescue effort, but also to enhance (or at least to impose minimal disruption on) the mode of operations by law enforcement.

This case study is organized as follows. In the next section, we survey and qualify the existing technologies to be considered for this pilot study. Then, an evaluation framework for testing the technologies is provided, followed by a description of the actual scenario-based field tests that we conducted. We conclude this report by summarizing the test results and making recommendations accordingly.

TECHNOLOGY SELECTION

The twenty-first century is experiencing a rapid proliferation of global positioning satellite (GPS) and airborne technologies in the form of drones. GPS is the backbone of recent location-based services, including maps and navigation in cars or small handheld devices. While drones are initially being used by the military, the capabilities of small drones have greatly increased, and their costs have declined rapidly. Combined with wearable devices that are based on GPS or

other technologies such as radio frequency (RF), drones have the potential to significantly improve search-and-rescue operations.

For this pilot project, we have reviewed a number of technologies, as described in the interim report, and selected two combinations of UAV and wearable devices most suitable for search-and-rescue missions involving eloping children with autism. Project Lifesaver is a RF-based tracking system that combines a wrist band and a (dedicated) handheld or UAV-based tracking unit. Keruve, on the other hand, is a GPS-based tracking system, mounted on a wrist watch, with its own handheld control unit. As such, it can work in conjunction with any camera-mounted UAV to locate and identify eloping children with autism. Table 1 below shows a comparison of the two selected technology combinations.

		Project Lifesaver	Keruve + UAV
WEARABLE	GPS	No	Yes (+ cell)
	RF	Yes	No
	Location accuracy	Medium	High (when signals are available)
	Waterproof	Yes	Yes
	Tranceiver wearability	Wrist or ankle band (PAL is watch)	Attached to wrist watch (belt or clothing attachment options also available)
	Battery	Monthly (replaceable)	2 days (rechargeable)
	2-way communication	No	Panic button
UAV	Dedicated UAV?	Yes, Lockheed Martin Indago	No (can use any UAV with camera)
	Camera on UAV	No	Yes
SYSTEM	Training requirement	UAV pilot, Liefsaver operation	UAV pilot, handheld control unit (self-training)
	Control management system	Field managed	Close range tracking and out-of-range alarm (on handheld)
	Costs	Transmitter: $300 Handheld Controller: $749 UAV + PLS Antenna integrated: $47500 + $10,750	Transmitter-Controller pair: $1425 Cost per GPS search: $0.10
	Systems integration	N/A	Allowed

Table 1: Comparison of Project Lifesaver and Keruve Systems

ANALYSIS METHODOLOGY

Drawing on Innovation and Diffusion Theory (IDT, Rogers, 1983) and Technology Acceptance Model (TAM, Davis, 1989), information technology (IT) and information system (IS) researchers identify that the relative advantage, compatibility, and complexity are consistently related to innovation adoption and implementation. Based on these models, we have developed an evaluation methodology for this project, shown in Figure 1 below.

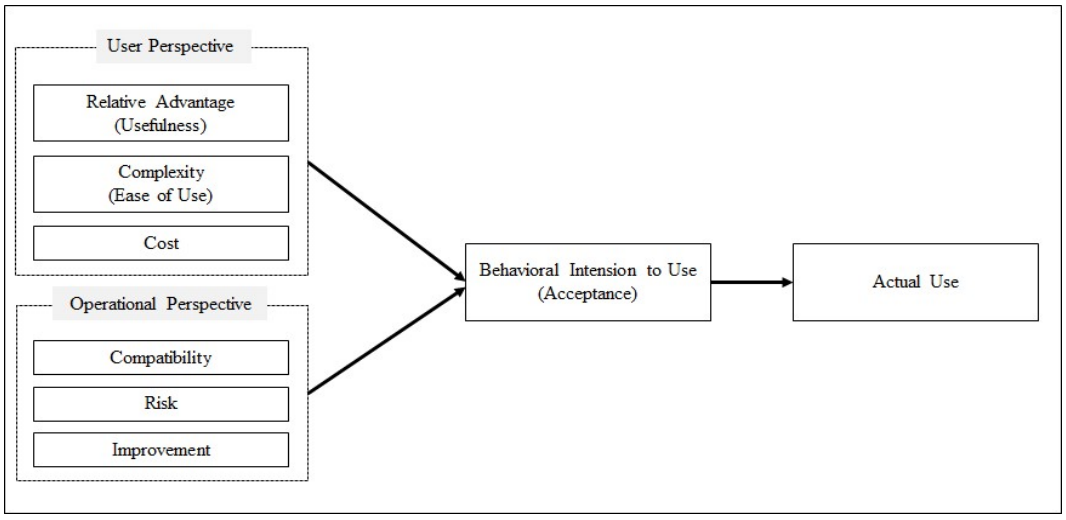

Figure 1: Evaluation Methodology based on IDT and TAM Models

User Perspective: Ease of Use, Usefulness, Cost

Relative advantage is the extent to which a potential adopter views a new technology or innovation as offering benefits over previous, old, or other ways of performing the same task. Because people tend to use (or decide not to use) a technology to the extent they believe it will help them better complete desired tasks, relative advantage is often captured through user's perception of usefulness of that technology to achieving their goals. In addition to the technology itself, its performance and design can greatly affect the perceived usefulness. In the case of tracking systems, factors such as slow location identification, location errors, out-of-date maps, and poor hardware design and software interface have disappointed search-and-rescue users. In a worst-case scenario, such poor performance could even result in a loss of life.

Complexity is the level of difficulty for users to understand and properly use innovations and is often measured through users' perceived ease of use. Even if potential users believe that a given technology is useful, they may, at the same time, perceive that the system is too hard to use and that the performance benefits of usage are outweighed by the effort required to use the application. Therefore, in addition to usefulness, usage is influenced by perceived ease of use.

Beyond usefulness and ease of use, cost concern is another important issue from the user perspective when adopting new technologies. In the context of this project, deploying new technologies to facilitate search-and-rescue efforts will incur non-negligible or sometimes significant cost to users (autism family and law enforcement agency alike). Equipment costs,

subscription fees, and transaction fees are just three important components that may make an innovative use of airborne technologies for search-and-rescue unaffordable, and high cost will be one of the essential factors considered by users when deciding whether to deploy new technologies.

In search-and-rescue operations, “users” are further divided into three parties—child with ASD diagnosis, autism family/caregiver, and law enforcement agency—with possibly different perspectives. Therefore, the current study captures usefulness, ease of use, and cost concerns from all users’ perspectives.

Operational Perspective: Compatibility, Improvement, Risks

While relative advantage, complexity, and cost impact user’s decision on technology adoption and use, operational issues need to be considered when a new technology is actually being deployed. Compatibility is the degree to which innovation is perceived to be consistent with potential users’ existing values and needs as well as with operational routines and systems. High compatibility implies minimal disruption to current operations and thus likely leads to preferable adoption. As such, compatibility of a new technology is a key issue in the operational view of technology adoption and is also used to predict the implementation of new technological innovations.

Improvement in the operational perspective is the equivalent of usefulness in user’s perspective. A new technology can help improve tasks in many ways, such as reducing the complexity of procedures and better communication among parties involved. The level of operational improvement will no doubt impact the decision of technology adoption.

As in all activities, there are potential risks of using wearable and airborne technologies in search-and-rescue operations. To begin with, regulations for new technologies, especially with breakthrough innovations such as drones, always significantly lag the development of applications and use. Operational uncertainties and risks can arise because of changing and unpredictable regulatory requirements. Also, the privacy impacts of civil applications of drones, including law enforcement and community policing, have already been subjected to analysis. Lastly, drone’s safety is of particular concern, because of the wide array of “failure modes” (that is, crash or collision) that may cause harms to property and people. Multiple reasons, such as interruptions to GPS or control-flow transmissions, inadequate fail-safe designs to cope with signal-loss, lack of collision avoidance system in a congested airspace, and a short battery life, may cause such safety concerns. For instance, the FAA has received an average of 250 reports of drones near airports every month, up from 159 for most of last year, and a new study commissioned by the FAA finds a high-speed collision between a drone and an airliner would be worse than a bird strike. This year. These examples highlight the importance of safety risks of using drones in search-and-rescue operations and the need for an assessment of the adequacy of existing regulatory frameworks for public safety as well as the need for proper and extensive pilot training.

PRELIMINARY EVALUATION

Before actual scenario-based field tests of staged elopement were conducted, we examined the two selected technologies based on the analysis framework of the six key dimensions: ease of use, usefulness, cost in user’s perspective and compatibility, improvement, risks in operational perspective. The initial evaluation is summarized in the Table 2 below.

			Project LifeSaver	Keruve (with UAV)
User Perspective	Cost	Child	N/A	N/A
		Family/Caregiver	Average initial cost, high recurring cost	High initial cost, low recurring cost
		Law Enforcement	High (dedicated UAV required)	Cost of shared UAV
	Relative advantage	Child	N/A	User-friendly wrist watch design
		Family/Caregiver	N/A	Knowing child's location at all times; configurable safety zone with visual and audio alarm or cellphone notification when breached
		Law Enforcement	Handheld receiver and deicated drone can identify general location and direction of child	GPS location as starting point of search operation; UAV cheaper and faster to deploy
	Complexity	Child	N/A	Wrist watch needs to be removed and recharged (by caregiver) every 2 days
		Family/Caregiver	Wristband battery needs to be replaced every two months.	Handheld controller relatively easy to use (but currently designed for Europe)
		Law Enforcement	Both UAV pilot training and Project LifeSaver training required	GPS location only shows on paired handheld controller (currently); UAV pilot training required
Operational Perspective	Compatibility	Family/Caregiver	Wristband can only be put on and removed by caregiver	Wrist watch can only be put on and removed by caregiver
		Law Enforcement	Dedicated UAV or handheld receiver needed; no integration with control system	Potential integration with control center; availability of UAV for mission required
	Improvement	Family/Caregiver	N/A	Early knowledge of elopement with location data
		Law Enforcement	Shorter mission completion time; potential reduction of resource requirements	Shorter mission completion time; potential reduction of resource requirements
	Risks	Family/Caregiver	N/A	Data privacy
		Law Enforcement	UAV safety	UAV safety and privacy (due to camera use)

Table 2: Initial Evaluation of Project Lifesaver and Keruve Systems

SCENARIO-BASED FIELD TESTS

Project LifeSaver and Keruve technologies were tested on three different days under different scenarios. The authors' research team and PBSO (command, pilots, and role players) were all present for all three tests. Project LifeSaver and Keruve were used on different days. One role player using the devices was deployed on each day.

Testing Project LifeSaver

This simulation used Project LifeSaver only. Two pilots were needed (project lifesaver UAV and UAV with camera). One role player was deployed with the wristband transmitter. Multiple

environmental conditions were simulated. The test location provides access to test in open areas, enclosed spaces, and wooded areas. Figure 2 below shows the UAV during this test.

Figure 2: UAV with Antenna for Tracking with Project Lifesaver

Scenario A
Missing 7 year old child with moderate autism; the back door was discovered open. The child resides in a gated community; the house is located 1.1 miles from a large community lake in the center of the community. From the time of the call to dispatch, the child has been missing for 15 minutes.

Traditional Response:
The traditional PBSO response to a missing child call involves resource allocation as follows:

- The first 15 minutes: 5 deputies, 1 sergeant and 1 lieutenant, helicopter
- From 20-60 minutes: 5 more deputies, 1 captain, 1 K-9 (bloodhound)
- From 60-90 minutes: Another K-9 (bloodhound), Detective bureau (4 detectives, 1 sergeant)

Expected Response:
With LifeSaver Project UAV, the expected response will be different from the traditional response. Initial responding units after they arrive, determine the child to be missing, request helicopter and UAV (Project LifeSaver/camera). Helicopter and UAV take 15-20 minutes to arrive on scene. UAV unit will deploy two UAVs, maximum 400 feet to help track child wearing project lifesaver bracelet. The whole scenario in this case is expected to play out as follows:

- Phone call comes in to PBSO dispatcher
- 2-3 officers search home first (closet, bed, garage, yard, etc.) except when eye witness reports seeing child.
- Within 20 min: Call for bloodhound (specifically trained for search and rescue), helicopter, and additional units (5-6 deputies); quicker than pulling together UAV (which are all dependent on availability and location and can take another 20-40 min)
- Notify detective specifically assigned to missing children cases (day shift 4-6 deputies/detectives + 1-2 sergeants; night shift is 2-3 deputies/detectives + 1 sergeant)
- 20-30 minutes later: drone unit arrives
    - 20-30 minutes extra if not already on duty
    - First one to get Project LifeSaver drone, the other meets at the site of the report

    - Note: Project LifeSaver drone requires tracker bracelet; commander's knowledge of equipment and asking the right questions may reduce turnaround time from confirming tracker by 50%
- Air assets (helicopter) are supplemented/enhanced by drone search (again, dependent on supervisor's knowledge and request to deploy drone)

Simulation Test:
Weather was Fair skies, Slight drizzle. Role player (with Project LifeSaver transmitter) is walking around community; deputy is on scene in 5 minutes and immediately asks about tracker; confirmed to have Project LifeSaver; reports back to dispatcher; drone deployed in 15 minutes. It took an additional 15 minutes flight time to locate the role player after following up on a second (weaker) signal. It took a total of 30 minutes from decision to deploy the drone to locating the role player.

Summary:
Searching for the role player (with Project LifeSaver transmitter) in the local community with UAV/Project LifeSaver receiver/antenna took a reasonable time (30 minutes) when there was visibility. When searching in areas with heavy vegetation and/or reduced visibility, the search was not possible probably due to signal interference.

Scenario B
Similar to Scenario A, except that the child, 10 years old, is missing for an hour, with no other information.

Traditional Response:
Similar to the scenario in the last section.

Simulation Test:
Weather was fair skies, 86°F, and 6 miles visibility. The role player (with Project LifeSaver transmitter) is about 1.5 miles away; in this scenario, it has been 30 minutes since call was made to PBSO before the drone is launched.

Drone with Project LifeSaver receiver/antenna is deployed at 150/170 feet till a gain of 99 (highest gain setting) is found to hone in on direction; complete 360° rotation to confirm direction (pro: must be done to acquire strongest signal and rule false readings; con: takes times; the faster the drone is rotated, the greater the chance of false positives, because Project LifeSaver receiver/antenna requires time to let band ping settle). After 15 minutes, a second drone with camera only is deployed. (There is no SIM card available for mapping the Project LifeSaver system, hence mapping is not available.) Two drones are used simultaneously in the search at this time. Five minutes later, the first drone with Project LifeSaver receiver/antenna is returned (20 minutes flight time), and a PBSO Deputy is deployed in the field using the Project LifeSaver handheld tracker in the approximate area located. The Deputy located the role player after 5 minutes, 25 minutes after initial drone deployment. The drone with Project LifeSaver receiver/antenna was re-launched with a different strategy of 180 degrees from the role player location. The role player was located within 5 minutes in this scenario, without using the handheld tracker. But it is important to note that in this instance, the exact location of the role player was known. Additional challenge was that the drone with the Project LifeSaver receiver/antenna was in flight for about 35 minutes in both situations, leaving a residual battery life of little over 10 minutes.

Summary:
Searching for the role player (with Project LifeSaver transmitter) about 1.5 miles away with Project LifeSaver UAV took a reasonable time (25 minutes) when an additional drone with camera and a Deputy with handheld tracker was deployed. The drone with camera was deployed because the drone with Project LifeSaver antenna had no mapping capabilities (no SIMS card on the UAV hand controller to provide a map overlay on RF signal) at the time of study. Hence it was necessary to complement the drone dedicated to Project LifeSaver antenna with additional resources (UAV with camera) in this scenario to provide visual support. However, with a known location, the search was possible within 10 minutes when both drones (Project LifeSaver receiver/antenna and camera) were deployed.

Testing Keruve
This simulation used Keruve in lieu of Project Lifesaver. One pilot was needed (UAV with camera only). One role player was deployed with the wrist watch transmitter. The same environmental conditions were simulated. The test location provides access to test in open areas, enclosed spaces, and wooded areas. Figure 3 shows in an image taken during this test.

Figure 3: UAV with Camera for Tracking with Keruve

Scenario C
Missing 7 year old child with moderate autism. The child resides in a gated community, the house is located 1.1 miles from a large community lake in the center of the community. From the time of the call to dispatch, the child has been missing for 15 minutes, the back door was discovered open.

Traditional Response:
Similar to the scenario in the previous section.

Simulation Test:
Weather was partly cloudy 80°F and 6 miles visibility. In this test, a predefined perimeter/geo fence (a built-in option of Keruve) is set. When the role player (wearing Keruve transmitter) breached the perimeter/geo fence, the system notified the handheld tablet (with the caregiver), an app (any family member can use this), and the company website (any family member can access this also).

Summary:
So elopement within the community is immediately recognized and alerts provided with mapping (on the caregiver handheld device), in addition to the app and website. This capability provides

families of children with autism with a proactive approach to stopping elopement before it results in a missing child, negating the need to report in the first instance. Failure of implementing geo-fences would result in no alert being sent, but local community search can still be conducted by family/caregiver using the handheld tablet with mapping to get an immediate (about 2 minute delay in GPS signals) location of the child. Figure 4 below shows the Keruve handheld display with that the role player located.

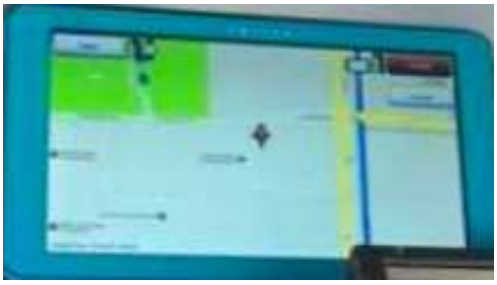

Figure 4: Keruve Handheld Display used for Tracking

The tracking function can also be used to map out the travel path over multiple location identifications (though this uses more battery and higher cost due to frequent GPS location access).

Scenario D
The child, 10 years old, missing for an hour, no other information. This will require for a longer search by placing the tracker about 1.5 miles away.

Traditional Response:
Similar to the above scenario.

Simulation Test:
Weather was partly cloudy 80°F, 6 miles visibility. The role player (with Keruve transmitter) is about 1.5 miles away. The predefined perimeter/geo fence is not set. At the start of the search, the handheld tablet was used and the role player was located within 1 minute on the tablet. Then the drone with camera was launched, and the role player was visually located in 4 minutes.

Summary:
Searching for the role player (with Keruve transmitter) about 1.5 miles away with the Keruve handheld tablet and drone with camera took a total of 5 minutes to have visual on the role player. In this scenario, the drone deployed is commonly used by PBSO with more reserve flight time (about 40 minutes left). A limitation of searching for a child who may have travelled a distance is that current FAA regulations require that the deployed drone should always be visible (in visible range) to the PBSO drone pilot. An advantage is that the Keruve handheld tablet has ability to time stamp and pinpoint last known location (using Live Track functionality that took one minute to activate, it renders location every two minutes, good for tracking moving child), that can also be useful information in PBSO deployment of PBSO Officers.
In addition, the next version of Eagle Eye (Drone with camera system used by PBSO) will include the ability to add coordinates (longitude/latitude). Supplying the coordinates from the handheld tablet to the drone controller will make the visual search using drone with camera much faster, instead of only depending on the drone with camera as “live eyes in the sky” to

assist with location. However, GPS signals could be lost in buildings when there is no available Internet service, which is used as an automatic backup to GPS. (Role player entered a port-a-potty in this field test, and signal was lost as there was no Internet.)

Testing Project LifeSaver and Keruve together

The test location provides access to test in open fields and in a building. Both Project LifeSaver and Keruve would be used simultaneously. Two role players using both devices were deployed.

Scenario E

Missing 7-year-old child with moderate autism. The child resides in a gated community, the house is located 1.1 miles from a large community lake in the center of the community. From the time of the call to dispatch, the child has been missing for 15 minutes, the back door was discovered open.

Traditional Response:
Similar to the scenario in the previous section.

Simulation Test:
Weather was Cloudy, 67°F, 6 miles visibility. In this test, two role players (one with Project LifeSaver and the other with Keruve transmitters) were walking around a corn maze with high hedges. The role player with the Project LifeSaver transmitter was located in 5 minutes. (The drone with Project LifeSaver receiver/antenna likely overshot role player initially, because the role player was actually too close for the airborne antenna to detect signals from the ground). The role player with the Keruve transmitter was located in 2 minutes on the handheld tablet.

Scenario F

Similar to Scenario 1, except that the child, 10 years old, is missing for an hour, with no other information.

Traditional Response:
Similar to the scenario in the previous section.

Simulation Test:
In this test, the two role players (one with Project LifeSaver and the other with Keruve transmitters) drove to park 1.5 miles from the farm market. Both drones with Project LifeSaver receiver/antenna and camera were deployed. The role player with Project LifeSaver transmitter was located in 10 minutes by the drone with the Project LifeSaver receiver/antenna with supporting drone with camera. The role player with the Keruve transmitter was located on the handheld device in 2 minutes and shortly thereafter sighted by the drone with camera. Again, it appeared that low battery levels and software updates may have affected the time it took to enable Live Tracking and Live View on the handheld tablet. But once tracking was enabled, the Keruve handheld device was used to track the role player successfully.

DISCUSSIONS AND CONCLUSIONS

This pilot project is executed and completed as stipulated in *Missing Persons with Special Needs Bill* that was the driver of driver for this project. Based on the initial target for improvement over traditional mode of search-and-rescue operations, we selected the enhancing technologies for testing, created a framework for evaluation, and performed preliminary and

scenario-based testing. In this section, we discuss the findings of this project and present our recommendations based on these findings.

First of all, the addition of location and airborne technologies to the traditional search-and-rescue operations in the case of eloping children with autism is clearly advantageous. Depending on the specific technologies used, compared with traditional methods,

- It is possible to detect elopement earlier and establish an initial search location more accurately;
- Search can be limited to a smaller area and better directed; and
- Positive identification can be made remotely.

And all these result in faster response, lower cost of operation, and better outcome. Using our evaluation framework, from the user perspective, the technologies show relative advantage over traditional methods and are easy to use. From the operational perspective, these new technologies are generally compatible with current organizations and procedures and show improvement in search-and-rescue efforts. There are cost issues as well as operational risks, but we believe, especially in the long run, benefits considerably outweigh the costs when deploying location and airborne technologies in search-and-rescue operations in the case of eloping children with autism.

With that established, the next question is, which technology to deploy? In this pilot project, we selected two most appropriate and promising technology combinations: GPS handset with camera on (generic) UAV and RF tracking with receiver/antenna on (dedicated) UAV. Our tests clearly show strengths and weaknesses of both. In addition to being offered and promoted by different vendors, these two technologies exemplify two distinctive approaches: GPS and generic UAV combination uses state-of-the-art, open-source technologies which may be less robust (subject to bad weather or physical blockage of signals) but are easier to use and customize, while RF with dedicated UAV receiver deploys old, proven technology in a proprietary package that is fool-proof but hard to modify. Based on our preliminary evaluation and field tests, we believe the former is a better fit for this project, because of the following:

- RF may outperform GPS under certain specific conditions (such as indoors without Internet services), but in general, GPS is more powerful and accurate, easier to use, and more likely to see further improvement in the future. Therefore, GPS is a better choice from the user perspective.
- Open-source technologies such as GPS allow additional services (such as geo-fencing, live tracking, and location history, to name a few) to be offered cheaply and quickly, with the potential of integration with other systems (such as law-enforcement command and control).
- When law enforcement can deploy any generic UAV with camera that it has on hand or nearby when it gets the call, the benefit of having an “eye in the sky” is maximized. On the other hand, the need for a receiver/antenna on a dedicated UAV (and properly trained operators) can lengthen the response time and limit coverage area. And it is an additional cost to law enforcement.

Therefore, our findings conclude that GPS with generic UAV is a better choice than RF with dedicated UAV receiver/antenna in search-and-rescue operations in the case of locating eloping children with autism, from both the user perspective (higher level of relative advantage, and lower cost, in particular) and the operational perspective (better improvement potential and compatibility).

In conclusion, based on our overall findings in this this pilot project, we offer the following recommendations:

1. In search-and-rescue missions involving eloping children with autism (or persons with special needs in general), deploying UAV presents many advantages over traditional operations. This is true even in the case when the eloping child has no location devices on him/her; just having an "eye in the sky" can reduce search time, lower resource requirements, and provide better outcomes. This can be an important incentive for law enforcement to have UAVs on the squad.
2. GPS technology is an effective addition to search-and-rescue operation of eloping children with autism. The system we tested (Keruve) is advanced and powerful with many features, but its high initial cost implies that it is probably most appropriate for those with high eloping risk only. But even having a simple GPS device can help greatly, and the cost of generic GPS wearables has come down to $100 or less. It is worthwhile for local community centers or autism advocates to look into funding for such devices for families and caregivers.
3. Finally, search-and-rescue missions are best accomplished when law enforcement and families cooperate and coordinate with one another, and such collaboration extends to the use of technologies. It is advantageous for both parties to jointly decide on a tracking technology that is not only cost effective and easy to use for the families, but also compatible with and beneficial to law enforcement's operations and command-and-control systems. And even with better tracking technologies, it is still very important for the family or caregiver to immediately inform law enforcement in case of elopement.

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DECISION SCIENCES INSTITUTE

Examining Impacts of Clinical Practice Variation on Operational Performance: Implications for Bundled Payment Reform Models

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ABSTRACT

Motivated by bundled payment policies that aim to reduce practice variation, this study examines whether and how lower variation in clinical practice relate to hospital operational performance. Using statistical process control as a theoretical lens, we hypothesize negative impacts of practice variation on operational performance. We also address intervening impacts of hospital quality evaluations on the relationship. We discuss our findings from analyzing six years of inpatient data from hospitals in NY and FL states. We believe better measurement and understanding of practice variation can facilitate healthcare systems to reduce waste and support policy-makers to design bundled payment reform models.

KEYWORDS: Healthcare, Practice variation, Operational performance, Process quality, Experiential quality, Bundled payments, Dynamic panel system GMM estimator

DECISION SCIENCES INSTITUTE

Examining Service Quality in The U.S. Airline Industry by Social Media Analytics

ABSTRACT

Social media has provided a number of online tools that allow people to discuss anything freely. Consumers are sharing their opinions online with others. Electronic Word of Mouth (eWOM) is the virtual communication in use. Customers can choose to complain or to compliment services or products on their social media platforms, rather than to complete the survey offered by the service providers. Compared with the traditional survey, social media offers features that can spread information quickly and broadly. This paper offers a novel methodology that, by utilizing emotional sentiment analysis, can help the airline industry to improve its service quality.

KEYWORDS: social media, service quality, SERVQUAL, emotional sentiment, text mining, natural languages processing (NPL), airline, sentiment analysis, eWOM

INTRODUCTION

With the emergence of the social media online platform, more and more consumers and companies are communicating and sharing experiences and product/service reviews online. Social media provides online tools and allows people to discuss anything freely, with the increase in mobile connectivity. According to research conducted by IBM Big Data, more than 2.5 quintillion bytes of data were generated daily in 2012 (Zikopoulos et al., 2012). Business analysis and big data mining were developed in order to extract insightful information from the collected massive data (He et al., 2015, 2016; Tian et al., 2016). In order to survive in the intense competition of today's business world, business can be based not only on the competition of lower prices, but also on service quality delivery (Zeithaml, Parasuraman, & Malhotra, 2000).

In the traditional way, businesses, including airline companies, use conventional survey-based techniques to conduct the measurements of service quality and customer satisfaction. Those survey-based techniques are AHP, SERVQUAL, and SERVPREF. And the most important technique to study service quality is SERVQUAL. SERVQUAL has been verified by past literatures in Table 1. Tsaur, Chang, and Yen (2002) studied the service quality in the airline service industry, using fuzzy MCDM. Tsaur et al. (2002) found that many intangible attributes are difficult to measure. A survey was conducted and, by applying AHP, Tsaur et al. found that the most critical aspects of service quality are tangible, and the least critical aspect is empathy, in airline service. In addition, Tasur et al. (2002) found, from survey results, that courtesy, safety, and comfort are the most important attributes. Another study performed about service quality in the airline industry identified several SERVQUAL and industry-based items that significantly influence consumers' perceptions of overall service quality and their intention to re-patronize (Young, Cunningham, & Lee, 1994). In addition, the results suggest that the Air Travel Consumer Report has not been properly disseminated, nor has it been used by most consumers (Young, Cunningham, & Lee, 1994). However, survey-based methodology has its limitations, such as sample size, group of participants, and its need for respondents' recall of past events. These limitations can constrain the scalability of the measurements of service quality.

Rather than using a survey-based approach, consumer-generated social media content contains a variety of valuable pieces of information, like opinions, experiences, and viewpoints.

The valuable information makes social media an important source to use in analyzing consumers' decision-making about purchases. Compared to the traditional method of conducting a market survey and social media data analytics, Leung, Lee, and Law (2012) suggest that social media content analysis may be more trustworthy and more reliable than information provided by the marketing departments within a company. Social media has characteristics that include its ability to spread messages more quickly and broadly than the use of any other methods. Thus, examining social media content is becoming important to businesses who want to pursue superior service quality and gain competitive intelligence with improved market performance. Previous studies (Parasuraman, Zeithaml, & Berry, 1988; Ramanathan & Karpuzcu, 2011) have already established multiple dimensions of service quality. Specifically, for airline service quality, Young et al. (1994) measured the service quality of passenger airlines based on SERVQUAL and discussed it in a U.S. Air Travel Report released and published by Department of Transportation (DOT).

This study seeks to develop a framework that uses social media analytics (with an emphasis on emotional sentiment analysis) to help to study the service quality perceived by consumers in the airline industry. According to SERVQUAL, the service quality will be investigated based on a benchmark dataset for each dimension of service quality. Furthermore, emotional sentiment (Lexicon-based) analysis will be applied, in order to examine the tweets for each service quality dimension. Compared with the Air Travel Report published by the DOT, the effectiveness of a social media analysis of service quality will be inspected.

Our research questions are as follows:

What is the relationship between textual social media data and the Airline Consumer Report by DOT?

The following of this paper are organized as follows. In the next section, past research and literatures are reviewed about service quality and social media analytics. The following section introduces out research model and hypotheses. And methodology and results are followed. In the last, we discuss the findings and conclude the paper with research limitations.

LITERATURE REVIEW

Service quality assessment is an important area for multidisciplinary research. Operational management, marketing, and management information systems have had many research articles written about measuring service quality. Prior work about measuring quality has mainly focused on physical products and on tangible goods (Palese & Piccoli, 2016). In the late 20th century, the famous model -- SERVQUAL-- for measuring quality of service was proposed by Parasuranman et al. (1985, 1988). According to Parasuranman et al. (1985), service quality is hard to measure because of intangibility. Most research papers cover the application of SERVQUAL and its ability to conduct a survey to evaluate consumers' perceived service. This method is feasible, but it is limited by the sample size, response rate, and reliability of the responses. With the emergence of social media and the prevalence of mobile platforms (mobile applications), socialized textual data has been found to be a boon to business. Customer experience is the basis for the effective measurement of service quality (Petter et al., 2012). Social media analysis provides the ability to retrieve socialized textual data and to analyze them through text mining, clustering, and sentiment analysis. Competition among airline carriers is becoming intense, and a competitive advantage can be discovered by airline carriers who take service quality into account. Most especially, with the emergence of technology and social media, airline carriers can now communicate with consumers in multiple ways: via online chat, Twitter, Facebook, official websites, phone calls, online surveys, and so on. Airline carriers may change their marketing strategies based on the results of their social media analytics, and can gain a reputation from the opinions of their consumers.

Literature Review of Service Quality in the Airline Industry

Studies about service quality have been done since the 1980s (Grönroos, 1984; Rust & Oliver, 1994; Cronin, Brady, Thomas & Hult, 2000). As defined by Grönroos (1984), service quality is "the outcome of an evaluation process, where the consumer compares his expectations with the service he perceives he has received." Grönroos suggested that, when considering service quality, technical quality, functional quality, and corporate image also must be considered. Further, other researchers have studied service quality and have suggested that customer satisfaction has a positive relationship with service quality (Mukherjee, Nath, & Pal, 2003; Ramanathan & Karpuzcu, 2011). Since service quality is highly related to customer satisfaction and firm performance, it is important for companies of the service industry to measure and to evaluate customer satisfaction. Sasser, Olsen, and Wyckoff (1978) mentioned, back in the '70s, that service quality could be measured by materials, facilities, and personnel. From the 1980s until the 2010s, service quality measurement has been developing, and the research method has improved over these thirty years. In order to measure service quality accurately, the SERVQUAL model is the fundamental model for assessing service quality, since it compares expected service and perceived service from consumers (Parasuraman et al., 1985). Ten dimensions are covered in the SERVQUAL model: access, communication, competence, courtesy, credibility, responsiveness, security, tangibility, and understanding/knowing the customer.

Several years later, Parasuraman et al. (1988) refined the ten dimensions into five major dimensions: reliability, responsiveness, assurance, empathy, and tangibility. Martin (1986) argued that only two main dimensions should be assessed for service quality: service procedure and consumers' conviviality. Martin (1986) considered the managerial portion and the communication with consumers. During the following twenty years, researchers expanded and modified the SERVQUAL five dimensions across different service industries. Ramanathan and Karpuzcu (2011), in their study, suggested using seven metrics to measure service quality: responsiveness, flexibility, availability, assurance, personnel contact quality, reliability, and tangibles (as shown in Figure 1). And Novack, Rinehart, and Langley (1994) argued that personnel of the company and the traits of executives can be used to measure service quality. Another aspect was proposed by Parasuraman et al. (1988), who said that customers' opinions can strengthen the understanding and the measurement of service quality. According to previous research (Parasuraman, Zeithaml and Berry, 1988; Ramanathan and Karpuzcu, 2011), service quality metrics can be defined as follows:

- Reliability: The ability to perform the promised service, both dependably and accurately
- Responsiveness: Willingness to help customers and to provide prompt service
- Flexibility: Flexibility to allow for different transaction options and methods
- Availability: The availability of products in stock
- Personnel Contact Quality: The knowledge and courtesy of employees, as well as their ability to ease communication with customers
- Tangibles: The appearance of the physical facilities, the equipment, the appearance of personnel, and the communication materials.
- Assurance: The ability to convey trust and confidence to customers and to make them feel that they are receiving good service

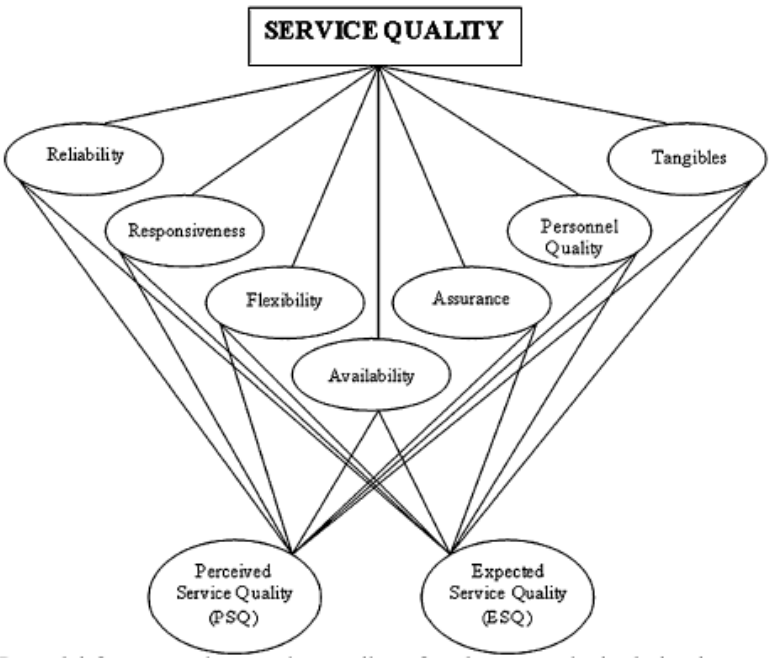


Figure 1. Seven Metrics for Measuring Service Quality
(Adapted by Ramanathan & Karpuzcu, 2011)

The SERVQUAL model has been applied to evaluate service quality in a variety of industries, as among them education, banking, insurance, airline services, and health care. Yang and Fang (2004) identified eight dimensions and sub-dimensions of online service quality. They are responsiveness, service reliability, ease of use, access, system reliability, timeliness, security, and competence. These eight dimensions derive from SERVQUAL; modifications were based on context. In another paper, El Saghier and Nathan (2013) found that only four dimensions (reliability, responsiveness, empathy, and assurance) can influence service quality in banking services. Bansal and Taylor (2015) examined switching intentions, service quality, and customer satisfaction, and argued that service quality is one antecedent to customer satisfaction, while service quality is the key for switching intentions.

To evaluate perceptions of airline service, prior studies were based on survey questions and on the SERVQUAL model. Ostrowski et al. (1993) examined the relationship between service quality and retained preference, which measured customer loyalty in the commercial airline industry. The data was collected from two air carriers; the researchers found a positive relationship between service quality and customer loyalty in the commercial airline industry. And AHP methodology was applied in measuring service quality in the airline industry by Tsaur et al. (2012). Applying the fuzzy set theory to evaluate the service quality of the airline, Tsaur et al. (2012) found that many intangible attributes are difficult to measure. Applying the AHP-based survey showed that the most concerning aspects of service quality are tangible, and that the least concerning aspect is empathy. Courtesy, safety, and comfort were the most concerning attributes for Tsaur et al. (2012). Mazzeo (2003) also found that being on-time plays an important role in service quality in the airline industry; flight delays are significantly related to weather conditions, air congestion, and scheduling decisions (U.S. Bureau of Transportation Statistics, 2000). The time lag is an obvious issue when analyzing service quality in the airline industry. Consumers need a service quality model to evaluate the service quality, and two

dependent variables – perceived service and expected service – are essential for measuring service quality (Grönroos, 1984). To maintain a business' market share, Mazzeo (2003) also argued that when customers have more choices, companies have more incentive to improve service quality by offering lower prices and better service. However, gathering the opinions of consumers is not easy. Surveys can be conducted with limited sample sizes, but the respondents may not represent all of the consumers. This dissertation will bridge the gap in the traditional survey method for service quality measurement in airline industry.

Hussain et al. (2015) investigated the relationships among service quality, service provider image, customer expectations, perceived value, customer satisfaction, and brand loyalty in a Dubai-based airline. Questionnaires were conducted based on the SERVQUAL model and identified six dimensions: reliability, responsiveness, assurance, tangibility, security and safety, and communication. Another research paper regarding service quality in the airline industry was written by Tsaur et al. (2002), who established five aspects and fifteen service quality criteria. We will use both of these research papers to design the benchmark dataset for assessing service quality in the airline industry using social media data. As the special service the airline companies provide, we use dimensions of service quality from prior studies and include security and safety as one of dimensions to measure service quality. Table 1 shows the six evaluation dimensions of airline service quality, as studied in this paper.

TABLE 1 SIX DIMENSIONS OF AIRLINE SERVICE QUALITY

Dimensions of Service Quality	Attributes and Key Words
Responsiveness	Willingness to help passengers; providing prompt service; keeping passengers informed about delivery of service; keeping passengers updated if any modified schedule; quickly response customer's requirements.
Assurance	Providing service actively; language skill or translation help of crew members; pilots' informative announcement in different contexts of culture; employee's skillfulness; courtesy towards customers
Tangibility	Comfortable seats and the cleanliness of the cabin; cleanliness of the aircraft interior and exterior; variety of food, food service and food quality; on-board entertainment: movie and music; the appearance of the crew; complimentary pillow or blankets
Reliability	Efficiency of the check-in process, flight punctuality, timeliness (arrival in promised time), handling of missing luggage complaints.
Security and Safety	Personal safety; luggage safety; animal safety
Communications	communication between cabin crew and passengers; the ability to communicate with passengers in different languages; the communication between pilot and passengers; informative announcement during the flight.

Literature Review of Social Media Analysis

A recent study by Xiang, Schwartz, Gerdes, & Uysal (2015) used a text analytical approach to analyze a large quantity of consumer reviews extracted from Expedia.com and demonstrated the utility of big data analytics to better understand the relationship between hotel guests' experience and satisfaction. Based on the SERVQUAL model and its variations, we can reasonably use big data technology to mine a large volume of social media data in order to potentially identify customer expectations for a service and the perceptions of those customers after they receive that service.

In this paper, we propose a framework for big social data comparative analytics (Figure 2) to help interested businesses to leverage big data solutions mine social media data in order to contextually compare the service quality among peers. The proposed framework adopts the seven service quality measurement metrics proposed by the five dimensions of service quality: reliability, responsiveness, empathy, assurance and tangibility.

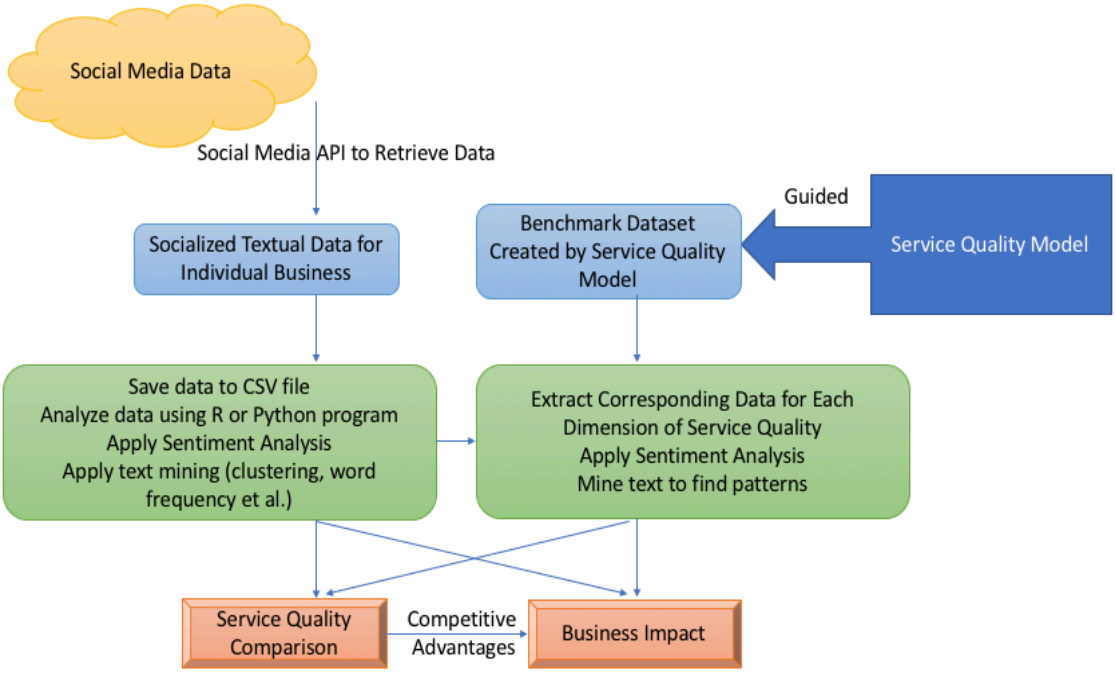


Figure 2. A Proposed Framework for Using Social Media Analytics to Study Service Quality

In the proposed framework, big data technology is used as a solution to analyze social media data from targeted business and their peers, in order to visualize and benchmark comparisons among peers across different service quality measurement metrics that may impact customer satisfaction. Text classification algorithms can be used to mine consumer-generated social media content based on the specified service quality measurement metrics. Then, sentiment analysis, which is the computational detection and study of opinions, sentiments, emotions, and subjectivities in text, can be conducted on the texts associated with each metric in order to identify consumer perceptions, generating a score from -1 (the most negative opinion) to 1 (the most positive opinion). The overall sentiment score of Dimension *i* can be calculated using the following formula provided by Duan et al. (2013):

$$S_i = \frac{N_{pi} - N_{ni}}{N_{pi} + N_{ni}} \quad (1)$$

where N*pi* denotes the number of positive sentences in Dimension *i* and N*ni* denotes the number of negative sentences in Dimension *i*. To make the process of conducting sentiment analysis easier, researchers can use existing popular sentiment analysis tools or services such as Lexalytics, SentiWordNet, SentiStrength, Social Mention, Trackur, Sysomos, and Viralheatto extract positive or negative sentiment scores from text (Pang & Lee, 2004). These sentiment analysis tools mainly rely on machine learning techniques such as Support Vector Machine (SVM), Naive Bayes, Maximum Entropy, and Matrix Factorization to classify texts into positive or negative categories, and they have been used in many studies in the sentiment analysis literature (Pang, Lee, & Vaithyanathan, 2002). Past research has found that a fluctuation in sentiment on social media has been identified to correlate with fluctuations in the stock market (Ranco et al., 2015). For example, the result of the presidential election can be predicted by gauging public opinion on social media when policy announcements are made. Anitsal et al. (2017) investigated the top ten airline carriers in the U.S. using sentiment analysis and found that the customer relationship can be investigated in detail, and that Delta, Southwest, Alaska, and SkyWest Airlines have the most positive sentiments expressed about their cabin crews and their attitude to their passengers. Waguespack and Rhoades (2014) argued that airline carriers have established a social media center in effort to avoid service quality failures, and that viral incidents can significantly affect publicity.

Based on the prior literature, we offer the following hypothesis:

H1: The sentiment analysis results of tweets will align with the DOT Air Travel Consumer Report.

METHODS

This paper will introduce a novel methodology and will utilize emotional sentiment analysis to help the airline industry to improve its service quality and respond to a public crisis in a short time. Bowen and Headley (2017) published the Air Quality Rating (AQR) to measure the service quality of U.S. airline carriers. Alaska Airlines and Delta Airlines were announced as No.1 and 2 in the AQR report in 2017. However, the data used for generating the AQR report was mostly based on that of the 2016 U.S. Airline Consumer Travel Report published by DOT. Bowen and Headley (2017) reported that nine airline companies showed improvement in the AQR report during 2016. In this study, all of the U.S.-based airline companies in the DOT airline consumer report are included: Southwest Airlines, Alaska Airlines, American Airlines, United Airlines, Delta, Express Jet, Hawaiian Airlines, Jetblue, Skywest, Spirit, Virgin America, and Frontier Airlines. The reason for choosing these companies is that each company can represent one type of airline carrier. For example, Southwest Airlines is known to be flexible by allowing passengers to choose their seats and by charging no baggage fee. Frontier Airlines, JetBlue, and Spirit are known by their cheap airfares; United Airlines, Delta, and American Airlines have the largest air route networks, and United Airlines suffered from the incident in April 2017; and Alaska Airlines is listed as No.1 in the AQR report for its excellent service. AQR has been cited to make an airline industry standard and to allow for a comparison of airline companies' performance (Bowen & Headley, 2017). In order to calculate the AQR score, DOT data is used and is applied to the formula, based on the on-time rate (OT), denied boarding (DB), mishandled baggage (MB), and customer complaints (CC). Only the on-time rate has a positive impact; the other three have a negative impact on AQR. The formula to calculate the AQR is listed below:

$$AQR = \frac{(+8.63*OT)+(-8.03*DB)+(-7.92*MB)+(-7.17*CC)}{(8.63+8.03+7.92+7.17)} \quad (2)$$

With its ability to measure service quality in the airline industry, AQR has been designed for the industry, and uses the data from DOT report. The results can be used by airline carriers, can help newly nominated airline services, and can assist DOT in modifying the rules. However, since the AQR is based on the Air Travel Report from DOT, the data in the report has at least a two-month time lag. Consumers cannot get real-time information when they need it to make purchase decisions, and airline companies are unable to improve their service right away.

Sometimes, consumers have reported incidents on their social media platforms and this information has spread rapidly. Then, airline companies can respond to it officially and can regain their reputations using social media tools. To monitor and analyze social media effectively, airline companies need to adapt multiple technologies and to hire data analysts and data scientists to mine tweets from Twitter, reviews on Tripadvisor.com, and comments from their websites and from other social media platforms. The most effective and feasible method is mining Twitter data, since Twitter has a lot of users and it provides an API to connect with the server and to retrieve the specific data. To better use these data, businesses can develop an information system to monitor their mentions on social media. For service companies, emotional sentiment and data mining can be applied to investigate service quality. Since service quality is the backbone of business, the earlier that any negative issues are found, the easier it is to improve service quality. If the sentiment has changed considerably, an alert can be sent to the appropriate person and then the proper operations and responses can be performed. Businesses can then use this information system to improve their service quality, to monitor their market performance, and to adjust their marketing strategies.

Sentiment Analysis

Opinion mining and sentiment analysis contribute to the development of an opinion-oriented information system for service or products providing companies (Pang & Lee, 2008). If service providing companies want to get feedback or opinions from customers, the traditional way is for them to conduct surveys and to distribute the surveys to the customers who have used the services in that company. However, a survey is not enough to get the customers' feedback in this digital world, because a survey needs time to be collected and analyzed. The issues of service cannot be addressed by the company quickly. Fortunately, customers like to post their service experiences on social media platforms rather than completing a survey or complaining to the company directly. Twitter and Facebook are the two of the most popular social media platforms.

Twitter Sentiment Analysis is the process of determining the emotional tone behind a series of words. It is used to gain an understanding of the attitudes, opinions, and emotions expressed within an online mention. Having a solid understanding of current public sentiment can be a great tool for any business. When deciding if a new marketing campaign is being received warmly, or if a news release about the CEO is causing customers to become angry, the people in charge of handling a company's public image need these answers quickly. And social media can deliver those answers quickly. One simple, yet effective, tool for testing the public waters is to run a sentiment analysis.

There are many ways to do sentiment analysis. Many approaches use the same general idea. Here are the three steps to do the sentiment analysis:

1. Create or find a list of words associated with strongly positive or negative sentiment.
2. Count the number of positive and negative words in the text.
3. Analyze the mix of positive to negative words. The use of many positive words and few negative words indicates a positive sentiment, while the use of many negative words and few positive words indicates a negative sentiment.

To perform the sentiment analysis, download the positive and negative words and evaluate the tweets with those positive and negative lexicons. The list of positive words contains 2,003 words and the list of negative words contains 4,782 words (Hu & Liu, 2004; Liu, Hu & Cheng, 2005). These word lists include some misspelled words that are possible appear frequently in social media content.

After having been run through the sentiment words lists, the tweets should be preprocessed before the sentiment scores can be calculated. First, the data must be cleaned. This step involves the removal of stop words, all of the numbers, and all of the white spaces, and the conversion of all of the words or letters to the lower case.

The first step, creating or finding a word list (also called a Lexicon), is generally the most time-consuming. In this study, I use the existing Lexicons and made some modifications to those Lexicons. For example, social media popular acronyms or slang are not included in the existing Lexicons. “omg”, “lol”, “thx”, and “wtf” are very common acronyms on social media platforms. I included these types of words in the Lexicon for in this study. Researchers can edit the Lexicons when they study specific topics. However, some words have double emotional meaning. For instance, “sick" is an example of a word that can have positive or negative sentiment depending on what it's used to refer to. If you're discussing a pet store that sells a lot of sick animals, the sentiment is probably negative. On the other hand, if you're talking about a skateboarding instructor who taught you how to do a lot of sick flips, the sentiment is probably very positive. Sentiment analysis uses machine learning algorithms. In this research, R Studio was used to load the sentiment analysis packages and to analyze the processed tweets for all twelve of the airline companies.

A sentiment analysis works like this: I first take a bunch of tweets about whatever I am looking for. I then parse those tweets out into their individual words, and then count the number of positive words and compare it to the number of negative words. I use the open source R program to calculate the sentiment score of the sentence from https://github.com/exploratory-io/exploratory_func. This function first maps the predefined sentiment type (positive or negative) or the value (how positive or how negative). And then it considers the intensity of the sentiment. If I am using the positive or negative to determine the sentiment, it is not enough to learn the mood or emotion of the customers. For example, here are two tweets in the dataset: “I’m feeling so good!” and “I’m feeling much better!” They are both positive. However, the two sentences express the intensity that influences the different results in emotion. “so” and “much” are the intensifiers in these sentences and score differently.

The Twitter datasets could be described in Table 2. United Airlines was mentioned by the largest number of unique users (135,569 unique users). And American Airlines received the highest number of average tweets per user (2.09). This can be interpreted to show that the customers of American Airlines would like to communicate with the airline company on Twitter. The highest number of tweets was received by Delta Airlines; it was mentioned by Twitter users (or its customers) over 227,000 times during this period (April - June 2017). Table 3 shows the AQR scores for each airline carriers in the period.

TABLE 2 THE DESCRIPTIVE OF PROCESSED TWITTER DATA

Airline Carriers	Number of Tweets from Apr.1 to Jun. 30, 2017	Number of Unique Users	Average Tweets Per User
United Airlines	224,789	**135,569**	1.66
Alaska Airlines	26,616	13,969	1.91
Southwest Airlines	68,522	42,561	1.61
Frontier Airlines	7,301	4,574	1.60
American Airlines	150,454	72,071	**2.09**
Delta Airlines	**227,121**	116,165	1.96
ExpressJet	58	45	1.54
Hawaiian Airlines	3,401	2,025	1.68
SkyWest Airlines	231	141	1.64
Spirit	23,045	13,095	1.76
JetBlue Airlines	49,503	24,693	2.00
Virgin America	11,817	7,270	1.63

TABLE 3 AQR SCORE FOR ALL AIRLINE CARRIERS FROM APR-JUN 2017

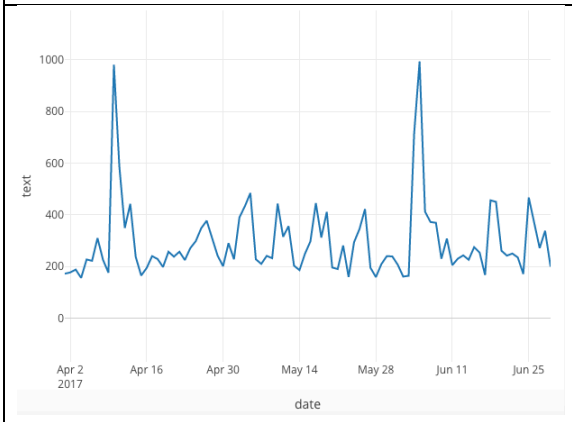
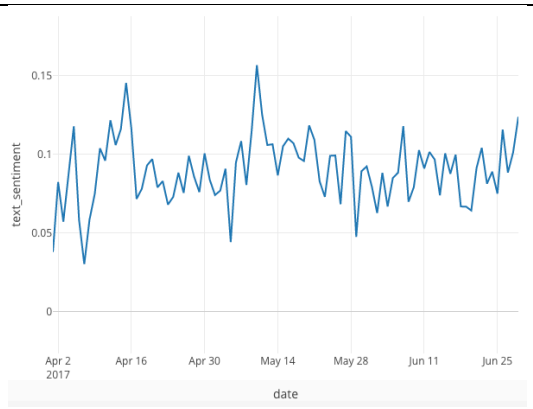
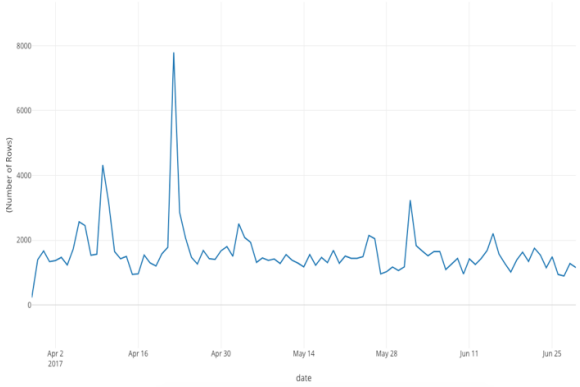
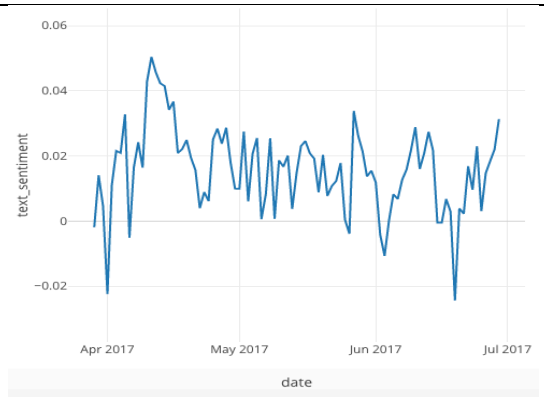
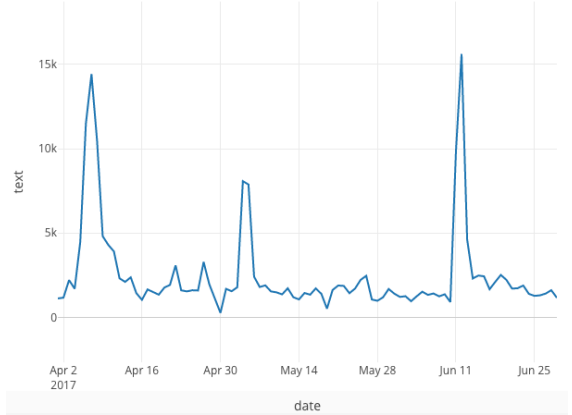
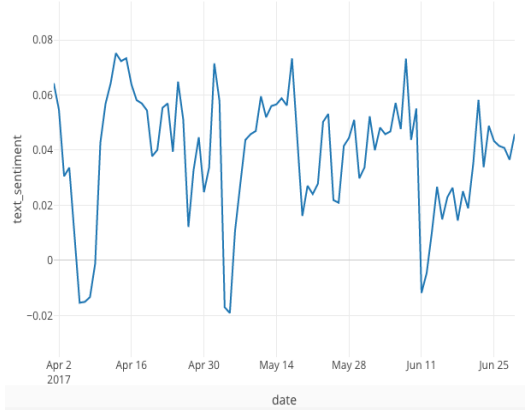
	AQR Score		
Airline Carriers	**April**	**May**	**June**
Alaska	**-0.46**	**-0.38**	**-0.45**
Frontier	-1.01	-1.24	-0.94
Southwest	-0.61	-0.81	-0.91
United	-1.10	-0.87	-0.98
Hawaiian	-0.85	-0.76	-0.53
SkyWest	-0.83	-0.65	-0.72
American	-1.20	-1.05	-1.21
Spirit	**-1.89**	**-3.11**	**-2.25**
ExpressJet	-1.47	-1.08	-1.14
Virgin America	-0.95	-1.07	-0.99
Delta	-1.22	-0.49	-0.50
JetBlue	-0.55	-0.57	-0.54

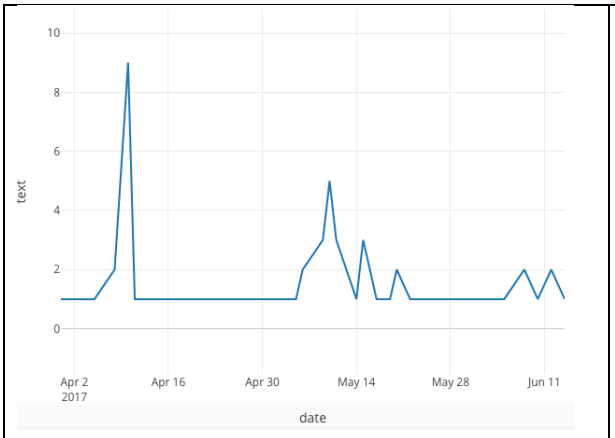
RESULTS

In the following figures showed in Table 4, all of the airline companies' Twitter data are shown in volume and in sentiment scores. I then put them into three categories: large airline carriers, cheap airline carriers, and other airline carriers. "Large airline carriers" comprises those that carry the largest number of passengers, including four airline companies: United Airlines, Southwest Airlines, American Airlines, and Delta Airlines. "Cheap airline carriers" means that the air fares on those are cheaper than on other major airlines. This category includes JetBlue, Spirit and Frontier. Those airline carriers always have their air fare deals online. For example, Frontier Airlines offers one-way air ticket for only $20 from ATL (Atlanta airport) to Orlando, FL. "Other airline carriers" include Hawaiian Airlines, Alaska Airlines, SkyWest Airlines and Virgin America. These airline carriers mostly have limited routes compared with the large airline carriers and the cheap airline carriers. Hawaiian Airlines mainly offers roundtrip fares from the U.S. mainland to Hawaii, and Alaska Airlines offers roundtrip fares from the U.S. Mainland to Alaska, as well as roundtrip fares among major cities in west coast in the U.S. Table 4 shows

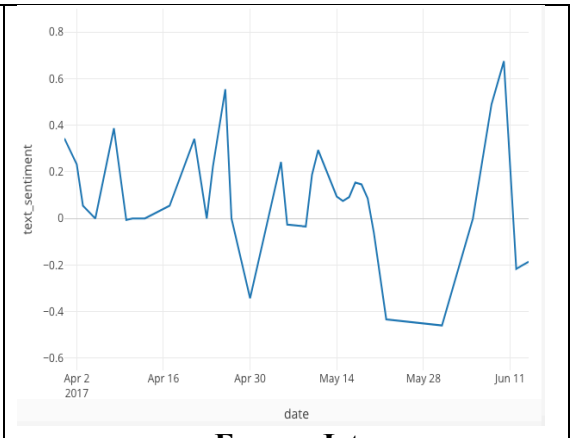
the trend of sentiment score and the trend of volume of tweets for each airline carrier in the three consecutive months.

TABLE 1 OVERALL VOLUMES AND MEAN OF SENTIMENT SCORE FOR EACH AIRLINE CARRIERS IN THREE MONTHS

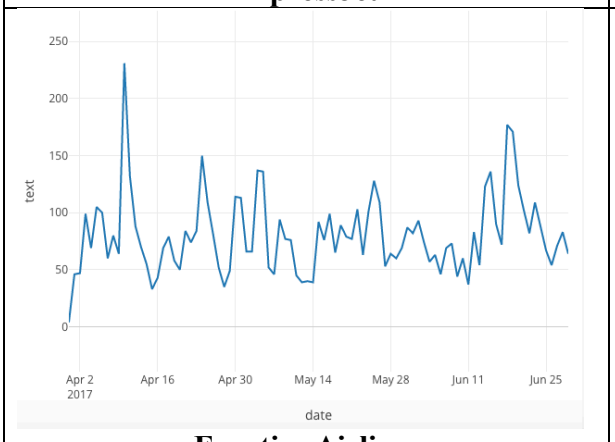
Overall Volume of Tweets	Overall Mean of Sentiment Score
 **Alaska Airlines**	 **Alaska Airlines**
 **American Airlines**	 **American Airlines**
 **Delta Airlines**	 **Delta Airlines**



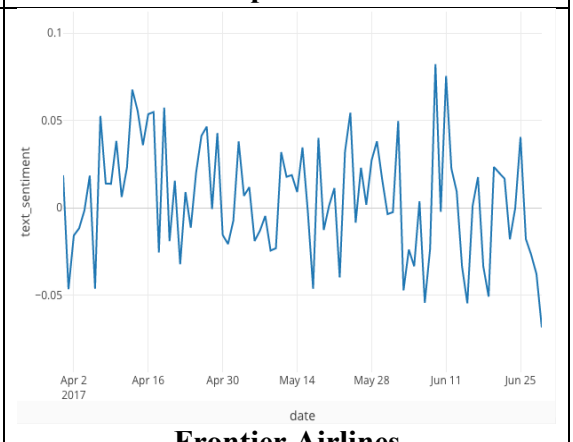
ExpressJet



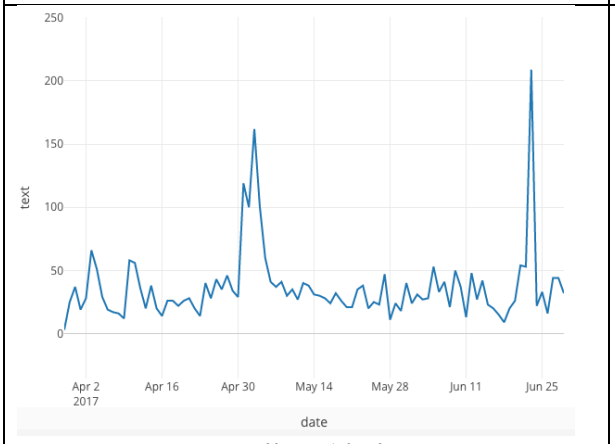
ExpressJet



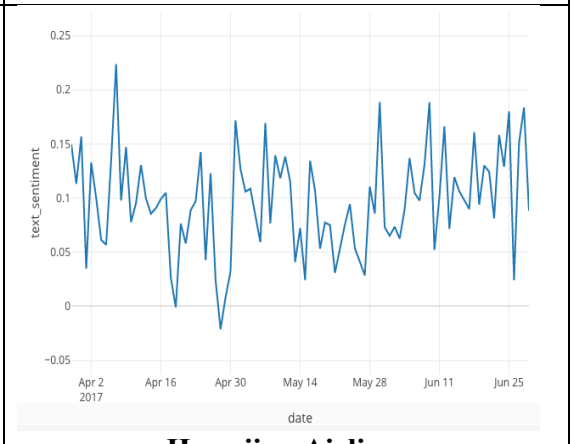
Frontier Airlines



Frontier Airlines



Hawaiian Airlines



Hawaiian Airlines


text
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May 14
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Jun 11
Jun 25
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Skywest Airlines
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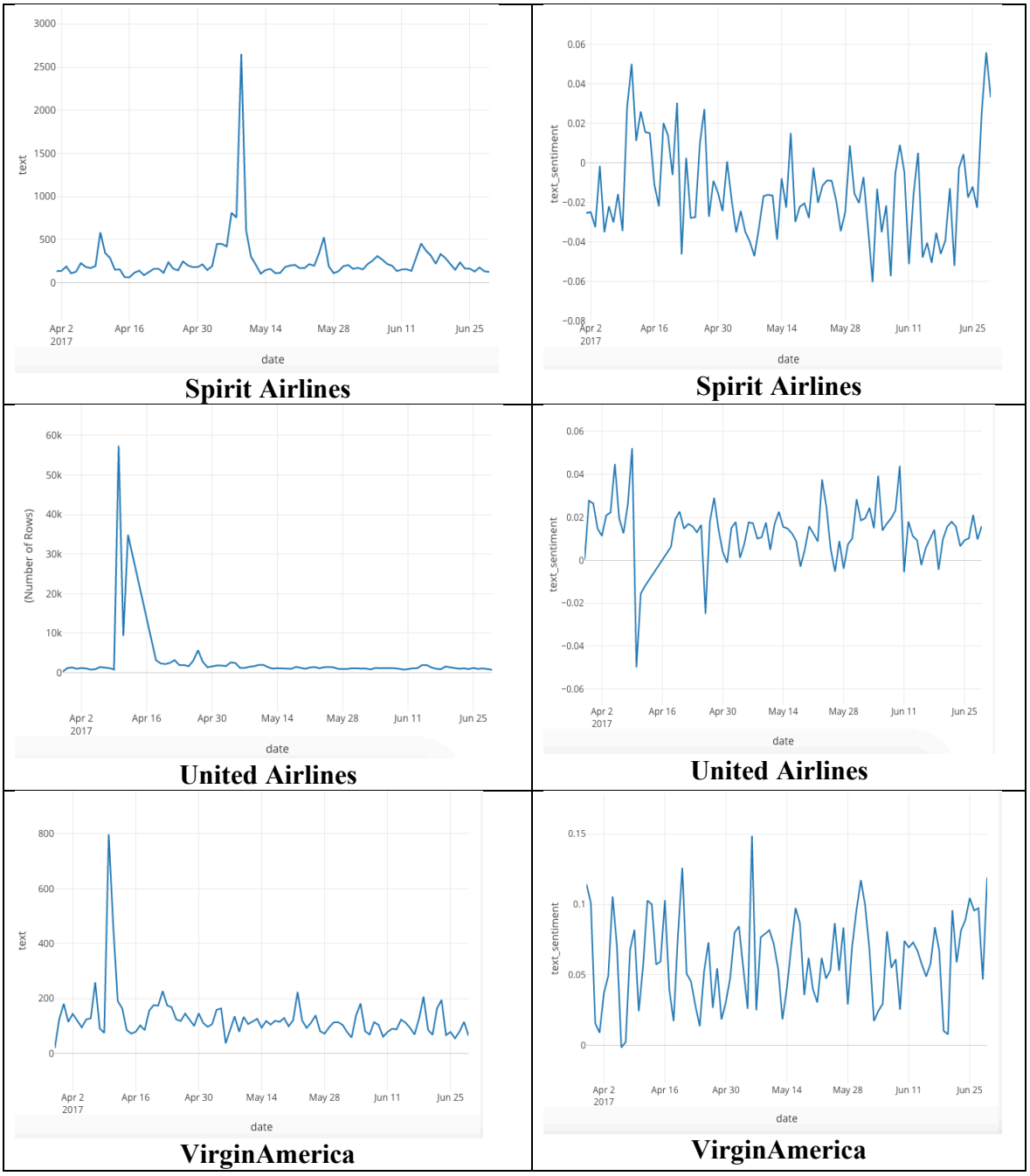
Southwest Airlines



From Table 4, we can see that United Airlines and Delta Airlines received the most tweets each day. If we look at the volume of the tweets, most of the airline carriers received a high volume of tweets during the period from Apr. 9 to Apr. 12. Since United Airlines had the critical incident on Apr. 9, and news of it was spread widely on social media, many people discussed and mentioned the incident on social media and expressed their indignant emotion and anger towards United Airlines. Southwest Airlines has a much lower volume of tweets compared to the large airline carriers and the other airline carriers. Due to the size of airline

companies and limited airline routes, Spirit and SkyWest Airlines received only fewer than 100 mentioned tweets per day.

Next, we report the results of having used OLS regression to examine the relationship between AQR and sentiment score. The regression results are reported in Table 5. To measure the service quality of airline industry, the dependent variable is the AQR score that is calculated by the formula using the data from DOT monthly report. In column 1, I wanted to test whether the volume of tweets would affect the AQR. The volume of tweets was converted to natural logarithm as log (volume). Other variables were included as control variables, such as the characteristics of the airline carrier and the characteristics of their Twitter account. The number of passengers and the number of scheduled flights are the characteristics of the airline carrier. I used a natural logarithm to convert these two variables, as well. They were converted to Log (passengers) and Log(flights). The number of Twitter followers, months on the Twitter (from the account creation), and whether using online response features on Twitter were the characteristics of Twitter account of each airline carrier. In this model, the R squared value was 0.389, and the p-value was .019, which is less than .05. That means that 38.9% can be explained by this model; this model is statistically significantly in predicting airline service quality - AQR score. The coefficient of log (volume of tweets) was -1.20 and the p-value is .402 which is not statistically significant. Only two variables - months on Twitter and online response feature on Twitter - had a p-value less than 0.1 and 0.05, respectively. However, in this model, I found two high variance inflation factors (VIF). Since the suggested threshold of multicollinearity problem is 10 (by Gefen, Straub, and Boudreau, 2000), the number of passengers (VIF: 25.234) and the number of scheduled flights (VIF: 25.214) were not tolerant in this model. They had the multicollinearity problems. If I included both of them in the regression model, it became problematic. Hence, I decided to eliminate the number of scheduled flights and keep the number of passengers, in this model.

Column 2 in Table 5 shows the model without variable - the number of scheduled flights. The VIFs in the second model were not over 3.5, which is acceptable; this indicates that the model doesn't have multicollinearity problem. The largest VIF was 3.214 of the number of followers on Twitter. In the second model in Column 2, the R squared value was 0.335 and the p-value was .025, which is less than 5%. That means that this model can explain 33.5% and is statistically significant at a level of 5%. After removing the scheduled flights in the model, I found that the coefficient of log (volume of tweets) was - 0.272 with a p-value of .018 (significant at the level of 5%). So, I could interpret that when the log (volume of tweets) increased by 1, then AQR would be negatively affected by that and decrease 0.272. In addition, the coefficient of online response feature on Twitter was 0.775 with a p-value of 0.006 (significant at the 1% level). Using the online response feature on Twitter will significantly improve the service quality of the airline carrier. This feature enables communication with customers on social media and leaves the responses on the airline's official Twitter account. This interaction can be read by other customers and can significantly benefit the airline's service quality. I would recommend all the airline carriers who would like to improve their service quality take advantage of this impressive feature on Twitter. Attracting more followers on Twitter may help to improve the AQR score in this case (p-value is .049). Because the coefficient of the number of followers is fairly small, it may not have a strong association with AQR, but it is still helpful for an airline to attract more followers on Twitter.

Next, we would like to find the association between the sentiment score and AQR. To check whether social media data can be used to measure service quality as DOT consumer reports do, the monthly data of Twitter was used to calculate the mean of the sentiment score that represents the monthly sentiment score for each airline carrier. Column 3 of Table 5 represents that the R squared value was 0.500 of this model with p-value 0.001 (significant at level of 5%). That means that this model can explain 50% and is a statistically significantly

predictor of the AQR score. The coefficient of the average sentiment score was 7.349, and the p-value is .000, which is significant at a 1% level. The sentiment score was positively and highly associated to AQR. This can be interpreted in this way: when the sentiment score increases by 1, the AQR will increase 7.349. The sentiment score can be used to measure the service quality and to predict the AQR score. The online response feature also significantly impacted the AQR, with a coefficient 0.443 at a significant level of 5%. This indicates that the sentiment score of tweets aligned with the DOT Air Travel Consumer Report. Hence, hypothesis was supported.

As shown in Table 5, we found that the number of passengers or the number of scheduled flights did not impact on AQR score. The online response feature on Twitter can be used by airline companies to improve their service quality. Analyzing the sentiment score and the volume of tweets was enough to measure the service quality of the airline industry and to predict the AQR score and complaints on DOT report.

TABLE 5 REGRESSION MODELS RESULTS (VOLUME, SENTIMENT SCORE AND AQR)

Dependent Variable	**AQR (1)**	**AQR (2)**	**AQR (3)**
(Constant)	3.091	-.841	-2.247
Log (Volume of Tweets)	-1.20	-.272 *	
	(-.253)	(-.572)	
Average Sentiment Score			7.349**
			(.579)
Log (Volume of Tweets) * Average Sentiment Score			
Log (The number of passengers)	-1.507	-.092	.020
	(-1.183)	(-.072)	(.016)
Log (The number of scheduled flights)	1.396		
	(1.121)		
Months on Twitter	.016 *	-.010	.005
	(.552)	(.335)	(.186)
Twitter Followers	.0002	.0002 *	.0002
	(.392)	(.545)	(.300)
Twitter Online Response	.822 **	.775 **	.433*
	(.563)	(.531)	(.297)
R-squared	.389	.335	.500
Adjust R-squared	.262	.224	.416

Standard deviation (in parentheses)
*. Significance at the 5% level
**. Significance at the 1% level
***. Significance at the 0.1% level

DISCUSSION AND CONCLUSIONS

Pang and Lee (2008) pointed out the challenges and opportunities engendered by the growing popularity of opinion-rich resources, such as online comments, blogs, social media platforms, and online forums. By investigating the value of those unstructured data, businesses are able to gather competitive intelligence and improve their products and services in a short time. In order to actively use information technology to seek and retrieve the data and to understand consumer's opinions, computational treatment of subjective texts like reviews, comments, and opinions have suddenly erupted in the past ten years (Pang and Lee, 2008).

With sentiment analysis, the information system could be developed for information retrieval, opinion mining, and sentiment analysis. This new system can provide data visualization and immediate responses to negative comments and can reduce the risk of public crisis. Business practices use the opinion-oriented information system to make decisions and to improve their products and services.

In this case, the airline industry indeed needs such an opinion-oriented information system to monitor the quality of their service to the public. The following steps and technologies can be used for creating the system. The entire system could be integrated, with all of its features, into one piece. Then, each step can be connected to the others, automatically. All of the data retrieved from social media should be saved in a CSV file and then saved to the database for later processing. A script language can be used to create the opinion-oriented system, to mitigate the work load for the employees and to provide the ultimate support from computing 24/7. Keywords can be created for each dimension, in order to track service quality; they can be saved into different tables in a database. And then all of the sentiment analysis and statistical analysis can be performed, in order to support business decision making. The concrete steps are listed below:

1. Use Python code using Twitter API to get the tweets for one's own company or for competitors
2. Gather all of the tweets or parts of tweets from past time or real time. The company can limit the tweets to specified numbers
3. Use the sentiment analysis packages of R to get the sentiment score and the emotion for each tweet
4. Apply the proposed service quality index
5. Save all of the tweets and the sentiment scores to Microsoft SQL Server Databases
6. Manipulate the data and find the pattern of the current data
7. Visualize the date, create report (weekly, monthly, quarterly, annual), respond to the public
8. Make decisions, adjust business strategy, respond to public if necessary.

Table 3 illustrates the conceptual layer of the opinion-oriented information system proposed by this study. With this information system, businesses in service industries can have analyze results every day to help them to better understand and connect to their customers. When something goes wrong, the system will send an alert to the proper departments and will direct them to perform some actions, depending on the type of alert. This information system has good scalability due to its expandable ability. This system should be able to monitor multiple popular social media platforms, such as Twitter, Facebook, and Instagram. When retrieving social media data from those social media platforms, Python can be used to connect the API provided by the social media or to web-scrap the social media data. In addition, the keywords in each dimension of service quality can be modified at any time. Since more customers will use social media platform to communicate and stay tuned with businesses, the keywords may be changed by time. More Internet slang is likely to emerge in the future. For example, "LOL" means "laugh out loud"; it is a popular element of Internet slang. And "bump" is always used in the forums that move the posts or comments to the top on the first page. "Troll" is another word in Internet slang that used a lot today. "Trolls" are the people who want to take pleasure from starting disagreements and angering other people online. "I can't even" is another way to say, "I'm speechless." This phrase is used when you have no words to express to respond to incredible or unbelievable things. There is much more slang that is used on the Internet today, and there is likely to be more and more in the future. Thus, updating the keywords for each dimension of service quality will be necessary.

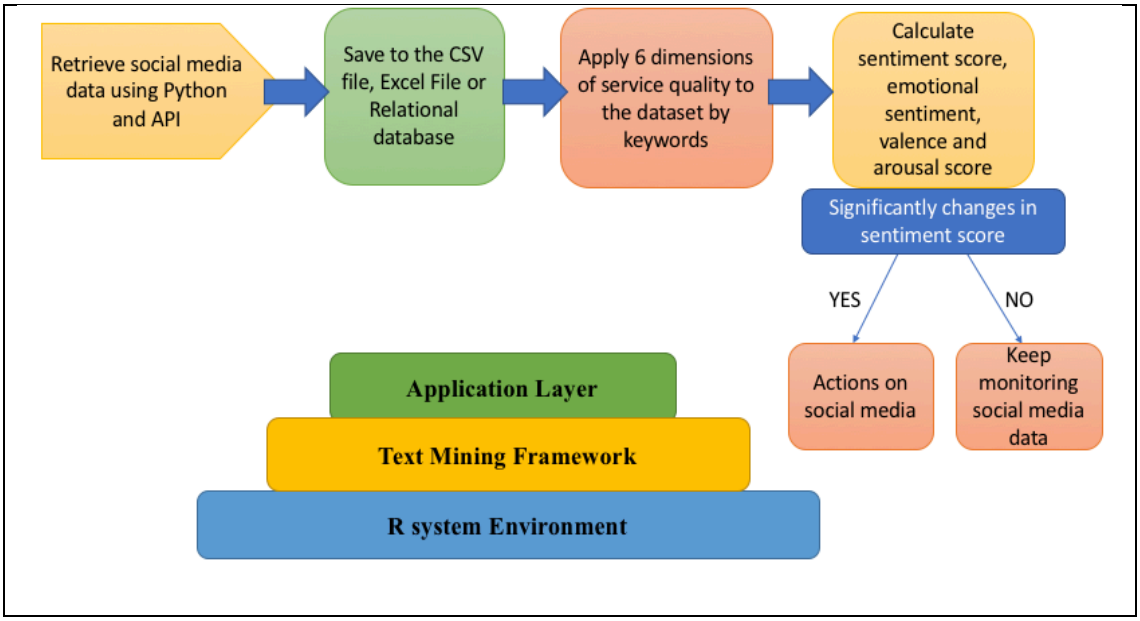


Figure 3. Conceptual Layer of Opinion-Oriented Information System

In this study, we can conclude that sentiment score from social media analysis could be used to predict the service quality in airline industry. Despite of the number of flights or the number of passengers or the size of airline companies, the service quality could be measured by monitoring social media platform and mining the textual social media data. The results can be used by business practitioners and used to adjust the marketing strategy with the marketing survey results. Hiring more business analysts and data scientists in the service-oriented companies are important to keep business advantages in the industry. To understand the customers' opinions, concerns and even their behaviors from the social media, it is valuable for all the business now. Sentiment score and emotional sentiment change were found to be consistent with the conclusion made by Wahba (2017). Negative sentiment could have a short-term effect on company's market value, but in the long run, may not have influence. Analyzing the social media data also can avoid the huge incident affects in public relationship.

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Exploring the moderating effects of individual and job characteristics on the relationships between work-family integration and employee outcomes

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ABSTRACT

Based on conservation of resources (COR) theory, this study first examines the impacts of three types of work-family integration activities (i.e., role segmentation, work-to-family integration, family-to-work integration) on employees' job performance and life satisfaction and, then, explores the moderating effects of individual and job characteristics on the relationships between these activities and job performance. Using a sample of 224 MBA students working full-time in China, the hypotheses derived from a proposed research model have been tested.

KEYWORDS: Role Segmentation, Work-to-Family Integration, Family-to-Work Integration, Mobile Technology, Job Performance, Life Satisfaction

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From Cost To Strategic Focused Offshore Information Systems Investment: The Impact Of Specialized Trainings In The Context Of National Culture

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ABSTRACT

The cost focused offshore Information Systems (IS) investment aims to reduce cost of IS investment, while the strategic focused approach concerns with increasing the rate of innovation in the offshore location. The relationship between specialized trainings and rate of innovation in offshore location was considered to be direct positive. However, this study identifies national culture as a moderator in this relationship and establishes that the trainings provided need to accommodate local culture This study uses the Hofstede's four-dimension model of national culture to examine the impact of cultural differences on individual learning behavior and therefore, trainings needed to address these differences.

KEYWORDS: Information Systems, National Culture, Rate of Innovation, Offshore Investment, and Learning Behavior

1. INTRODUCTION

Offshoring of Information Systems (IS) investment, referred to as the process of sourcing and coordinating tasks and business functions across national borders by Lewin, Massini and Peeters, (2009), has evolved from a risky strategy into a routine business decision (Dossani & Kenney, 2007). However, most of the firms take it as a growth opportunity to gain short-term competitive advantage rather than as an investment on achieving long-term competitive advantage (Lewin & Peters, 2006). This is due to the fact that the firm's aim in offshoring is often to exploit the low cost human resource available in the host countries (Lewin & Peters, 2006).

However, the problem with focusing on short-term gain is that it is, as the name suggests "short-term". As more firms engage in this strategy the competition gets higher and as a result the return on investment becomes smaller. This is the simple economic rule of demand and supply. As established in the field of business, the only sustainable way to gain long-term competitive advantage is by "innovation".

Extant literature explains that firms attempt to increase the rate of innovation by increasing R&D spending (Maskell et al., 2006; Shefer & Frenkel, 2005). Increased R&D investment enhances the ability of the offshore location to spend more in providing in-house work place related trainings as well as hire employees with highly specialized skills (Caramel & Agarwal, 2006). However, only 5% of the offshore location has shown significant increase in generating innovative technologies and products (Caramel & Agarwal, 2006). Therefore, according to Caramel & Agarwal (2006), firms attempt to increase the rate of innovation by providing highly

specialized trainings to the staff in the offshore location. This raises an important question on whether this relationship between rate of innovation and highly specialized trainings is exactly like presented in the extant literature or are there other contextual factors that have been overlooked by previous studies. This study focuses on national culture as an important factor having impact on learning behavior of offshore staff. Trainings provided by the firms are only as successful as the learning capacity of the staff participating.

This paper proposes national culture as an informal institutional factor that moderates the learning behavior of individuals involved in the offshore locations. National culture thus impacts the rate of innovation in the offshore locations and provides a more detailed explanation on why only handful of companies have been successful in achieving the desired rate of innovation. In short, this study aims to fill the aforementioned gap in literature by investigating the role of national culture in the relationship between specialized skills trainings and rate of innovation.

This paper is organized as follows: section 2 includes literature review, section 3 has theoretical development, section 4 discusses data analyses and methods, section 5 is the conclusion and section 6 discusses limitations of this research.

2. LITERATURE REVIEW

Firms try to achieve a long-term competitive advantage by treating the offshoring activity to achieve innovation (Carmel & Agarwal, 2006). Firms offshore core corporate activities including new system and products termed as “proactive strategic focus” (Carmel & Agarwal, 2006, p. 67). The market norm is that firms offshore non-core activities like support and product enhancements termed as “proactive cost focus” (Carmel & Agarwal, 2006, p.67). The difference between these two stages is that the objective during “proactive cost focus” stage is to reduce cost while that of the “proactive strategy focus” is to gain long term sustainable competitive advantage through higher rate of innovation (Carmel & Agarwal, 2006). In this process of shifting from proactive cost to proactive strategic focused phase, the literature available is focused on formal institutional factors such as inter-organizational level information exchange and the economical and financial issues such as increasing R&D investment in the offshore locations which would then be invested in establishing research facilities and providing highly specialized trainings and hiring world class skills (Carmel & Agarwal, 2006; Luo, 2005; Wilhelm, 2011). The current studies operate under a basic assumption that all offshore locations can achieve the status of “proactive strategy focus” stage if world-class talent are hired and provided with highly specialized trainings in the work place, regardless of the environment they are operating in. According to Caramel & Agarwal (2006) only 5% of the firms, that are attempting to increase rate of innovation by increasing number of specialized trainings to their workforce are successful in achieving this target. Their success has been credited to having superior inter-organizational information exchange and past experience in handling offshore activities. This implies that specialized trainings provided at work place do not play a role in increasing rate of innovation of that location. The important question here is, does this result hold true for all environment/host country? The problem is that the above conclusion was based on a finding that there is a direct relationship between specialized trainings and rate of innovation. This direct relationship does not consider impact of any other environmental factors.

The nature of information systems is such that highly specialized skills play an important role in rate of innovation (Black & Lynck, 2001). However, according to Caramel & Agarwal, (2006), highly specialized trainings provided to staff has not resulted in higher rate of innovation in all of

the offshore locations. Learning environment plays an important role in the success of learning program. However, learning is a function of one's individual characteristics and environment, and it is influenced by national culture (Bandura, 1977; Magini, Paolino, Cappetta and Proserpio, 2013). The 5% firms that are successful in achieving their target might have understood the importance of incorporating differences in national cultural dimension in their trainings. This factor has not been examined yet in the literature. Therefore, crediting the

3. THEORETICAL DEVELOPMENT/MODEL

3.1. Training and Rate of Innovation

Extant literature explains that firms attempt to increase the rate of innovation by increasing R&D spending (Maskell et al., 2006; Shefer & Frenkel, 2005). Increased R&D investment enhances the ability of the offshore location to spend more in building better research facilities, providing in-house work place related trainings as well as hire employees with highly specialized skills (Caramel & Agarwal, 2006). The constantly changing requirements and technologies required in IS projects make the option of hiring specialized skills/workforce for every new project less feasible both financially and operationally (Feeny & Willcocks, 1998; Nuseibeh & Easterbrook, 2000). Furthermore, the newly hired workforce will also be provided with workplace related trainings to update them with the required technologies and methods used in the firm. Firms rely on specialized trainings to achieve a higher rate of innovation rather than hire new work force for every new project or upgrade of their system. Trainings therefore, play an important role in the performance output of an employee and impact the rate of innovation (Black and Lynck, 2001).

However, as discussed in earlier section, most firms are unable to generate higher level of innovative technologies and products just through specialized trainings (Caramel & Agarwal, 2006). This raises an important question on whether the relationship between rate of innovation and highly specialized trainings is as direct as presented in the literature or there are other contextual factors that have been overlooked by previous studies. Considering the relationship between training and rate of innovation as a closed system without any interference from the environment does not provide a complete explanation. A detailed analysis will be helpful in understanding the environmental (informal institutional) factors that might play an important role in defining the relationship.

Trainings provided by the firms are only as successful as the learning capacity of the staff participating in the program. Learning ability is a function of one's personality and environment (Bandurra, 1977; Magini et al., 2013). National culture plays an important role in shaping an individual's personality with respect to a social group (Hofstede, 1983). Therefore, the role of national culture cannot be neglected when studying the success of learning program (trainings) regardless of the nature of trainings conducted.

3.2. National Culture as A Moderating Factor

Specialized skills, play an important role in a successful IS project (Black & Lynck, 2001). IS staff working on the project can already have these skills or they can be trained in these skills. A firm expects increased rate of innovation as a result of successful training (Black & Lynck, 2001). The success of the training depends on the ability of a trainee to absorb and assimilate the knowledge learned during the training (Downey, Wentling, Wentling & Wadsworth, 2005). The ability to absorb and assimilate the knowledge gained highly impacts an individual's learning behavior (Magini et al., 2013). According to Bandurra (1977), one's behavior is a

function of one's personality and environment. Personality and environment is in turn is a function of national culture as according to Hofstede (1991), it is "defined culture as the "training or refining of one's mind from social environments in which one grew up" (p.4). Therefore, it has an impact on learning behavior of an individual when studying the individual behavior with respect to a human group. National culture is the collective programming of the mind that distinguishes the members of one human group from another (Hofstede, 1983). In other words, differences in national culture impact the perception of an individual and in turn their perception towards a learning module/method/technique. This difference in individual perception will impact how easily or to what extent the learning module (specialized trainings) will be successful in helping the staff understand and implement the subject matter of the trainings and therefore result in a higher output (rate of innovation in this case). Hence, it can be suggested that national culture plays a moderating role in the relationship between specialized trainings and rate of innovation. If the specialized training modules incorporate the difference in the local cultural norms into its training module, the relationship becomes stronger and should result in a higher rate of innovation compared to training modules that does not incorporate it.

This study will use Hofstede's (1983), four dimension of national culture to present why customized trainings are needed that reflect the difference in local culture. The four dimension of national culture are: individualism/collectivism, uncertainty avoidance, masculinity/femininity and power distance. For example: the perception of individual in an individualistic society is different from an individual in a collectivist society. Trainings that focus on certain characteristic of a human behavior related to individualistic society will positively strengthen the relationship between trainings and rate of innovation resulting in a higher rate of innovation. However, if the same training module is utilized in a collectivist society, the relationship might not be positively strengthened and a higher rate of innovation is not achieved. In a collectivist society a training module designed around the cultural norms of a collectivist society will be more successful. For a list of characteristics of each dimension of national culture, please refer to Appendix A.

3.2.1. Individualism/Collectivism

According to Hofstede (1983), individualism/collectivism pertains to the degree to which individuals are integrated into groups and their feeling of being in a group. According to Straub (1994), perceived social acceptance impacts acceptance of an individual in a collectivist society whereas in an individualistic society, individuals' self-perception triumphs over social perception. The characteristics explained below for both individualistic and socialistic society is based on Hofstede (1983).

One of the major characteristics of a collectivist society is that individuals have close ties with group and value joint efforts and group rewards. They interact in an interdependent, cooperative mode and have strong interpersonal ties. Therefore, group perception triumphs over individual perception. However, for an individualistic society where social ties are not strong and interaction is on individual, competitive basis, trainings that involve group interaction or simulates group working environment will not be perceived to be valuable. Furthermore, individualistic society is characterized by low loyalty to other people and institutions while a collectivist society is characterized by high loyalty to other people and institutions. Similarly, individual opinions and behavior are tolerated in individualistic society whereas in a collectivist

society behavioral conformity is expected. Therefore, as explained in earlier section, due to the difference in characteristics of society that impacts the individual perception towards a certain

learning method/techniques, one single training module/technique can not be successful universally. The difference in characteristics of an individual from different society leads to difference in their learning behavior and therefore, a difference in the impact of workplace training in rate of innovation. An individual from an individualistic society where individual ideas are encouraged will tend to bring in more innovation than an individual from a collectivist society where the group ideas are preferred. Therefore, group agreement is sought out and hence, rate of innovation will not be high. The local individualism/collectivism norm will moderate the outcome of the training and therefore, the relationship between training and rate of innovation.

> **Hypothesis 1:** Individualism/Collectivism dimension of national culture impacts the relationship between workplace training and rate of innovation. Individualistic culture will have a positive moderating effect and collectivist culture have negative moderating effect.

3.2.2. Uncertainty avoidance (UA)

According to Hofstede (1983), it is a cultural trait that determines the risk taking nature of the people in a country. The country where this index is high implies that the population is more risk averse while the country with low uncertainty avoidance index imply that the population is more risk seeking. The reason behind uncertainty avoidance is because of the fear of unknown effects of new technologies or products. This makes people more resistant towards change (Hill, et al, 1998). Specialized education and trainings help alleviate such fear of unknown from people (Veiga et al., 2001), therefore the impact of trainings that provide high specialization will be higher on rate of innovation in a high risk averse society than on a low risk averse society.

The characteristics explained below for both high and low risk-averse society is based on Hofstede (1983). High uncertainty avoidance society is characterized by need for formal structure, in other words, formal rules and regulations while low risk averse society tend to act beyond the structure of formal rules and regulations. Another character associated with high risk averse society is belief in experts and their knowledge. A low-risk averse society has weak faith in people and institutions while a high-risk averse society has strong faith in institutions. As explained in earlier section, due to the difference in characteristics of society that impact the individual perception towards a certain learning method/techniques, one single training module/technique cannot succeed across all different cultures. The difference in characteristics of an individual from different societies leads to difference in their learning behavior and therefore, a difference in the impact of workplace training on the rate of innovation. An individual in low risk averse society is encouraged to bring in ideas of change and therefore aid in generating higher rate of innovation. The local uncertainty avoidance norm will moderate the outcome of the training and therefore, the relationship between training and rate of innovation.

> **Hypothesis 2:** Uncertainty Avoidance dimension of national culture impacts the relationship between workplace training and rate of innovation. Low risk averse societal culture will have a positive moderating effect on the relationship and high risk averse societal culture will have negative moderating effect.

3.2.3. Masculinity (M)

According to Hofstede (1983), masculine societies place greater emphasis on individual achievement and rewards than do feminine societies. Therefore, training modules that emphasize rewards for individual achievement will become more successful in masculine

society whereas it will not impact the success of training in feminine societies. The characteristics explained below for both masculine and feminine society is based on Hofstede (1983).

Masculine societies are characterized by features like emphasis on individual achievement and encouragement of independent thought and action, while societies that are more feminine focus more on solidarity and service as well as cooperation. Furthermore following social norms is a matter of moral obligation for a feminine society while masculine society emphasizes in independent thought and actions. Therefore, the individuals in these two different societies will react differently to different learning environment. For example, an individual from masculine society will put high emphasis on individual achievement and is more likely to work towards achieving individual goals and progress and upon seeing more progress and achievement through innovation is more likely to use the knowledge from trainings to achieve this goal. However, an individual from a feminine society will put more emphasis on solidarity and service. Trainings that focuses on solidarity and service will become more successful in such a society. Similarly, individuals belonging to masculine society will be more inclined to have independent thoughts and action and therefore, a training environment that encourages independent thoughts and actions will be more successful.

As explained in earlier section, due to the differences in characteristics of society that impact the individual perception towards a certain learning method/techniques, a one-size fits all approach to specialized trainings does not work. The difference in characteristics of individuals from different societies leads to difference in their learning behavior and consequently to a difference in the impact of workplace training in rate of innovation. Individuals from masculine society will be encouraged by the environment to work towards achieving individual goals and achievements and if rate of innovation is tied to individual goals and achievements, then they are more likely to turn in more innovation. Local masculinity/femininity norm will thus moderate the outcome of the training and therefore, the relationship between training and rate of innovation.

> **Hypothesis 3:** Masculinity/Femininity dimension of national culture impacts the relationship between workplace training and rate of innovation. Masculine societal culture will positively moderate the relationship while feminine societal culture will have a negative moderating effect.

3.2.4. Power distance (PD)

According to Hofstede (1983), power distance index represents importance of hierarchy, vertical communication patterns, centralization of power, resistance to change and control over subordinates. The characteristics explained below for both high and low power distance society is based on Hofstede (1983). The society with high power distance is characterized by norms for differential prestige, power and wealth, whereas in a low power distance society egalitarian relationships prevail. Therefore, while organizing a training module that include staff in different hierarchy of power will become more successful in a society with low power distance, such

training modules are less likely to succeed in a society with high power distance. Furthermore, low power distance society is characterized by norm for cooperation, interdependence, solidarity and affiliation, group trainings and sharing of information.

The norm of conflict in high power distance society is a part of national culture and innovation requires cooperation at individual and higher levels. Thus a high power distance culture in society negatively affect rate of innovation. However, Hasan & Dista (1999), argue that when employees have or gain highly specialized skills, they gain more equity with managers and thereby reduce the effect of power distance. Providing staff with specialized skills will help in reducing power distance resulting in a positive impact on rate of innovation. However, local managers may be wary of such trainings that reduce power distance. Therefore, in these societies, trainings designed for managers and employees that are conducted in group is more likely to reduce the power distance and therefore have higher positive impact on the rate of innovation. A low power distance society is more encouraging to innovation due to its collaboration and open to discussion characteristics while comparatively a high power distance society that is characterized by closed-door discussion is not encouraging of innovation. The local power distance norm will moderate the relationship between training and rate of innovation.

> **Hypothesis 4:** Power distance dimension of national culture impacts the relationship between workplace training and rate of innovation. A low power distance societal culture will positively moderate the relationship while a high power distance societal culture will negatively moderate the relationship.

A model representing the impact of all national culture on the relationship between training and rate of innovation is presented in Appendix D and E.

4. RESEARCH DESIGN

4.1. Sample

This study uses a sample of the top 25 largest U.S. Fortune 500 firms. Out of the 500 firms listed in the Fortune 500 magazine, the 25 largest firms that have at least 10 offshore IS investments are selected for this study. The list of the largest U.S firms is selected from Fortune 500 list that is compiled and published by Fortune magazine. It ranks 500 of the top U.S firms on the basis of total revenues reported. The firms selected are from both technology and non-technology groups. The assumption behind choosing both technology and non-technology firms is that technology firms might be more active in offshoring and so behave differently than non-technology firms. The firms selected have U.S based headquarters. To select firms amongst the Fortune 500 that have at least 10 offshore IS investments, event study is carried out, where the event (announcement by firms to invest in offshore location) is collected from firms monthly/annual reports which is publicly available on Bloomberg and or company website. Furthermore, a survey questionnaire is sent out to the executives in the headquarters to verify the total number of their offshore subsidiaries.

The total number of offshore subsidiaries studied, from the top 25 firms selected above, is 250. The time frame of study is between January 2014 and December 2015. The total number of executives in headquarters that were surveyed is 50 and the total number of managers surveyed in offshore subsidiaries is 500. The response rate from this survey is 14.3%.

4.2. Variables & Measures

4.2.1. Dependent Variable

Number of innovation/year (NumOfInno): The number of innovation per year is measured as the total number of new product and process introductions, Rothaermel and Hess, (2007) describe

it as firm's innovative capability. New product/process introductions are those products/process that have a significant design change (Parente & Geleilate, 2015). Therefore, this variable consists of the total number of incremental and completely new products/processes introduced in a given year, as not all product/process introduction can be considered as innovation. In the first phase, offshore managers were surveyed to provide the total number of new product/process introduced in the past year. The survey questionnaire is presented in Appendix B. In the second phase, the same questionnaire is sent to managers in headquarters. This step is carried out to verify the numbers provided by the managers in both offshore subsidiaries and headquarters. The questionnaire was back translated to avoid translation errors. There are 4 items in the scale.

4.2.2. Independent Variable

Total Number of Trainings (NumOfTrainings): This variable is adapted from the eight item scale presented by Gallivan, Spitler and Kufaris (2005). It measures the total number of training sessions attended by a staff in a particular offshore subsidiary. Each session is measured by number of hours and each session can range between 2 to 4 hours. Traditionally, this variable is supposed to have a direct positive impact on rate of innovation. However, this study proposes that the impact of this variable on rate of innovation is moderated by Hofstede's four dimension of national culture. The eight scale measure in presented in APPENDIX B.

4.2.3. Moderating Variable

Individualism/Collectivism (IC): This study adapts the Individualism/Collectivism measure proposed by Hofstede, 1980, pp. 403-410 and further validated by Yoo, Donthu and Lenartowicz (2011). This new set of questionnaire has 6 items that measure the collectivism of the society and present that high score in this dimension pertains to collectivist society while the low score pertains to individualistic society.

Uncertainty Avoidance (UA): This study adapts the Individualism/Collectivism measure proposed by Hofstede, 1980, pp. 403-410 and further validated by Yoo, Donthu and Lenartowicz (2011). This new set of questionnaire has 5 items that measure the uncertainty avoidance norm of the society and present that high score in this dimension pertains to high risk averse society while the low score pertains to low risk averse society.

Masculinity (M): This study adapts the Individualism/Collectivism measure proposed by Hofstede, 1980, pp. 403-410 and further validated by Yoo, Donthu and Lenartowicz (2011). This new set of questionnaire has 4 items that measure the masculinity/femininity norm of a society and present that high score in this dimension pertains to masculine society while the low score pertains to feminine society.

Power Distance (PD): This study adapts the Individualism/Collectivism measure proposed by Hofstede, 1980, pp. 403-410 and further validated by Yoo, Donthu and Lenartowicz (2011). This new set of questionnaire has 4 items that measure the power distance of the society and present that high score in this dimension pertains to high power distance while the low score pertains to low power distance.

All items in the questionnaire and source and validity is presented in APPENDIX C. 4.2.4. Control Variables

Firm Structure: According to Teece (1994), a firm's structure (formal or informal) has a direct impact on rate of innovation of the firm. As we want to study the moderating role of national culture on the relationship between trainings and rate of innovation, firm structure is controlled so as to remove the potential impact that can be caused by this variable on the relationship.

Firm Age: According to Sorensen and Stuart (1999), firms that have been in existence for longer period of time will have higher rate of innovation than the firms that are newer. Furthermore, they mention that this is due to firm learning from their experience and knowing the patterns to achieve higher rate of innovation. Therefore, in this study firm age is controlled. This is done to exclude the potential impact of firm age on rate of innovation for firms that have been in existence longer than other firms in the sample.

4.3. Data Collection

The data was collected in two separate sets of interviews. One was conducted on executive level in headquarters and next on the executive level in offshore subsidiaries. The executive level interviews were conducted in two steps: one for the executives at headquarter that was conducted on 50 executives from 25 firms. The second phase of executive questionnaire survey was sent to the 500 managers in the offshore subsidiaries. These interviews were supplemented with follow-up messages and conversations. The respondents were "head of global software engineering", "head of enterprise development services", and "director of global IS planning". Questionnaire data was supplemented with publicly available data about the firms and was analyzed utilizing qualitative methods. In the first analysis, factual answers to questions were analyzed, such as the extent of offshoring, decision drivers and rationale for site decisions. In the second analysis, more concrete answers were analyzed such as the extent of customization of trainings provided to different locations for both staff and local managers.

4.4. Data Analysis

A pilot study was conducted on a sample of 4 executives from offshore subsidiaries and 2 from headquarters. The necessary adjustments were made to the questionnaires. The sample survey was then used to conduct a confirmatory factor analysis to validate the developed model and once the validity of the model was established, the final survey is conducted. The chi-square fit, RMSEA and CFI fit were checked for model validity. The RMSEA value is desired to be below 0.8 (Browne and Cudeck, 1998) and CFI above 0.9 (Bagozzi and Yi, 1988). The final survey will be conducted by sending the adjusted questionnaire to all of the potential respondents (50 executives in headquarters and 500 managers in offshore subsidiaries). The result of the survey is then used to run the regression model, the first model consists of the main effects variables only and is shown below:

$$N\text{umOfInno} = \beta 0 + (\beta 1 * T\text{raining}) + \varepsilon \quad (1)$$

Then the interaction effects will be introduced in the second step. The reason behind this is to check whether the moderation effect introduced by the four dimension of national culture are significant or not. The regression equation to analyze hypothesis 1 through 4 in this study is presented as:

$$NumOfInno = \beta 0 + (\beta 1 * Training) + (\beta 2 * (Training * IC)) + (\beta 3 * (Training * UA) + (\beta 4 * (Training * M)) + (\beta 5 * (Training * PD)) + \varepsilon \quad (2)$$

The R^2 value for both models are noted and compared to reach a conclusion regarding whether the hypothesis are supported or not. The expected result from this test is that all the interaction effect is significant, thereby supporting all the hypothesis and therefore suggesting that national culture does moderate the relationship between trainings and rate of innovation.

5. CONCLUSION

IS investment can be considered different from other types of business investment, since technology is same worldwide. However, it is people who use the technology, therefore neglecting the "human behavior" out of the environment may not be able to project a complete picture. The results expected from this study will highlight the importance of "people" factor in IS investment. This study supports national culture as an informal institutional factors that impacts the learning behavior of an individual. Any relationship that studies an individual learning behavior with respect to a group without considering the impact of national culture will not be able to properly address the complete phenomena. Therefore, taking "national culture" into consideration, this study will be able to explain some of the reasons behind only some firms being able to achieve the desirable level of innovation while others lagging behind.

6. LIMITATIONS

6.1. Data Sample

The sample included are divided into technological and non-technological firms and has not been further categorized into manufacturing or service firms, therefore, a detailed analysis of the moderating impact on different kinds of firms is not possible. It is difficult to check whether firm characteristics play any role in the relationship.

6.2. Method

This study uses Hofstede's four dimension of national culture that was established in 1980. The more newer version that has six dimension has not been included in this study therefore, this limits the ability of this study to predict other dimensions in national culture that might impact the relationship between rate of innovation and trainings.

6.3. Model

The only moderating effect that has been examined here is that of national culture and therefore, this study is not able to analyze whether it is just the national culture that has the moderating effect on the relationship or there are other factors that moderated the relationship along with national culture. For example: Would Composition of Top Management moderate this relationship, how about the role of a firm's experience in offshore IS investment? These factors might be able to negate the moderating role of national culture on the relationship, but this study does not venture into studying these additional factors.

APPENDICES
APPENDIX A

Individualism	Collectivism
• Value individual accomplishment • Tolerate individual behavior and opinion • Interact on an individual competitive basis • Loose interpersonal ties • Low loyalty to other people and institutions	• Value joint efforts and group rewards • Norms for behavioral conformity • Interact in an interdependent, cooperative mode • Strong interpersonal ties • High loyalty to other people and institutions
High Risk Averse	Low Risk Averse
• Need for formal rules and regulations • Norm for compromise • Strong faith in institutions • Belief in experts and their knowledge	• High tolerance for deviance • Norm for conflict • Weak faith in people and institutions
High Power Distance	Low Power Distance
• Norms for differential prestige, power and wealth • Norm for conflict • Authoritarian norm	• Prevailing egalitarian relationship • Norm for cooperation • Norms for interdependence, solidarity and affiliation
Masculinity	Femininity
• Value individual achievement • Norms for independent thought and action	• Norms for solidarity and service • Norm for cooperation • Social norms honoring and moral obligation

Source: Hofstede (1983)

APPENDIX B
Measurement Development

Measures	Items	Sources
Number of Innovation/year	• Total number of entirely new products introduced from the location between January 2014-December 2015 from the location? • Total number of new models/variants introduced between January 2014-December 2015 from the location?	Parente & Geleilate, 2015 Chi-square=213.6, p<0.05 RMSEA=0.04, CFI=0.96

	• Total number of entirely new processes introduced between January 2014-December 2015 from the location? • Total number of new processes/variants introduced between January 2014-December 2015 from the location?	
Total Number of Trainings	• Over the past year, how many trainings were conducted on the following topics? a) An updated word processor applications program such as the Word? b) An updated spreadsheet application program such as Excel? c) A special purpose application system (for example: case tracking or development) d) The local Area Network e) Any updated internet browser For each item in this section, response choices were: 1) None at all 2) One session (2-4 hours)	(Gallivan, Spitler and Kufaris, 2005)

	3) Two sessions (4-8 hours) 4) Three sessions (8-12 hours) 5) Four sessions (12-16 hours) 6) Five sessions (16-20 hours) More than five sessions	

APPENDIX C
Power Distance

People in higher positions should make most decisions without consulting people in lower positions.
People in higher positions should not ask the opinions of people in lower positions too frequently.
People in higher positions should avoid social interaction with people in lower positions.
People in lower positions should not disagree with decisions by people in higher positions.
People in higher positions should not delegate important tasks to people in lower positions.

Uncertainty Avoidance
It is important to have instructions spelled out in detail so that I always know what I'm expected to do.
It is important to closely follow instructions and procedures.
Rules and regulations are important because they inform me of what is expected of me.
Standardized work procedures are helpful.
Instructions for operations are important.

Individualism/Collectivism
Individuals should sacrifice self-interest for the group.
Individuals should stick with the group even through difficulties.
Group welfare is more important than individual rewards.
Group success is more important than individual success.
Individuals should only pursue their goals after considering the welfare of the group.
Group loyalty should be encouraged even if individual goals suffer.

Masculinity/Femininity
It is more important for men to have a professional career than it is for women.
Men usually solve problems with logical analysis; women usually solve problems with intuition.
Solving difficult problems usually requires an active, forcible approach, which is typical of men.
There are some jobs that a man can always do better than a woman.

Reliability Of This Scale:

- .91 (power distance) for Americans
- .89 (collectivism) for Koreans
- The five-dimensional measurement model exhibited an excellent fit.
- The model's χ^2 with 289 degrees of freedom is:
  - 496.27 for Americans
  - 416.34 for Koreans.
- RMSEA is:
  - .058 for Americans
  - .039 for Koreans.
- CFI and TLI are:
  - .91 for Americans
  - .94 for Koreans
- The item loadings to their constructs ranged from:
  - .43 (t-value = 5.97) to .85 (t-value = 15.10) for Americans
  - .56 (t-value = 4.71) to .87 (t-value = 14.24) for Koreans.

Source: Hofstede (1980), pp-403-410; Yoo, Donthu and Lenartowicz (2011)

APPENDIX D

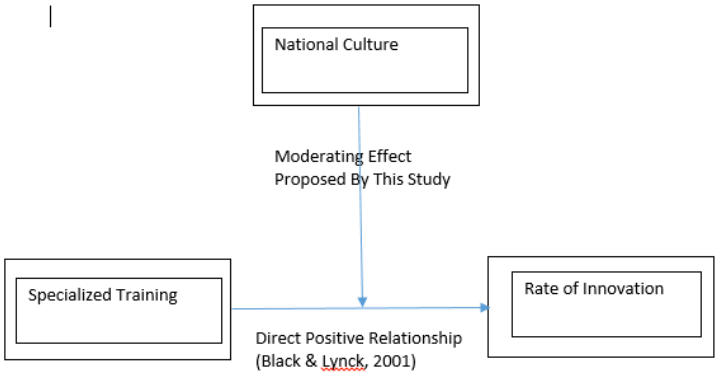

Figure 1: Conceptual Model Illustrating the Moderating Effect of National Culture on Relationship between Specialized Trainings and rate of Innovation

APPENDIX E

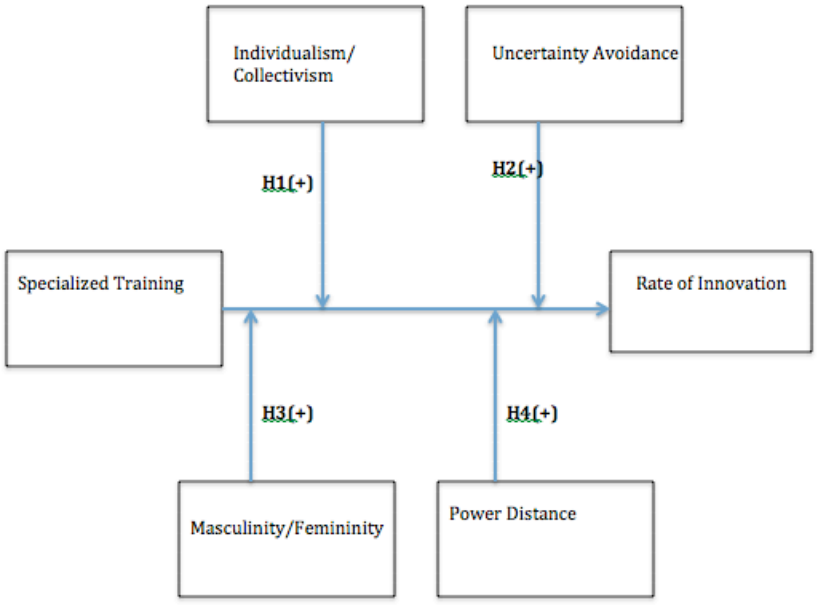

Figure 2: Conceptual Model Illustrating the Proposal Of this Paper

APPENDIX F

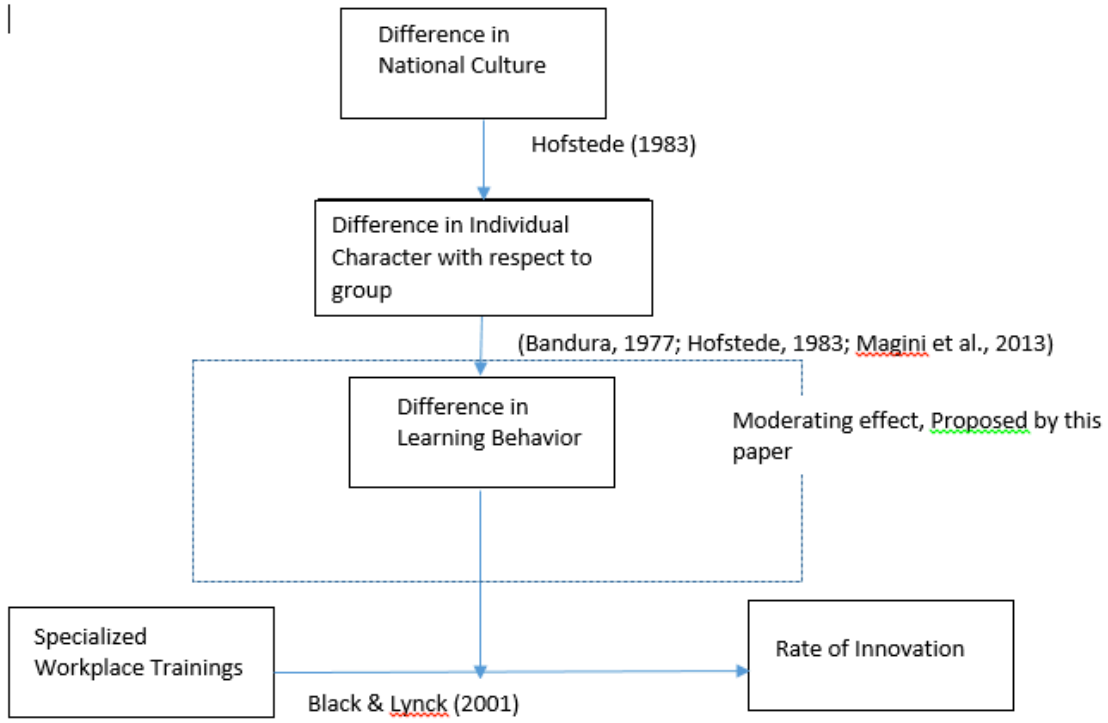

Figure 3: A Complete Model Illustrating the Theoretical Development

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DECISION SCIENCES INSTITUTE
Grouping-matching Heuristic for Single-machine Flow-rack AS/RS with Duration-of-stay Storage

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ABSTRACT

The single-machine flow-rack automated storage and retrieval system (AS/RS) has high storage density, high floor space utilization, low investment cost and low operational cost. Unit-loads in each bin of the single-machine flow-rack follows the first-in-first-out (FIFO) rule, which implies that inappropriate stored sequence of unit-loads brings extra travel time for restoring blocking unit-loads. In duration-of-stay (DOS) storage policy, the arrivals and departures of all unit-loads within a whole planning horizon are determined in advance. Therefore, a grouping-matching heuristic assigns FIFO unit-loads to the same group in the grouping step and matches group with most unit-loads to the bin closest to the pick-up/drop-off (P/D) station in the matching step. Simulation experiments are conducted to evaluate the performance of the grouping-matching heuristic.

KEYWORDS: single-machine flow-rack, AS/RS, duration-of-stay, storage assignment

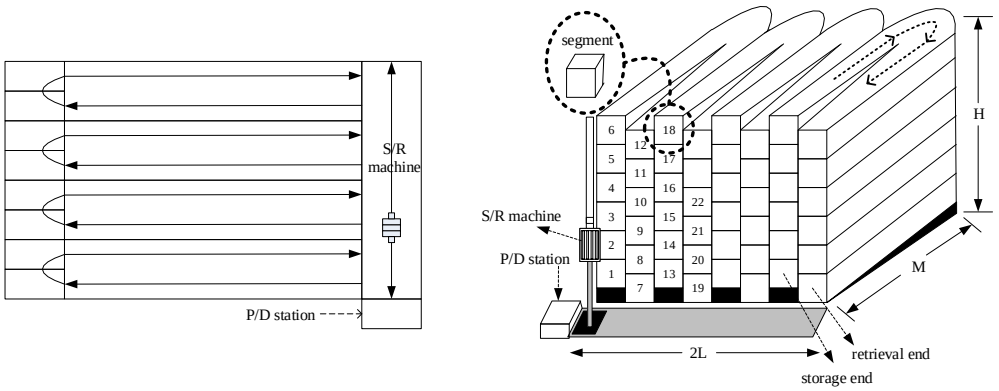
INTRODUCTION

Single-machine flow-rack AS/RS (Sari & Bessnouci, 2012) has high storage density and low implementation and operational costs since the depth movement of unit-loads in each bin is driven by the gravity. A single-machine flow-rack consists of multiple columns and rows of U-shaped bins as illustrated in Figure 1. Each bin has two adjacent ends, one is the storage end and another is the retrieval end. Unit-loads are stored to the storage end of a bin, slide to the retrieval end driven by the gravity and retrieved from the retrieval end. Since storage and retrieval ends located on the same face, one S/R (storage/retrieval) machine can perform storage and retrieval operations for a single-machine flow-rack AS/RS. Unit-loads in each bin follow the FIFO rule, which requires the appropriate stored sequence to avoid blocking unit-loads in each bin.

In DOS storage policy (Goetschalckx & Ratliff, 1990; Chen, Langevin & Riopel, 2010), arrivals and departures of unit-loads are known, based on which proper sequence of stored unit-loads can be generated in each bin to avoid blocking unit-loads. As well, to store as many unit-loads as possible to bins near the P/D station can save the total travel time of warehouse operations.

In this paper, a grouping-matching heuristic is applied for the storage assignment in a single-machine flow-rack AS/RS with DOS storage policy. In the grouping step, FIFO unit-loads are assigned into the same group based on the arrivals and departures of unit-loads. In the matching step, groups are matched to bins based on the number of unit-loads in a group and the travel time between the bin and the P/D station. A greedy-based heuristic is designed as the benchmark in this paper. Simulation experiments are conducted for the performance evaluation.

Figure 1: The structure of single-machine flow-rack AS/RS



PROBLEM DESCRIPTION

Assume a single-machine flow-rack AS/RS consists of L-column and H-row of bins as shown in Figure 1. There are a total of K bins where $K = LH$. Each bin can simultaneously store at most $2M$ unit-loads. The storage end of bins in the x^{th} column are labeled as $(2x – 2)H + 1$, $(2x – 2)H + 2$, …, $(2x – 2)H + H$ from the P/D station to the highest row where $x = 1, 3, …, L$. As well, the retrieval ends of bins in the x^{th} column are labeled as $(2x – 1)H + 1$, $(2x – 1)H + 2$, …, $(2x – 1)H + H$ from the P/D station to the highest row where $x = 1, 3, …, L$. An S/R machine performs the storage and retrieval operations. Let t_h and t_v be the travel times between horizontal and vertical adjacent ends, respectively. The travel times from the storage end and the retrieval end to the P/D station of a bin locates at x^{th} column and y^{th} row are $\max\{(2x – 1)t_h, (y - 1)t_v\}$ and $\max\{2xt_h, (y-1)t_v\}$, respectively. Blocking unit-loads are restored to the storage end of the same bin, which implies that the travel time of restoring a blocking unit-load is $2t_h$. Based on above estimations, the travel times of storage and retrieval operations can be easily calculated.

For the DOS storage policy, a planning horizon is divided into a number of T periods, which are denoted as 1, 2, ..., T. Let {1, 2, ..., N} be the set of unit-loads. A tuple of $[a_i, d_i]$ represents that a unit-load i is stored at period a_i and retrieved at period d_i. It can be known that $1 \le a_i < d_i \le T$. The length of a period is much longer than the total travel time of warehouse operations in the period, which ensures that all warehouse operations can be finished within the period. As well, the number of simultaneously existing unit-loads is less than or equals to the number of segments to let all unit-loads can be stored to the single-machine flow-rack. For period t, let $S^t = \{i_1, i_2, …, i_n\}$ be the sequence of incoming unit-loads where $a_{i_1} = a_{i_2} = . . . = a_{i_n} = t$ and $d_{i_1} \le d_{i_2} \le . . . \le d_{i_n}$. Correspondingly, the set of outgoing unit-loads is $R^t = \{j_1, j_2, …, j_m\}$, where $d_{j_1} = d_{j_2} = . . . d_{j_m} = t$.

In each period, outgoing unit-loads are retrieved before storing incoming unit-loads. In other words, the S/R machine performs retrieval operations then conducts storage operations. The primary aim of storage assignment in a single-machine flow-rack AS/RS with DOS storage policy is to minimize the average travel time of storage and retrieval operations.

PROPOSED METHODS

Greedy-based heuristic

Greedy-based heuristic is a simple and straightforward way to solve the optimization problems. It can get a feasible solution in a short time. For outgoing unit-loads, greedy heuristic generates retrieval operations based on the ascending order of bins. Blocking unit-loads are directly restored to the storage end of the same bin. After all outgoing unit-loads have been retrieved, storage

operations are generated. Assuming an incoming unit-load i with $[a_i, d_i]$, there is a bin k has a number of b unit-loads where $0 \le b \le M$-1. For a unit-load i stored to bin k, the number of blocking unit-loads of i is the number of unit-loads depart after period d_i stored in bin k. Therefore, the greedy-based heuristic chooses a bin closest to the P/D station from a bin set, in which all bins have empty segments and minimal blocking unit-loads of i. The Greedy heuristic is detailed in Algorithm 1.

Algorithm 1 Greedy

Input: N
Output: storage and retrieval operations
$t \leftarrow 1$;
while ($t \le T$) **do**
  Build S^t and R^t;
  while (R^t is not empty) **do**
    Let j be an outgoing unit-load in R^t;
    Restores blocking unit-loads, retrieve j, $R^t \leftarrow R^t - \{j\}$;
  while (S^t is not empty) **do**
    $i \leftarrow$ head(S^t), $S^t \leftarrow S^t - \{i\}$;
    Build a bin set B, in which all bins have empty segments and minimal blocking unit-loads of i;
    Select bin k closest to the P/D station of B;
    Store i to bin k;
  $t \leftarrow t + 1$;
  return.

The Grouping-matching heuristic

To store FIFO unit-loads to the same bin can avoid blocking unit-loads. Two grouping heuristic, the forward-grouping heuristic (FG) and the backward-grouping heuristic (BG), have been proposed to assign FIFO unit-loads to the same group (Chen, Li & Gupta, 2016).

FG selects a unit-load with minimal sum of a_i and d_i as the seed of a group and appends FIFO unit-loads with smallest d_i one by one to the end of group. The number of simultaneous existing unit-loads in each group is less than or equals to $2M$. Based on above mechanism, a total of K groups are generated at most. However, it cannot guarantee that all unit-loads are assigned to a certain group. In this case, FG must re-organize some of groups to let all unit-loads be assigned to a certain group. So, the remaining unit-loads are appended sequentially to the group containing the smallest number of unit-loads. The FG is detailed in Algorithm 2, in which o(G, j) represents the number of unit-loads in group G simultaneously existing with unit-load j.

Algorithm 2 FG

Input: N
Output: groups
for (g = 1**..**K) **do**
  $i \leftarrow \arg\min_{i' \in N}\{a_{i'} + d_{i'}\}$, $G_g \leftarrow \{i\}$, $N_G \leftarrow \{j | a_j \ge a_i, d_j \ge d_i, \text{o}(G_g, j) \le 2M-1\}$
  while ($N_G \ne \{\}$) **do**
    $j \leftarrow \arg\min_{j' \in NG}\{d_{j'}\}$, $G_g \leftarrow G_g \cup \{j\}$, $i \leftarrow j$, $N_G \leftarrow \{j | a_j \ge a_i, d_j \ge d_i, \text{o}(G_g, j) \le 2M-1\}$
  $N \leftarrow N - G_g$
  if (N = {}) **then**
    return.
while ($N \ne \{\}$) **do**
  $g \leftarrow \arg\min_{k \in \{1,\ldots,K\}}\{|G_k|\}$, $N \leftarrow N \cup G_g$, $G_g \leftarrow \{\}$
  sort $N = \{1, \ldots, n\}$ where $a_1 \le a_2 \le \ldots \le a_n$ and $d_i \le d_{i+1}$ where $a_i = a_{i+1}$
  for (i = 1..n) **do**
    if (o(G_g, i) ≤ $2M$–1) **do**

13: $G_g \leftarrow G_g \cup \{i\}$
14: $N \leftarrow N - G_g$
15: **return.**

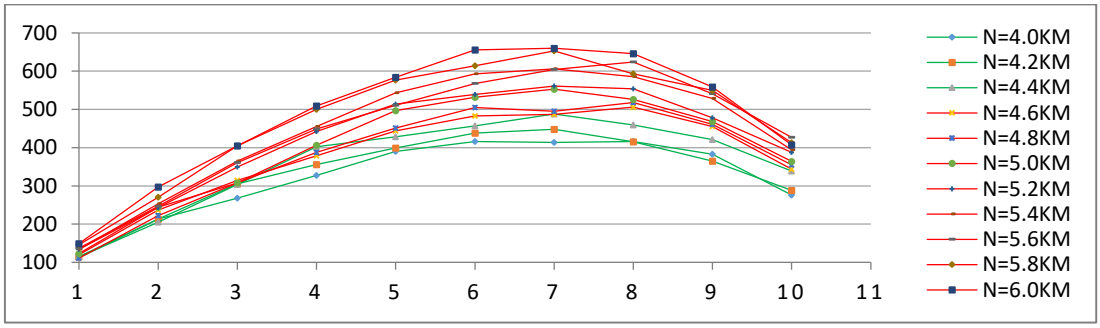
BG selects a unit-load with maximal sum of a_i and d_i as the seed of a group and appends FIFO unit-loads with maximum d_i one by one to the head of group. The number of simultaneous existing unit-loads in each group is also less than or equals to $2M$. Based on above mechanism, a total of K groups are generated at most. However, it also cannot guarantee that all unit-loads are assigned to a certain group. In this case, BG applies the same mechanism of FG to let all unit-loads be assigned to a certain group. In short, BG applies "$i \leftarrow \arg\max_{i' \in N}\{a_{i'} + d_{i'}\}$, $G_g \leftarrow \{i\}$, $N_G \leftarrow \{j | a_j \le a_i, d_j \le d_i, o(G_g, j) \le 2M-1\}$" and "$j \leftarrow \arg\max_{j' \in NG}\{d_{j'}\}$, $G_g \leftarrow G_g \cup \{j\}$, $i \leftarrow j$, $N_G \leftarrow \{j | a_j \le a_i, d_j \le d_i, o(G_g, j) \le 2M-1\}$" to replace Step 2 and 4 of Algorithm 2.

After the grouping step, groups are matched to bins. To maximize the number of unit-loads allocated in the first one, the first two, …, the first K bins can minimize the total travel time for storage and retrieval operations (Goetschalckx & Ratliff, 1990). Therefore, a group with the most unit-loads is matched to a bin closest to the P/D station. The aim of matching step is to let as many unit-loads as possible be stored to bin near the P/D station.

EXPERIMENTAL RESULT AND ANALYSIS

In simulation experiments, 50 bins in the single-machine flow-rack AS/RS were set, where $L = 5$, $H = 10$, $t_h = 2.0$s and $t_v = 1.0$s. The number of stored unit-loads in each period must be smaller or equal to the number of segments, i.e., $2KM$. Let $M = 5$. It can be known that the number of segments is 500. Therefore, the maximum number of stored unit-loads in a period must be smaller than or equal to 500. Figure 2 illustrates the average number of stored unit-loads for each period under different values of N. The curves reveal that when $N \ge 4.6$KM, the number of stored unit-loads easily exceeds the limitation of 500. Therefore, let $N = 4.4KM$ in simulation experiments. Let $M = \{10, 14, 18, 22\}$ and $T = \{11, 13, 15, 17\}$. It needs to analyze 16 combinations of M and T and generates 100 instances for each combination.

Figure 2 The number of unit-loads stored in AS/RS under different *KM* coefficients for each period



The number of incoming unit-loads in each period is randomly generated. For unit-load i arrives at period a_i, let d_i be uniformly distributed in the interval of $[a_i + 1, T]$. All simulation experiments are coded in C++ and executed on a laptop with 2.5GHz CPU and 8GB CPU.

Table 1 demonstrates the experimental results of the greedy and the grouping-matching heuristics. "*Cost*" represents the average travel time to store and retrieve a unit-load, "*Block*" indicates the average number of blocking unit-loads, "*ARPD*" is the performance measure of of the algorithm ($Z_{min} = \min\{Z_G, Z_{FG}, Z_{BG}\}$, $ARPD_G = (Z_G - Z_{min}) / Z_{min} * 100$, $ARPD_{FG} = (Z_{FG} - Z_{min}) /$

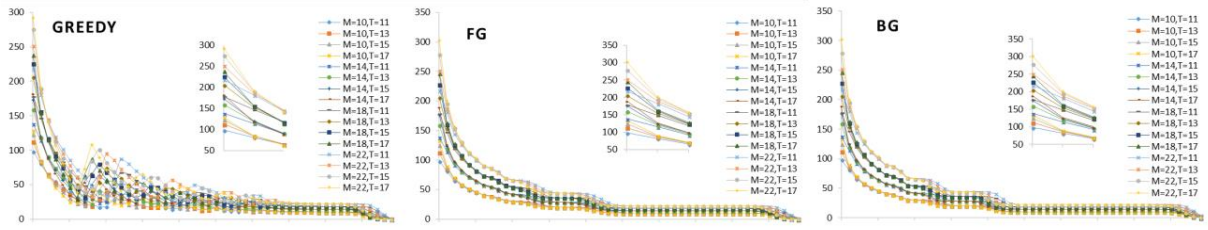
Z_{min} * 100, $ARPD_{BG}$ = (Z_{BG} - Z_{min}) / Z_{min} * 100) where Z is the total travel time of storage and retrieval operations within the whole planning horizon and "*CPU*" is the efficiency performance of algorithm (in seconds). Table 1 clarifies that FG obtains the lowest average travel time to store and retrieve a unit-load. Although the differences between FG and BG are not obvious, the values of ARPD show that FG can gain better solution than BG does. The values of *CPU* clarify that the computation speed of the greedy is faster than FG and BG, since greedy checks the departures of unit-loads and grouping-matching heuristic considers arrivals and departures of unit-loads.

Table 1: Performance evaluation of the greedy and the grouping-matching heuristics

		Greedy				FG				BG			
M	*T*	*Cost*	*ARPD*	*Block*	*CPU*	*Cost*	*ARPD*	*Block*	*CPU*	*Cost*	*ARPD*	*Block*	*CPU*
10	11	28.87	4.04	0.00	0.11	27.75	0.02	0.00	1.16	27.92	0.65	0.00	0.78
	13	28.00	4.33	0.00	0.08	26.84	0.01	0.00	1.14	27.15	1.14	0.00	0.71
	15	27.55	4.93	0.00	0.16	26.25	0.01	0.00	1.07	26.59	1.29	0.00	0.68
	17	27.48	6.40	0.00	0.06	25.82	0.00	0.00	1.04	26.20	1.46	0.00	0.73
14	11	28.91	4.22	0.00	0.13	27.75	0.03	0.00	0.97	27.96	0.78	0.00	1.29
	13	28.04	4.31	0.00	0.17	26.88	0.01	0.00	1.99	27.16	1.07	0.00	1.33
	15	27.43	4.83	0.00	0.20	26.17	0.01	0.00	1.91	26.52	1.37	0.00	1.24
	17	27.31	6.06	0.00	0.18	25.76	0.02	0.00	1.94	26.10	1.35	0.00	1.23
18	11	28.89	4.06	0.00	0.21	27.77	0.01	0.00	3.11	27.96	0.73	0.00	2.10
	13	27.88	4.07	0.00	0.27	26.79	0.01	0.00	3.22	27.08	1.11	0.00	2.02
	15	27.28	4.70	0.00	0.27	26.05	0.00	0.00	3.17	26.44	1.47	0.00	1.99
	17	27.17	5.99	0.00	0.27	25.63	0.00	0.00	3.01	26.03	1.55	0.00	1.86
22	11	28.84	4.07	0.00	0.29	27.71	0.01	0.00	4.56	27.89	0.65	0.00	2.95
	13	27.92	4.22	0.00	0.28	26.79	0.00	0.00	4.38	27.09	1.13	0.00	2.78
	15	27.27	4.63	0.00	0.33	26.07	0.00	0.00	4.42	26.43	1.39	0.00	2.74
	17	27.10	5.70	0.00	0.35	25.64	0.01	0.00	4.34	25.99	1.38	0.00	2.60

The average numbers of unit-loads assigned to bins with the ascending travel time to the P/D station are illustrated in Figure 3. The horizontal axis in Figure 3 is arranged in ascending sequence according to the travel time between storage end and P/D station. Figure 3 illustrates that FG and BG can simultaneously maximize the number of unit-loads allocated in the first one, the first two, …, the first *K* bins. However, the greedy cannot simultaneously maximize the number of unit-loads allocated in the first one, the first two, …, the first *K* bins. Therefore, greedy has the longest average travel time of storing and retrieving one unit-load among all three methods, as represented in Table 1. Therefore, the grouping-matching heuristic is suitable for the storage assignment in single-machine flow-rack AS/RS with DOS storage policy.

Figure 3 The number of unit-loads stored in AS/RS under different KM coefficients for each time period



CONCLUSIONS

In this paper, the effectiveness of the grouping-matching heuristic for the storage assignment in a single-machine flow-rack AS/RS with DOS storage policy is analyzed by simulation experiments. In the grouping step, FIFO unit-loads are assigned into the same group based on the arrivals and departures of unit-loads. FG appends FIFO unit-loads at the end of group and BG appends FIFO unit-loads at the head of group. In the matching step, groups are matched to bins based on the

number of unit-loads in a group and the travel time between a bin and the P/D station. FG and BG can simultaneously maximize the number of unit-loads allocated in the first one, the first two, …, the first K storage bins. According to simulation experiments of performance evaluation, the grouping-matching heuristic is an effective and efficient method. FG has better performance than BG does.

Since grouping-matching heuristic only generates storage and retrieval operations, novel heuristic should be designed to generate DC (dual-command cycle) operations based on the storage assignment results obtained by the grouping-matching heuristic to further reduce the total travel time of warehouse operations.

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Health Information Technology Adoption and its Impact on Quality of Care, Efficiency, and Patient Flow

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ABSTRACT

This study examines the relationship between health information technology (HIT) practices and patient care quality characteristics for acute care hospitals. More specifically, using a sample from Pennsylvania hospitals using econometric analyses we examine the impact that HIT functionalities such as electronic health record and health information exchange have on quality of care measures such as risk adjusted mortality and risk adjusted readmission rates; hospital efficiency measures such as cost per inpatient day and cost per inpatient admission, and on patient flow measure such as average length of stay. Our findings indicate a mixed bag. Implications of the study are discussed.

KEYWORDS: Hospital efficiency, quality of care, health information technology, electronic health records, health information exchange.

INTRODUCTION

The United States spends far more per person on healthcare than other industrialized nations but fares worse on most of them on several health indicators even though comparatively Americans use fewer medical services (Lee, 2014). Setting aside factors like fraud, human error, inflated prices, or prevention failure, this waste can be attributed to money spent on inefficient care delivery, and the slack in system elements such as unnecessary services or administrative staff. In fact, inefficient care delivery and unnecessary services are explanations often offered for higher healthcare costs, which could be avoided with better health information management. Proponents of health information technology (HIT) claim there are tremendous benefits such as reduction in length of hospital stays, reduced readmissions, greater information exchange, improved patient safety, improved quality of care including reduction in medical errors, among others, for the U.S. health care system. Despite these apparent benefits, the U.S. lags other developed countries in HIT use (Blumenthal, 2009). In order to promote HIT use in hospitals and clinics, the American Recovery and Reinvestment Act of 2009 allocated $19.2 billion (Prasad, 2014).

Previous researches have produced mixed results pertaining to the benefits of HIT. For instance, Devaraj and Kohli (2003) found that HIT usage is associated with a reduction in patient mortality rates and greater hospital productivity measures as revenue generated per admission. Menon et al. (2000) provide evidence of a positive impact such as of medical information technology (IT) capital on hospital output as well as marginal hospital revenue. Zhivan and Diana (2012) demonstrate that hospitals with more cost inefficiency were more likely to introduce electronic health record (EHR). More recently, Bardhan and Thouin (2013) show positive association between HIT usage and quality of delivery and reduced operating expenses. However, there are several studies that have found little or no positive association between HIT usage and hospital performance. For instance, Furukawa et al. (2010) examined the impact of EHR adoption on hospital cost-inefficiency in medical-surgical units and found that the presence of an EHR was associated with significantly higher inefficiency. Kazley and Ozcan (2009) found no significant improvement in efficiency over time due to EHR usage. Agha (2014) analyzed the impact of HIT on the quality and intensity of medical care and found no evidence of cost savings even five years after adoption; and HIT adoption appeared to have little impact on the quality of care. Thompson et al. (2015) found that HIT had no substantial effect on mortality, length of stay, or cost in the inpatient and ICU. Most scholars have empirically chosen to investigate a lot of hospital variables in conjunction with HIT, some of which may be inter-related and thus, there may have been compounding effects. Given that the impact of HIT on organizational-level variables such as hospital efficiency and the quality of care has been mixed, we wanted to take a slightly different methodological approach by adopting econometric analyses with longitudinal panel data to investigate the link between HIT and hospital efficiency measures; and between HIT and hospital quality. In this research we investigate the following question: *what is the link between health information technology (HIT) practices and the quality of care and between HIT practices and other quality of care-related hospital level variables—hospital efficiency measures and patient flow?*

This study extends the existing literature in several ways. First, we include a broad spectrum of HIT functionalities to study its impact on hospital performance. Second, our recent data set provides us an excellent opportunity to determine HIT's impact due to the long gestation period that may be necessary before the effects of learning curve with HIT implementation can set in throughout the organization/hospital. Finally, this study specifically focuses on Pennsylvania, which is a compelling target state for this study for several reasons: first, it captures national trends toward increased HIT use; second, due to its patient demographics, Pennsylvania (PA) is the home to the nation's third-largest rural population and it has the third-largest population of elderly in the United States; and finally, the level of uninsured Pennsylvanians as of 2013 were roughly the same as that of the national average.

The remainder of our paper is structured as follows. First, we draw from tenets of the Theory of Swift, Even Flow (TSEF) to theoretically ground our expected relationships among the variables, expressed in propositions. Second, we present our regression models that we would use for our study, explaining the variables in detail. Finally, we discuss the implications of our model, address the limitations of the study, and conclude with future directions.

THEORETICAL BACKGROUND AND HYPOTHESES

The Theory of Swift, Even Flow (TSEF) (Cf. Devaraj & Kohli, 2013; Deming, 1986; Fredendall et al., 2009; Schmenner, 2004; Schmenner & Swink, 1998; Venkatesh, 2006) notes that the swifter and more even is the flow of materials through a process, the more productive that process becomes. Thus, productivity of any process—labor, machine, materials, or total factor productivity—increases with the speed by which materials flow through the process, and decreases with increases in the variability associated with the flow—variability associated with the demand on the process or with steps in the process itself.

TSEF has been applied to the healthcare context in extant literature. Devaraj and Kohli (2013) empirically demonstrated that HIT is associated with swift and even patient flow, which in turn is associated with increased hospital revenues. Their 2013 study demonstrated the differential effects of swift flow and even flow on various measures of hospital performance and noted that although swift flow affects financial performance, even flow primarily affects quality performance; and taken together, they have a mutually reinforcing overall impact on hospital performance. Applying TSEF, Yeow and Goh (2015) examined how resources are allocated to healthcare tasks and processes and their study suggested that the gains in allocative efficiency for a few processes are associated with improved organizational outcomes.

In the following sections we draw from the tenets of TSEF to support our hypothesized relationships among the variables in the study. We first discuss quality of care and then introduce HIT and other associated variables that help improve the quality of care delivered in hospitals.

Quality of Care

Quality of care in U.S. hospitals has been a growing concern ever since the Institute of Medicine's (IOM's) quality chasm report revealed widespread incidence of medical errors and substandard care. Because of preventable medical errors, hospitals incur an estimated total cost of between $17 billion and $29 billion per year (Kohn, Corrigan, & Donaldson 1999). Hospitals have been continually working on improving all three measures of quality of care: *structural*–-by adopting HIT and improving staffing ratios; *process*–-the generally accepted recommendations for clinical practice such as providing preventative services or conducting tests; and, *outcomes*–-hospital-acquired infections, risk-adjusted mortality, and risk-adjusted readmissions, among others. Previous literature has frequently cited several measures pertaining to quality including risk-adjusted mortality, risk-adjusted readmissions, average length of stay, registered nurse per bed, and risk-adjusted morbidity (Hvenegaard et al., 2011; Needleman et al., 2006; Pai, Hosseini, & Brown 2017). In this paper, we use two commonly cited measures of quality of care: *readmission index* and *mortality index*.

Preventable hospital readmissions constitute a significant part of avoidable medical spending. In 2013, nearly 18 percent (or roughly two million) of Medicare patients who had been hospitalized were readmitted within a month, costing Medicare $26 billion, an estimated $17 billion of which came from potentially avoidable readmissions (Rau, 2014). These hospitals faced a penalty rate as high as 3 percent for readmissions and additional penalties for hospital acquired conditions. In 2015, 72 percent (or 126 hospitals) of the Pennsylvania hospitals were penalized for excessive readmissions, with an average penalty of 0.63 percent of Medicare reimbursements (Rau, 2014). Prior research suggests that large hospitals, teaching hospitals, and safety-net hospitals are more likely to be penalized for excessive readmissions under the HRRP due to both medical complexity and socioeconomic mix of the patient population (Joynt, Orav & Jha, 2011; Joynt & Jha, 2013). For instance, teaching hospitals are generally resource-intensive and may incur higher operating expenses because they are affiliated with medical schools, located in urban areas, treat the most complex patients' cases and the urban underserved population (Shahian et al., 2012). Furthermore, safety-net hospitals treat large numbers of low-income patients, who face financial and access challenges that may deteriorate their medical condition after discharge compared with others. Joynt and Jha (2013) observe that there is less evidence that differences in readmissions with their smaller, nonteaching and non-safety-net counterparts are related to quality of care. Prior research as well as anecdotal evidence suggest that HIT systems may help prevent readmissions by improving access to clinical data across hospital systems, especially after discharge from hospital (Walker et al., 2005; Jones, Friedberg, & Schneider, 2011). The second quality of care indicator, *mortality*

index, measures to what extent a hospital's inpatient mortality rate is higher or lower than expected for a group of diagnoses and procedures given the risk factors of the patient population, where an index of 1.00 indicates that the actual mortality rate equals the expected rate.

Health Information Technologies and Hospital Efficiency

Health Information Technology (HIT) has impacted hospital operations in many ways. First, HIT help providers with easy access to patient health information such as diagnosis, lab results, list of medications, among others, so they can focus more on patient care activities. Second, coordination, quality, and cost of patient care may be improved as technologies are used to exchange patient information with external providers. For instance, the ability to electronically send patients reminder notices for preventive or follow-up care (e.g., computerized reminder system) may reduce in hospital costs and increase life expectancy (Shekelle et al., 2006). Finally, administrative costs, which accounts for 25 percent–-or over $200 billion–-of total U.S. hospital spending (Himmelstein et al., 2014), are expected to fall as new technologies are adopted that enable paperless transactions.

This study focuses on two types of health information technologies: *electronic health records (*EHR*)* and *health exchange information (*HIE*)*. An EHR is a digital version of a patient's medical records that can be accessed by authorized providers and staff across more than one health care organization. Health Information Exchange allows healthcare providers including doctors, nurses, pharmacists, and other healthcare providers to electronically access and share a patient's clinical information that are constantly updated on demand at the point of care.

The EHRs used by the hospitals in this study has some or all of the following capabilities: electronic clinical documentation (e.g., demographics, vital signs, provider notes, medication lists, allergy lists), results viewing (e.g., lab reports, radiology reports), computerized provider order entry (e.g., lab tests, radiology tests, consultation requests), closed-loop medication tracking system, population health management, medication management, automated quality measures reporting, and public health reporting. King et al. (2014) in their study argue that most physicians reported EHR use enhanced patient care overall, helped them access a patient's chart remotely, and alerted them to a potential medication error and critical lab values. Furthermore, the authors found that between 30 and 50 percent of physicians reported that EHR use led to clinical benefits related to providing recommended care, ordering appropriate tests, and facilitating patient communication. Anecdotal evidence suggests that the use of an EHR eliminates the potential for confusion and medical error, and shortens the average work-up time from weeks to less than a day. In an integrated, multi-specialty medical group, for example, the average work-up time from lung cancer diagnosis to surgery dropped by more than half: from 40 days, the U.S. average, to just 16 days (Pearl, 2016). Thus, there is reason to believe that the adoption of EHR may contribute to overall healthcare productivity.

The health information exchange (HIE) functionalities used by hospitals in this study have the ability to electronically exchange or share patient information with one or more of provider types: with hospitals and ambulatory providers in the system, and with hospitals and ambulatory providers outside of the system. The following information could be shared by the hospitals' HIE - patient demographics, laboratory results, medication history, radiology reports, and clinical and summary care records, among others. Anecdotal evidence suggests that use of HIE has resulted in improved quality and efficiency of healthcare by allowing healthcare providers to access and share patient clinical information. Hersh et al. (2015) review the available literature on health information exchange. The authors observe that the use of HIE has risen over time, and is the highest in hospitals. They also find evidence that the use of HIE has led to reduced use of some specific resources and improvements in quality-of-care measures. The authors, however, claim that the full impact of HIE on healthcare outcomes,

especially clinical outcomes, is inadequately studied and future studies are needed to advance understanding of HIE. Jung et al. (2015) find positive association between HIE use and cost savings attributable to repeat imaging. Carr et al. (2014) investigate the ability of an HIE to decrease health services use for patients at an urban emergency department (ED). Clinicians participating in the study reported that the use of HIE resulted in reduced use of hospital resources, cost savings, decreased LOS, and improved quality of care.

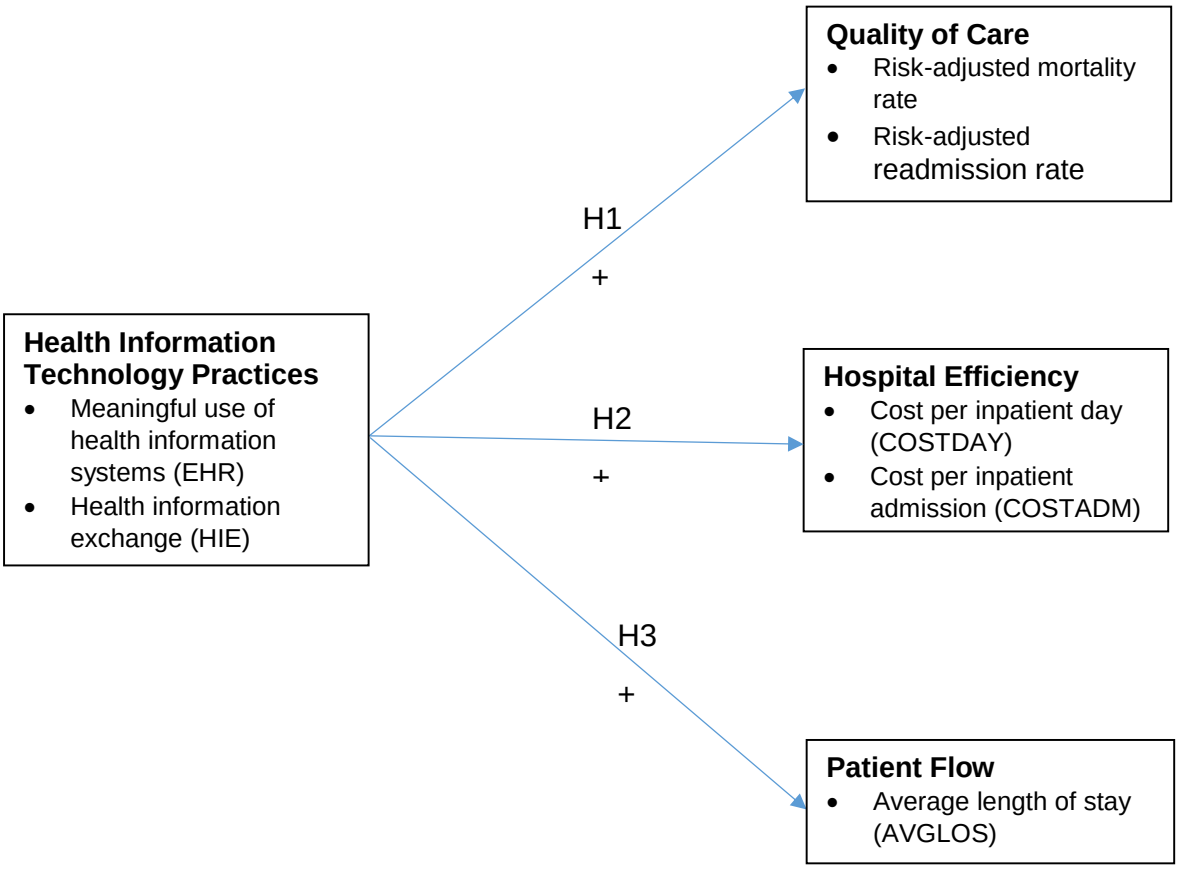
Now taking all the above variables together and drawing from the tenets of TSEF we suggest that if hospitals can smoothen/even out their patient flow in the hospitals, the day-to-day tasks related to patient care in the actual departments such as the operating rooms, blood banks, X-rays, CT scan, radiology and testing labs can all be done quickly and efficiently. This will consequently result in better time utilization of the healthcare team members (physicians, nurses and support staff) and with the advantage of receiving the correct and up-to-date information regarding the patient from the health information technology, better quality care can be delivered to the patients, on time, and their needs can be addressed by the healthcare team members. As a result, readmission and mortality rates should decrease over time. In sum, based on the above discussions, drawing support from TSEF we hypothesize three aggregate relationships among the variables:

> *Health information technology (HIT) practices are positively related to: (1) quality of care (**H1**); (2) hospital efficiency (**H2**); and (3) patient flow (**H3**) in the hospital.*

The research model being empirically tested is presented below. Although each of our hypotheses has a few sub-parts—one each for the indicators of the predictor and criterion variable combinations, for brevity we have numbered the hypotheses only at the aggregate variable level.

FIGURE 1

Health Information Technology Practices and Quality of Care, Hospital Efficiency and Patient Flow



METHODS

Procedures

The data for these analyses come from four different sources: (1) the Pennsylvania Health Care Cost Containment Council (PHC4) Hospital Performance Reports (HPR) provide data pertaining to financial analysis, health performance, utilization, among others; (2) the CMS cost reports provide data pertaining to case mix index and average hourly wages; (3) the demographic data come from the County Health Profiles; and (4) the HIT functionalities data are obtained from American Hospital Association.

Variables

Quality of care variables. We considered two quality of care indicators: *readmission index* and *mortality index*, which measure outcome quality by taking a weighted average of risk-adjusted readmissions rate and risk-adjusted mortality rate, respectively, for 11 common medical procedures and treatments identified by the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes for hospitals in Pennsylvania. The following procedures and treatments were used: abnormal heartbeat, chest pain, chronic obstructive pulmonary disease, congestive heart failure, diabetes, gall bladder removal, heart attack, hypotension, kidney failure, pneumonia, and stroke. The weighted outcome quality index was computed as follows:

$$Mortality\ Index_{ht} = \frac{\sum c_{pht} RAM_{pht}}{C_{ht}}\ \ \forall h; Readmission\ Index_{ht} = \frac{\sum c_{pht} RAR_{pht}}{C_{ht}}\ \ \forall h$$

where RAM_{pht} captures the risk-adjusted mortality rate from the p^{th} procedure for the h^{th} hospital in year t. Similarly, RAR_{pht} captures the risk-adjusted readmission rate from the p^{th} procedure for the h^{th} hospital in year t. c_{pht} captures number of cases in p^{th} procedure for the h^{th} hospital in year t. C_{ht} captures the total number of cases across all 11 procedures.

Efficiency variables. We considered two measures of efficiency: *cost per patient day* and *cost per adjusted admission*. Regardless of the reimbursement methodology used, lower costs—cost per patient day and cost per adjusted discharge—lead to higher profitability, *ceteris paribus*.

The efficiency measure—*cost per patient day* (COSTDAY) is computed by dividing the total operating expenses by patient days, whereas, the other efficiency measure—*cost per adjusted admission* (COSTADM) is computed by dividing the total operating expenses by total admissions adjusted for case-mix index.

Other variables. As a proxy for smooth patient flow, we used the average length of patient stay (AVGLOS) in the hospital. Based on an extensive literature search, quite a few key control variables were identified and incorporated. The choice of the variables included in the study is consistent with existing literature in the healthcare and operations management areas (Ciliberto & Lindrooth, 2007; Deily, McKay, & Dorner, 2000; Kim, 2010; Mullner et al., 1982): *beds set up and staffed*, a better indicator of hospital capacity compared with licensed beds; *occupancy rate*, a measure of hospital utilization, which past literature suggests may have frequently been the cause of financial distress in many hospitals and their eventual closure; *case mix index*, used to capture the complexity of operation of a hospital; *ownership*, by which hospitals are categorized as either for-profit and not-for-profit; *teaching status*, as teaching hospitals are generally resource-intensive and may incur higher operating expenses because they are affiliated with medical schools, located in urban areas, treat the most complex patients' cases and the urban

underserved population, train physicians and other health professionals, and advance research (Shahian et al., 2012); *location*, which the empirical evidence shows impacts hospital performance (Younis, 2003; McKay, Lemak, & Lovett, 2008); and *year*, which accounts for possible trend effects.

Payer mix, which in this study refers to the percentage of revenue coming from Medicare and Medicaid was controlled for in this study. Payer mix is important because Medicare and Medicaid typically pay hospitals less than what it costs them to treat. *Percentage of bad debt* and *charity care* were also controlled for as both are known to inflate hospital operating expenses and to be highly correlated with not-for-profit status (Ding, 2014). In the PHC4 data set, both bad debt and charity care were combined; hence, bad *debt and charity care* were treated as a single variable.

In addition, two demographic variables were included that provide information about the county in which the hospital is located: *percentage population below poverty line* (BPL) and *percentage of residents who are age 65 or older*. Also included were the variables *operating margins* and *number of general acute care hospitals* in the county. Operating margin is one of the most popular metrics for determining hospital profitability.

Regression Models

We examine the relationship between HIT adoption and hospital efficiency, quality of care and patient flow using ordinary least squares model with hospital random effects. We intend to use a continuous measure of hospital HIT adoption based on the proportion of functionalities implemented.

$$COSTDAY_{it} = \beta_0 + \beta_1 (EHR_{it-1}) + \beta_2 (HIE_{it-1}) + \beta_3 (Beds_{it}) + \beta_4 (Case\ Mix_{it}) + \beta_5 (Operating\ Margins_{it}) + \beta_6 (Charity_{it}) + \beta_7 (Medicare_{it}) + \beta_8 (Medicaid_{it}) + \beta_9 (Ownership_{it}) + \beta_{10} (Teaching_{it}) + \beta_{11} (Location_i) + \beta_{12} (\%\ Population\ Aged\ 65\ Years\ or\ Above_{it}) + \beta_{13} (\%\ Population\ Below\ Poverty\ Line_{it}) + \beta_{14} (Number\ of\ Acute\ Care\ Hospitals_{it}) + \beta_{15} (Years_t) + \varepsilon_{it} \quad (\textbf{\textit{Model 1}})$$

$$COSTADM_{it} = \beta_0 + \beta_1 (EHR_{it-1}) + \beta_2 (HIE_{it-1}) + \beta_3 (Beds_{it}) + \beta_4 (Case\ Mix_{it}) + \beta_5 (Operating\ Margins_{it}) + \beta_6 (Charity_{it}) + \beta_7 (Medicare_{it}) + \beta_8 (Medicaid_{it}) + \beta_9 (Ownership_{it}) + \beta_{10} (Teaching_{it}) + \beta_{11} (Location_i) + \beta_{12} (\%\ Population\ Aged\ 65\ Years\ or\ Above_{it}) + \beta_{13} (\%\ Population\ Below\ Poverty\ Line_{it}) + \beta_{14} (Number\ of\ Acute\ Care\ Hospitals_{it}) + \beta_{15} (Years_t) + \varepsilon_{it} \quad (\textbf{\textit{Model 2}})$$

$$READMIN_{it} = \beta_0 + \beta_1 (EHR_{it-1}) + \beta_2 (HIE_{it-1}) + \beta_3 (Beds_{it}) + \beta_4 (Case\ Mix_{it}) + \beta_5 (Operating\ Margins_{it}) + \beta_6 (Charity_{it}) + \beta_7 (Medicare_{it}) + \beta_8 (Medicaid_{it}) + \beta_9 (Ownership_{it}) + \beta_{10} (Teaching_{it}) + \beta_{11} (Location_i) + \beta_{12} (\%\ Population\ Aged\ 65\ Years\ or\ Above_{it}) + \beta_{13} (\%\ Population\ Below\ Poverty\ Line_{it}) + \beta_{14} (Number\ of\ Acute\ Care\ Hospitals_{it}) + \beta_{15} (Years_t) + \varepsilon_{it} \quad (\textbf{\textit{Model 3}})$$

$$MORTIND_{it} = \beta_0 + \beta_1 (EHR_{it-1}) + \beta_2 (HIE_{it-1}) + \beta_3 (Beds_{it}) + \beta_4 (Case\ Mix_{it}) + \beta_5 (Operating\ Margins_{it}) + \beta_6 (Charity_{it}) + \beta_7 (Medicare_{it}) + \beta_8 (Medicaid_{it}) + \beta_9 (Ownership_{it}) + \beta_{10} (Teaching_{it}) + \beta_{11} (Location_i) + \beta_{12} (\%\ Population\ Aged\ 65\ Years\ or\ Above_{it}) + \beta_{13} (\%\ Population\ Below\ Poverty\ Line_{it}) + \beta_{14} (Number\ of\ Acute\ Care\ Hospitals_{it}) + \beta_{15} (Years_t) + \varepsilon_{it} \quad (\textbf{\textit{Model 4}})$$

$$AVGLOS_{it} = \beta_0 + \beta_1 (EHR_{it-1}) + \beta_2 (HIE_{it-1}) + \beta_3 (Beds_{it}) + \beta_4 (Case\ Mix_{it}) + \beta_5 (Operating\ Margins_{it}) + \beta_6 (Charity_{it}) + \beta_7 (Medicare_{it}) + \beta_8 (Medicaid_{it}) + \beta_9 (Ownership_{it}) + \beta_{10} (Teaching_{it}) + \beta_{11} (Location_i) + \beta_{12} (\%\ Population\ Aged\ 65\ Years\ or\ Above_{it}) + \beta_{13} (\%\ Population\ Below\ Poverty\ Line_{it}) + \beta_{14} (Number\ of\ Acute\ Care\ Hospitals_{it}) + \beta_{15} (Years_t) + \varepsilon_{it} \quad (\textbf{\textit{Model 5}})$$

Where, the subscript i = 1…N represents each hospital and t = 1, 2, …T represents each year from 2014 to 2016.

RESULTS

Health information exchange (HIE) had a negative but statistically significant impact on efficiency measure—COSTDAY, whereas it had a positive and statistically significant impact on patient flow measure—average length of stay (AVGLOS). Surprisingly, HIE also was positively associated with mortality index. Contrary to our expectation, electronic health record (EHR) was positively associated with readmission index; however, it did not significantly impact mortality index, efficiency measures and ALOS. The detailed results are presented in Table 1.

TABLE 1

Results of Regression Analyses

Variables	Cost per Day	Cost per Admission	Readmission Index	Mortality Index	Avg. LOS
EHR	0.000	0.011	0.065 **	0.001	-0.004
HIE	-0.021 ***	-0.026	0.003	0.008 **	0.014 ***
Beds	0.000	0.001	0.037 ***	0.004 ***	0.001 ***
Case Mix Index	-3.563 ***	-9.868 ***	-2.108	0.462 *	0.887 ***
Operating Margins	-0.729	-6.410 **	6.700 **	0.969 **	-1.243 ***
Bad Debt & Charity Care	-3.333	-4.902	51.032 **	9.137 **	3.691
Medicare as % of NPR	-8.423 ***	-27.300 ***	16.327 ***	2.921 ***	1.727 ***
Medicaid as % of NPR	-1.200	3.169	-8.604 **	-1.266 **	2.296 ***
Ownership	-0.582 *	-2.138 **	0.286	0.327 **	0.113
Teaching	0.682 **	1.800 *	0.288	0.128	-0.211 *
Location	-1.382 ***	-2.812 ***	2.215 **	0.070	0.501 ***
% Population Over 65 years	-0.033	0.258	-0.114	0.071 **	0.120 ***
% Below Poverty Line	0.025	0.188 **	-0.065	-0.003	0.013
#Acute Care Hospitals	0.015	0.026	-0.026	-0.023 *	0.024 **
Year 2015	0.461 *	0.905	-0.342	-0.389 ***	-0.197 **
Year 2016	0.898 ***	1.563 *	-0.783	-0.264 **	-0.421 ***
(Constant)	14.132	35.573	-4.428	-3.046	-0.673

****p<0.01; **p<0.05; *p<0.1; NPR - Net patient revenue*

In line with the major findings in extant literature on impact of HIT on hospital quality-related variables, a summary of all the hypotheses tested in our study, presented in Table 2, indicate only partial support for hypotheses. While two out of four hypotheses under ***H1*** were supported (one with each of our predictor-criterion combination), only one of the four hypotheses under ***H2*** were supported and similarly only one of the two hypotheses under ***H3*** were supported. Thus, with statistical significance of only the four out of the 10 regression coefficients we can only claim partial support for the hypotheses tested in this study. Like several other past studies, our research too reveals mixed impact of HIT on quality of care, efficiency and patient flow.

TABLE 2

Hypotheses Testing Summary

Hypothesis	Predictor	Criterion				
		Quality of Care		Hospital Efficiency		Patient Flow
		Mortality Rate	*Readmission Rate*	*Cost per inpatient day*	*Cost per inpatient admission*	*Average Length of hospital stay*
H1	*EHR*	No support	Supported			
	HIE	Supported	No support			
H2	*EHR*			No support	No support	
	HIE			Supported*	No support*	
H3	*EHR*					No support*
	HIE					Supported

Notes. EHR-electronic health record; HIE- health information exchange. *Regression coefficient is negative, contrary to our expectations.

Based on the extant literature discussed earlier, we incorporated as many as 14 controls in our study. Quite a few of them turned out to be significant, as indicated in Table 1. First, the number of beds (proxy for the hospital's size) was significant with both criterion for quality of care and mortality index, patient flow indicator (AVGLOS) but not with any of the two criterion variables for hospital efficiency. As already noted in healthcare literature, this indicates that bigger sized hospitals having more resources at their disposal can benefit more and deliver improved patient care to their patients but there may be an optimal hospital size only beyond which, hospitals are able to enjoy the improved hospital efficiency. Second, the case mix index was found to be significant with both hospital efficiency measures, with the patient flow indicator and only one of the quality of care characteristics (mortality index) thereby indicating that choosing the right case mix is important for hospitals to improve their patient flow and efficiency measures. Third, the operating margin was found to be significant with only one of the hospital efficiency measures, with both quality of care measures and with patient flow thereby indicating similar importance of having high operating margins for hospitals. Fourth, bad debt and charity care are found to be significant only with the quality of care indicators, thereby indicating their effect on the quality of care. Fifth, Medicare as a percentage of net patient revenue is significant with each of the two quality of care characteristics, each of the two hospital efficiency measures and the patient flow indicator thereby indicating the importance of Medicare reimbursement for hospitals. In comparison, Medicaid as a percentage of net patient revenue is significant with each of the two quality of care characteristics and with patient flow but not with hospital efficiency indicators. Sixth, the other commonly used controls in the healthcare literature such as hospital ownership, teaching status and location are significant with both the hospital efficiency indicators indicating that the hospital efficiency may be impacted by these three factors. Seventh, the demographic factors used as controls—percentage of population over 65 years and the % below poverty line are not consistently significant with the indicators of hospital efficiency, quality of care and patient flow. Similarly, the number of acute care hospitals

did not have any significant effect except on mortality index and on patient flow. Finally, the 2015-year indicator has a significant effect on only one of the hospital efficiency indicators and on mortality and patient flow. Similarly, the 2016-year indicator has a significant effect on both hospital efficiency indicators, on patient flow and only on mortality index. In sum, it is truly a mixed bag with some of the controls having a significant effect on the relationships hypothesized in the study.

DISCUSSION AND CONCLUSION

In this paper, drawing support from the tenets of TSEF and based on extant literature we tested a research model using econometric analyses wherein health information technology (HIT) practices such as the meaningful use of systems (EHR usage) and health information exchange (HIE) were hypothesized to be positively related to: (1) the hospital's quality of care characteristics such as risk-adjusted mortality rate and risk-adjusted readmission rate; (2) hospital efficiency measures such as cost per inpatient day (COSTDAY) and cost per inpatient admission (COSTADM); and (3) patient flow measures such as the average length of stay (AVGLOS). Our findings indicate a mixed bag with only partial support for the hypotheses.

Our study contributes to advance the knowledge in the healthcare information technology domain. This research demonstrates that HIE has partial positive effect on patient flow, hospital efficiency and consequently, on quality of care. With recent data from hospitals in PA, the study once again, reiterates the positive effects of smooth and even flow (TSEF) in the hospital context. There are several reasons why our results may have turned out a mixed bag. First, we used only a sample of hospitals from the state of Pennsylvania (PA). Although we know that the PA healthcare data captures national trends toward increased HIT use it is possible that currently, the average EHR usage in the state's hospitals may be quite low. This may explain why we could find a significant relationship with EHR as a predictor only with one out of all five criterion variables—with one of the two quality of care measures (readmission index). Second, perhaps as a related effect of the low extent of HIT usage in the state of PA, the total cost of implementing newer technologies has not yet reach the optimal level; hence it is likely that hospitals in the state are not yet able to reap all true benefits of HIT including optimal hospital efficiency. This is indicated by the negative regression coefficient or the negative relationship among HIT practices (HIE) and hospital efficiency measures such as cost per day and cost per inpatient admission that we found which indicate that the costs are actually increasing now. In comparison, HIE is significant with at least one indicator of each of the three criterion variables—quality of care (readmission index), hospital efficiency (cost per day) and patient flow (AVGLOS). Our study should spur more replication studies with these variables with data collected from hospitals all over the country.

The study has the following implications for medical practitioners and hospital leaders. First, the results of the study should re-emphasize the positive relationship between health information exchange (HIE) and hospital efficiency measure such as cost per day, quality of care indicator such as mortality index and the patient flow characteristic such as the average length of patient stay in the hospital. Hospital leaders may need to invest more in HIE systems such as EHR; and also pay more attention to propagation and use of EHR across their hospitals and all their internal departments. Second, our study results from PA data should also demonstrate to the hospital leaders across the rest of the country that HIE is the way of the future. The business press still routinely publishes articles detailing problems due to incomplete information available to the physician/nurses while making patient-related decisions, which arises due to inappropriate integration of health information systems in many hospitals across many small and big cities across the country. It is time that hospital leaders clearly understand that investing in health information systems are a way of the future as they help improve the patient flow, hospital efficiency and ultimately help in delivering higher quality of care to patients.

Like in most studies, this study too suffers from several limitations. First, we used secondary data from only one state (PA) for our study. While PA healthcare data is truly reflective of the emerging population trends of this country and PA has many big and small hospitals, the extent of healthcare technology usage is still low when compared to some of the western states of the country. Future studies would do well to collect more data from hospitals across the country so as to spread it over the other regions. Second, only three years (2014-16) data was available and used for this study. While this period is certainly long, future studies may want to extend over more number of years to clearly identify trend effects. Third, one of the possible reasons for the lack of clear and consistent effects of HIT in our study may be that the effect on the outcomes studied in this research may generally take a very long time, in general, in most hospitals. Although we have captured this dimension of the problem already by considering lagged effects by considering the t-1 period for both EHR and HIE, it is possible that other spurious and compounding variables, not identified in this research may have also played a part in partially affecting our outcomes. Future research may also consider much-more short-term effects of health technology usage such as study of the improvement in healthcare team level coordination and patient care delivery measured by the reduction of inpatient complaints related to physicians and nurses after technology usage.

In closing, we would like to place our results in the context of the findings in extant literature. Quite a few studies have already demonstrated mixed results with HIT and other quality of care-related hospital outcomes. Our study too, using a different methodology than most studies that use surveys (econometric analyses) could still find partial effects of HIT on quality of care, hospital efficiency and patient flow. In the future, we hope more replication studies with even longer periods of data and spread across more hospitals in more U.S. states will be able to clearly demonstrate all positive effects of health information technology usage for hospitals.

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Available upon request.

DECISION SCIENCES INSTITUTE
How Consumers Evaluate Hotels – Insights from Consumer Online Reviews

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ABSTRACT

With the rise of social media such as blogs and social networks, these interpersonal communication expressed by online reviews has become more and more important as an influential source of information both for the managers and consumers. In-depth purchasing related information is made available to markers. Now we can utilize this new source of information to understand how consumers evaluate hotels. In this paper we not only examine the contents of attributes of hotels consumers value when they stay but also attempted to categorize a number of key areas by the level of importance as measured from consumers' online reviews also. Moreover, the means-end chain theory was used as a theoretical framework to analyze the attributes of the hotels with the dimensions of the key areas in evaluating hotel qualities.

KEYWORDS: Online reviews, Text-mining, Key areas, Evaluate, Means-end chain theory

INTRODUCTION

With the rise of social media such as blogs and social networks, these interpersonal communication expressed by online reviews has become more and more important as an influential source of information both for the managers and consumers. With the rapid growth of comments by consumers over the Internet, in-depth purchasing related information is available to markers. The wide availability of lengthy and numerous text-based online reviews provides a treasure trove of information that can potentially reveal a much wider set of variables that determine the consumers' attitude/evaluation towards the products. With the large amount of information, data-mining methodologies are needed to uncover the hidden information from the unstructured text/data (Lee & Siau, 2001; Hoontrakul & Sahadev, 2008).

However, as there has been ample research on text mining, they mainly aim at improving the methodology it self a lot like classification performance of text classifier, feature selection methods, etc. (Ng et al. 2006; Pang, Lee, & Vaithyanathan, 2002; Bast, Kuzey, & Delen, 2015). Or data mining is used as a tool for the prediction power of the words itself (Rickman &Cosenza, 2007; Ghose, Li and Ipeirotis, 2012; Mostafa, 2013) and are missing the diagnostic aspect of using reviews, which is of important use to marketers. The identification of attributes can be used to help marketers in understanding what contribute to the evaluations by consumers toward the products; or even at a more abstract level.

In our research, instead of using the traditional experiment/survey method, we extract attributes from online text reviews through pre-processing and indexing et al. standard natural language processing algorithms. . We partnered with orbitz.com, a leading hotel booking websites with

ample true consumer reviews about their stay at the hotel. The importance of the attributes is also developed through online review analysis instead of surveys. This way, we not only examine the attributes of hotels, but also attempt to categorize a number of key areas by the level of importance. Moreover, the means-end chain theory was used as a theoretical framework to analyze the quality of the hotels.

The rest of the paper is organized as follows: in section 2 we discuss the fundamentals of text mining approach and means-end theory. In section 3 we discuss the details how we implement this for our research. In section 4 we analyze the results we get and provide the insights of our discussions. Section 5 provides a summary of our findings and suggests future directions for research.

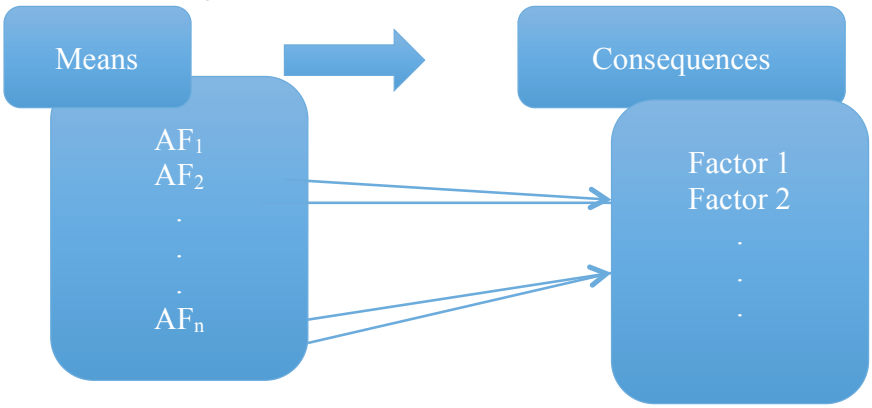
LITERATURE REVIEW

Means-end Chain Theory

We adopted means-end chian theory as the conceptural framework. This conecptural cognative model suggests that conusmer decision-making process is a series of cognitive developments through linkages between product attributes, consequences, and value (Gutman, 1984). In the context of product usage, product it self is the “means” and the value of the products is the “end”. The product attributes are retained in the minds of consumers at abstract level and can influence the evaluation of the product by the consumers. Means-end theory has been used a lot e-service quality research (Ladhari, 2010; Rowley, 2006; Wolfinbarger & Gilly, 2003). Parasuraman et al. (2005) applied this theory as the theoretical foundation to develop and conceptualize e-service quality delivered by websites.

In our research, the means are the attributes of the hotels extracted from online consumer reviews while the end (consequences) are the key areas categorized by factor analysis based on the importance of the attributes also extracted from online consumer reviews through text mining.

Figure 1: Proposed Theoretical Framework



Text Mining Review

In this section we describe the overall approach that we use for analysis of text content. In the following sections, we will explain the complete process of how we used text mining.

Preprocessing and Text Representation

Before a learning method can be applied, several preprocessing steps are required to get the data in ready format for further analysis. Raw text is divided into tokens (single word, special symbols, etc.), converted to lower cases, remove stop-words (eg: the, a, etc.), stem into word-root, and represent the text value by indexing into a term-by-document matrix. The columns of the matrix represent terms (words), and the rows represent documents (reviews for example). Jones (1972) showed that there is a significant improvement in retrieval performance by using weighted terms vectors. The term weight is generated by multiplying Term Frequency (TF) with the Inverse Document Frequency (IDF) (Jones, 1973; Coussement & Van Den Poel, 2008; Salton & Buckley, 1988). Now this term-by-document matrix becomes a structured table with numerical values, which can be analyzed using standard statistical method.

Dimensionality Reduction

So far this weighted term-by-document matrix is a high dimensional matrix due to the many distinct terms. Moreover, it is very sparse with many zeros since not all documents contain all terms. Large attribute dimensionality incurs high computational cost and more seriously cause over-fitting problem on many classification methods. We choose Gini-index as our method for attributes selection since it is base upon the distinguishing ability of the word as well as importance of the word.

Gini-index was proposed and sudied by Aggarwal & Chen (2010). It aims to decide which feature variables are decision variables for a decision support appication. In the training data the key decision variables are identified and trained to predict the decisions classes. Training dataset D_{trian} contains n reviews and each review q belong to a predefiend class with lables s which is drawn from the set {1…k}. Overall we have a dxn feature-review matrix with each feature is denoted i with i range from 1 to d and each review is denoted by q with q range from 1 to n. In our case since the lables will be a binary situation of reconmend or not. Now the Gini index is calculated to define the level of class dscrimination among the data points of each feature as follows:

$$G(i) = \sum_{s=1}^{k} f(i,q,s)^2$$

Then we can use gini index to help us find the key features that are important to the decisions. With a bigger Gini index, it indicates a higher discriminating abillity of that word. So we set a threshhold of choosing higg value Gini-indexd attributes. In previous research the frequency of occurrence of an indexed word has been used to indicate term importance for content representation (Baxendale, 1958; Luhn, 1957; Salton & McGill, 1983). So we set another threshold of selecting attributes based on the frequency.

Classification

We use the Support Vector Machine (SVM) approach for classification purposes. SVM was invented by Vapnik and Chervonenkis (1962) and has been used a lot in various areas (Pang, Lee, & Vaithyanathan, 2002; Bast, Kuzey, & Delen, 2015). SVM are supervised learning models that can classify data into the groups. Given a set of training examples, each data record is marked as one or the other of two categories. An SVM training algorithm builds a model that

can assign new examples to one category or the other. In our case, we have categories of class: recommend or not recommend the hotel to others.

Classification performance is measured by the percentage correctly classified. If *TP*, *FP*, *TN*, *FN* are respectively the number of correctly predicted positive reviews, the number of negative reviews predicted as positive, the number of correctly predicted negative reviews, and the number of positive reviews predicted as negative, accuracy is defined as $\frac{(TP+TN)}{TP+FP+TN+FN}$.

DATA AND ANALYSIS RESULTS

Data Collection

In our study, we used data obtained from orbitz.com, which is one of the leading websites in the travel industry. On the websites, consumers can only leave their reviews, ratings, and recommendation choices after they stayed in the hotel and registered with the hotel. We collected the data of a high quality hotel in Las Vegas: 5-star hotel "Venetian". We chose Las Vegas among the various cities across the whole nation because it is one of the most popular tourist cities in the U.S., and attracts a large number of hotel consumers staying and leaving reviews. We pick a 5-star hotel because as in Las vegas, in order to attract visitors, lots of high-level hotels were built and also because of the low price comparing to other locations, 5-star hotels are very popular among consumers. Table 1 represents the summary of the review data of the two hotels.

Table 1: 5-star Venetian Descriptive Statistics

	All	Business	Couple	Family	Friend	Other
Overall ratings	4.5	4.5	4.5	4.4	4.4	4.4
Recommendation (actual)	92%	92%	92%	87%	92%	87%
# of reviews	2286	188	1109	296	342	351

Analysis Results

After preprocessing of the raw reviews we get the term (attribute) by document matrix. For each attribute, we calculated the Gini index of that feature and select only the ones with a Gini value higher then 0.75 (Aggarwal et al. 2009) and also frequency is higher than the average frequency of the words appearence. Through this we are able to find the major attrbiutes that are both important and distingushing in the evalutions of the hotel. List of feature is shown in table 2.

From the table we see, around 40 features which are both important and distinguishing were extracted from the consumers online reviews. For each feature, we calculated the tf-idf value to reflect the frequency of occurrences of the word features, which indicate the importance of the features for representation of the content of the reviews. The evaluation of importance of features was usually determined by consumer surveys in the past.

Table 2: Venetian Gini Selection of Words, Mean & SD (n=2286)

Feature	Mean	SD
77315room	0.615905982	0.840249787
29733stai	0.551547381	0.82165562

88564staff	0.400633212	0.777731114
38586time	0.468865486	1.014960226
3343beauti	0.386801959	0.830438556
105417locat	0.369390225	0.805449742
70746servic	0.398964787	0.993875946
80313strip	0.360965236	0.937546462
78256restaur	0.323249126	0.818511494
55318casino	0.358101524	1.021703983
107009pool	0.366315944	1.102540841
84314shop	0.302824825	0.8928519
105376experi	0.319579518	0.940387285
63878comfort	0.283232639	0.809203564
98053friendli	0.271059238	0.786200556
98561food	0.267736792	0.85655244
66324bathroom	0.265218368	0.859496882
40527bed	0.27890465	0.937873975
84318show	0.265786823	0.903504893
74378price	0.229886661	0.855276916
4056view	0.248388399	1.00651292
44890luxuri	0.221286503	0.832020881
91332getawai	0.19446686	0.748517432
53441spaciou	0.177143261	0.74316694
25711weekend	0.185364962	0.791939957
71300huge	0.177202338	0.777282242
29727star	0.189608358	0.94537057
84647charg	0.193639941	1.107387953
45608fun	0.156195461	0.769228367
16666close	0.146094318	0.717195468
63566coupl	0.136324894	0.694853203
43745shower	0.146251093	0.843647845
105560expens	0.123541624	0.695041725
81315smoke	0.176175837	1.211246955
81581size	0.111322238	0.638559951
78951smell	0.137813083	0.880136225
40466bar	0.114751923	0.694104255
79248drink	0.124056133	0.760623902

Next, we performed classification (SVM) using the sleeted 38 features as the predictive variables. The accuracy is 91.6%. The high accuracy indicated text reviews can be used to represent the true thinking of the consumers towards the hotel, which can be fatherly used to identify the factors that consumers value as when they evaluate the hotels.

Last, we conduct factor analysis using principal axis factoring in order to identify the underlying factors of the two hotels. The principle axis factoring analysis with a Varimax rotation showed 14 factors with an eigenvalue of one or greater for the functions of apps. As stated in Table 3, total

variance explained by each factor of apps' functions was also revealed. Specifically, the first factor has an eigenvalue of 3.48, which is 21% of the total variance of 7 items. The second factor has an eigenvalue of 1.74, which is 16% of the total variance of 7 items. Then the next five factors have an eigenvalue bigger then 1.3. The rest has too small values (either below 1 or close to 1) so we didn't include them. Normally, eigenvalues greater than 1.0 are recommended as a criterion. We pick the first 7 factors.

Table 3: Total Variance Explained				
Component	Eigen Value	% of Variance	Cumulative %	SS loadings
1	3.48	21%	21%	1.53
2	1.74	16%	37%	1.13
3	1.57	15%	53%	1.10
4	1.51	13%	66%	0.95
5	1.41	13%	79%	0.91
6	1.32	12%	91%	0.86
7	1.30	9%	100%	0.66

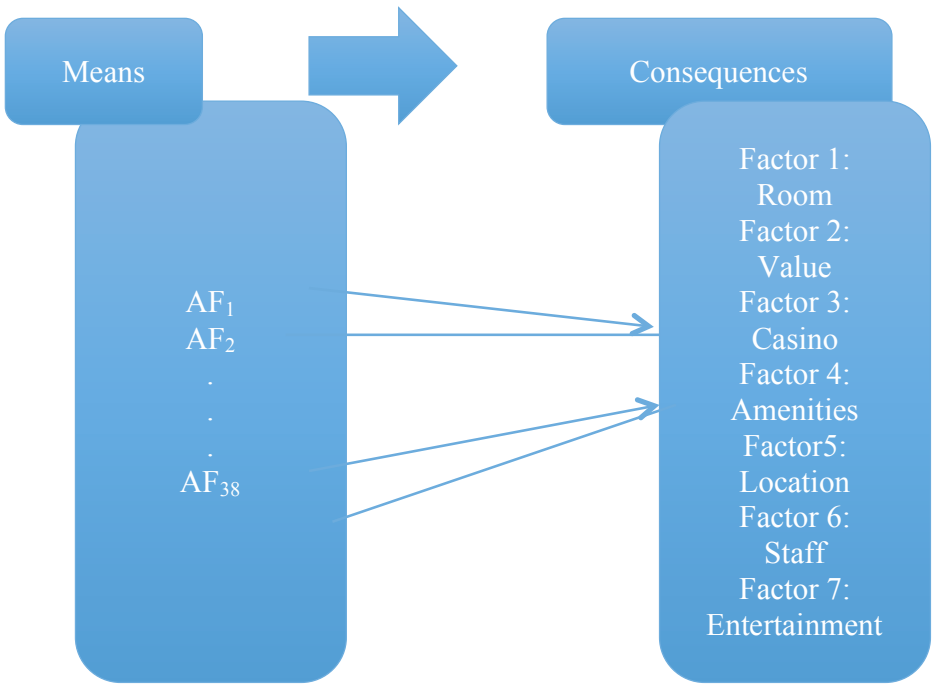
The factors are labeled as: 1) room, 2) value, 3) Las Vegas specific hotel amenity-casino, 4) other amenities, 5) location, 6) staff, 7) Las Vegas specific hotel amenity-entertainment. Among the 38 items, three items were deleted for appropriate data reduction for future statistical analysis. As you can see in table 4, AF5 (beautiful), AF13 (experience), AF25 (weekend), AF30 (close), and AF33 (expense), were eliminated because they had no significant loading on any of the factors above (factor loading less than .20).

Table 4: Summaries of Features and Factor Loadings									
		Factor Loadings							
	Features	1	2	3	4	5	6	7	Communality
1)	AF1-room	.46							3.0
	AF14-comfort	.52							1.1
	AF17-bathroom	.51							1.2
	AF18-bed	.58							1.1
	AF22-luxury	.28							1.7
	AF24-spacious	.20							1.9
	AF32-shower	.32							1.4
	AF26-huge	.20							2.5
	AF35-size	.26							1.1
2)	AF2-stay		.22						4.2
	AF7-service		.28						2.2
	AF20-price		.21						2.7
	AF27-star		.25						1.3
	AF28-charge		.38						1.1
	AF37-bar		.28						1.8
	AF38-drink		.35						1.4
3)	AF10-casino			.52					1.8
	AF34-smoke			.71					1.0
	AF36-smell			.35					1.2
4)	AF9-restaurant				.45				1.3
	AF12-shop				.47				1.3

	AF16-food				.31				2.8
5)	AF6-location					.35			1.9
	AF8-strip					.70			1.2
	AF21-view					.34			2.3
6)	AF3-staff						.60		1.1
	AF15-friendly						.63		1.0
7)	AF4-time							.29	3.0
	AF11-pool							.32	2.5
	AF19-show							.19	4.8
	AF23-getaway							.22	1.3
	AF29-fun							.23	1.8
	AF31-couple							.31	1.2

As revealed in Figure 2, there are 38 features (means) of evaluations of the hotels by consumers that were categorized by 7 factors (consequences) in the given framework.

Figure 2: Theoretical Frameworks



On the website, there are already separate ratings by consumers towards 5 aspects: room, value, location, staff and amenities. In our results, we also identified the same dimensions except that for amenities, due to the uniqueness of Las Vegas, hotel amenities contain more meaning than usual hotels in other places. Therefor, we identified three categories of amenities: regular, casino, and entertainment. Also the hotel we analyzed here is the 5-star hotel venetian. For Venetian, and also many other high level hotels in Las Vegas, besides the regular hotel amenities, casino is a big area to draw attention and entertainments is another like show/pool etc. People especially couple come here for a getaway.

DISCUSSION AND CONCLUSIONS

A major finding of our research is that we can utilize the great volume of reviews online to help us identify the key aspects of hotel industry. Online reviews of products and services are present all over the Internet. Potential consumers value these greatly. Marketers can also get valuable information from reading these reviews. These reviews predominantly contain text-based information. In our present research we utilize text-mining methodology to show that consumers' attitudes can be accurately predicted by text mining.

In addition to making predictions of recommendations, marketers would benefit tremendously if they can identify key information from many thousands of reviews; we suggest a framework by which companies can get this important *diagnostic* information. This framework consists of reliance on the importance of words based on frequency of occurrence and a new way to look at how certain words have greater power to discriminate/distinguish between existence and non-existence of recommendations (Gini index). Factor analysis is conducted to extract the key dimensions for hotel evaluations.

While the contribution of this research is clear, there is still limitation of it. In this research we studied one hotel-venetian, it will be beneficial to include more hotels to see the generality across hotels and also across cities.

The potential future directions for this research stream are numerous. The overall methodology designed in this paper is a foundation that can be applied to a variety of marketing situations. In today's digital era consumers freely express their opinions about products and services on many websites. This provides numerous information sources that can help academicians and practitioners in analyzing consumer attitudes. We can extend this methodology to study a tremendous variety of research questions that would benefit from the analysis of text content posted by web users all over the Internet. Advertisers and marketers would be among the prime beneficiaries once they can glean the appropriate information from text-based reviews. The identified information can either be strongly used in advertising or to improve the business.

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DECISION SCIENCES INSTITUTE

The Impact of Design Dimensions, Dominance and Meaning of an Icon on App adoption

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ABSTRACT

How do customers make selections from among millions of smartphone apps? In this study, we analyzed the relationship between icon attributes and choice of apps. Based on the literature, 5 icon attributes were identified: active, balance, complexity, depth, and organic. 12 app categories were explored. Explicit policy implications were exploited for icon design. For example, for arcade games, icons should be active or organic. For brain games, icons should be balance. For social, organic is the top choice. It is proven that meaning and dominance are two decisive factors for design dimensions as top choices for downloading.

KEYWORDS: Icon attributes, Meaning, Dominance, Download, Wilcoxon test

INTRODUCTION

Today's smartphones are full of apps – mini software applications designed to run on smartphones, tablet computers, and other mobile devices. Two prominent app markets are Android's Android Market (Google Play) and Apple's Apple Store (Annie, 2017). Since its opening on July 14, 2008, Apple Store has received 75 billion downloads as of October 2014 (Statista, 2015a), and 180 Billion in 2017 (Apple Inc, 2017). Google Play reached 50 billion downloads in July 2013 (Statista, 2015b) and 64 billion in 2017 (Sensor Tower Inc, 2017) with more than 1 billion monthly active users (Protalinski Emil, 2017). Our question is: Given millions of apps to choose from, how do customers make their selections? Most of these apps are free. Techcrunch (Perez, 2015) reported that 90% of Apple apps are free in 2013. This number may rise to 93% by 2016 (Gartner Newsroom, 2012) Although, the market share of free APPs is shrinking in 2018 (Dinsmore et al, 2017; Ying et al, 2017).For app developers, "free" is a strategy (Arora et al, 2017; Finkelstein et al, 2017). Making the software free increases the user base, which is especially useful if the software demonstrates "network externality". These developers make their profits by applying "In App Purchase" (IAP).

How can a single product attract attention in a sea of millions of "free" software apps? In our study, 159 of 208 survey respondents acknowledged that they chose apps based on their icons – the small graphical squares which deliver the messages the software apps are intended to deliver. The literature also demonstrates that logos, typefaces, package designs, and other exterior designs can affect customer loyalty, brand impression, and purchasing behavior (César Machado et al, 2012; Fu, 2016; Henderson and Cote, 1998; Machado et al, 2015; van der Lans et al, 2009; Zhu et al, 2014).According to pattern recognition theory (Selfridge & Neisser, 1963), features such as attributes function as stimuli that provide a foundation that viewers can use to decode the meaning of the icons.

In their pivotal work, Henderson and Cote (Henderson & Cote, 1998) identified certain design principles for logos. Our study shifted the focus from “what makes good logos” to the causality between the adoption of apps and icon attributes and between the icon attributes and meaning and dominance of icons. We wanted to explore which icon attributes improve the adoption of a given app category, if an icon’s meaning and dominance affect app downloads, and how meaning and dominance affect app downloads through icon attributes.

LITERATURE REVIEW

Research has identified the effectiveness of images (including icons, logos, and packages) in product recognition, corporate identification, marketing, brand impression creation, etc.(Bresciani and Del Ponte, 2017; César Machado et al, 2012; Chiu and Lee, 2018; Henderson and Cote, 1998; Hyeyeon, 2018; Machado et al, 2015; van der Lans et al, 2009). Peters (Peters, 1999) recognized the importance of a visually strong logo: “Humans think visually. A picture is really worth a million words. And great brands have readily identifiable icons – just ask Nike or Apple or Shell – strong simple images that connect with customers.”

However, there have been only a few recent published studies on the relationship between logos and the choice of products/services. Prominent among these, Henderson and Cote (1998) and Henderson, Giese, and Cote (2004) proposed guidelines for good design of logos and typefaces. Orth and Malkewitz (2008) developed a holistic package design that creates a better brand impression for consumers. Pham, Pallares-Venegas, and Teich (2012) delineated relationships among logos, storytelling, and customer loyalty. Kang believes that the user will choose to have a good icon design in the APP that has been downloaded and has similar functions. To increase the user's download quantity and frequency, it is necessary to increase its icon features and brand (Kang, 2017). Burgers et al. used APP online reviews and visual features to analyze users and developers and thought that user reviews and developer designs have a strong influence on APP downloads (Burgers et al, 2016). Machado, Vacas-de-Carvalho, Costa, and Lencastre (2012) and Hagtvedt (Henrik Hagtvedt, 2011) analyzed the effect of logo designs in specific circumstances. Although these studies have paved the way for logo research in the field of management, they provide little guidance for choosing the best logo design for a particular product/service. We believe this guidance is important to have, especially when customers must choose from a large number of logos. As noted by Pham et al. (2012), logos tell stories. But if the logo doesn’t catch the customer’s eye, the story has no place to start. Due to the proliferation of software packages, a tempting research question is how to apply these logo studies to research on software adoption.

Based on Henderson and Cote (1998) and Nemett (Nemett, 1992), we distinguished 5 different attributes of icons and predicted which of these would draw the most attention for which app categories.

(1)Organic
According to Henderson and Cote (1998), “Organic designs are those that are made up of natural shapes such as irregular curves. Graphic design literature suggests that organic designs are more meaningful (Dondis, 1973)” (see Table).
(2)Balance
According to Henderson and Cote (1998), “Balance captures the notion that there is a center of suspension between two weights or portions of the design. Graphics design literature has suggested that imbalance is more upsetting to viewers (Dondis, 1973).”

(3)Complexity
According to Henderson and Cote (1998), “Complexity can arise from many different design features such as irregularity in the arrangement of elements, increases in the number of elements, heterogeneity in the nature of elements, and how ornate the design is ((Berlyne, 1971; Schmitt, Simonson, & Marcus, 1995).”
(4)Active
Henderson and Cote (1998) defined active designs as “those that give the impression of motion or flow. This flow is the basis for the design notion of rhythm (Bevlin, 1989).”
(5)Depth
According to Henderson and Cote (1998), depth “gives the appearance of perspective or a three-dimensional design.”

Table 1 Attributes of logo designs

Table 1 Attributes of logo designs		
Attribute	High	Low
Organic		
Balance		
Complexity		
Active		
Depth		

Henderson and Cote (1998) also described symmetric and representative designs. Symmetric designs are those that “appear as reflections along one or more axis. That is, the elements on one side of the axis are identical to the elements on the other side.” A “representative design and its opposite endpoint, abstract, capture the degree of realism in a design.” “Symmetric designs are normally considered balanced.” In the same vein, they cite other researchers (Block, 1969; Clark, 1988; Durgee & Stuart, 1987; John Peter, 1989; Keller, 1993; Kropp et al, 1990; Masten, 1988; Siegel, 1989; Vartorella, 1990; Yeung, 1988), claiming that the “logo strategy literature frequently suggests using representative logos.” We thus incorporate the symmetric

design as a subset of the balance design and ensure that all our logos have the representative design feature.

In addition to the above design dimensions, there are response dimensions. One is dominance. Dominance through emphasis of one or more particular elements creates a focal point in a design. It's where most people will instinctively go when first looking at a work ((Vanseodesign,2010). Goonetilleke ((Goonetilleke, Shih, Kaion, & Fritsch, 2001) believed that the dominant element will result in shorter response times than single-element representations with the non-dominant (redundant) element. We expected that icons with higher dominance level would generate more downloads.

Another response dimension is meaning. (Horton, 1994) argued that icons alone are meaningless without a particular context (meaning). If a logo has a clear meaning, it can be linked more easily to the company or product ((Hazarika and Nath, 2017; Johannessen, 2017; Kelly, 2017; Park et al, 2017). We expected that icons with higher levels of meaning would generate more downloads.

THE SURVEY

To evaluate how icon attributes affect the choice of apps, we designated 15 icons for each app type, with each attribute represented by 3 icons. To guarantee that the icons represent the attributes well, we first interviewed domain experts to understand the design principles for each of the 12 app types.

Then, 9 designers were invited to design the icons for all the apps. Initially, 480 icons were drawn, representing 40 icons for each app or 8 icons for each app /attribute combination. Because all the icons were designed exclusively for this experiment, there is little chance that the participants had ever seen them. The next step was to assure that the icons represent the attributes well. This is said to happen if and only if a significant number of respondents agree that the representation is valid. To achieve this objective, we needed to set a threshold value. A value of 6 means that the icon can be considered to represent the attribute only if 60% of the respondents agree that this is so. The Delphi method (Dalkey & Helmer, 1963) was employed to determine the appropriate threshold value. 7 experts, including 2 professors, 2 designers, and 3 MIS professionals, participated in the Delphi session. A web-based GDSS tool, TeamSpirit, was employed (Chen, Liou, Wang, Fan, & Chi, 2007) for the session. The experts started brainstorming in the first round; the main topic was, "What makes an icon a good representation of an attribute?" In the second round, the discussion was routed to the determination of "reasonable threshold values for an icon to represent an attribute well." The proposed values were 6.0, 7.5, and 9.0. In the last round, the participants voted for the final threshold value of 7.5.

Next, all 480 icons were presented to 50 pilot study participants. They observed each one and selected which attribute or attributes it represented. An icon was considered well represented if 38 (50*0.75=37.5) or more participants identified 1 and only 1 attribute. An icon was labeled as over-represented if it was considered by 75% or more of the participants to represent 2 or more attributes. It was labeled as under-represented if it failed to represent any attribute. All over- or under-represented icons were discarded. The 3 best well-represented icons then were chosen to represent each app/attribute combination (total 12*5*3 = 180 icons).

The above procedure guarantees the reliability and validity of the icons' attribute representations. It assures that each set of 3 icons represents one and only one attribute. Similar icons are joined in single sets. Thus, reliability, convergent validity, and discriminant validity are all achieved.

During the main test, each participant was given an imitation smartphone with cardboard icons attached to its screen and covered by glass. Both the phone and icons were the same size as their real counterparts. To avoid fatigue (van der Lans et al, 2009), each participant was given only 1 of the 3 icons for each app/attribute combination. The participant was then asked to rank the 5 icons for each app category based on their preferences: a rank of 1 represented the greatest desire to download the game app when observed and 5 represented the least.

The experiment was conducted in Taiwan near the university campuses we believed had the highest likelihood of many smartphone users. Those who had previously downloaded apps with smartphones were asked to participate. The experimenter gave them the instructions and recorded their answers.

In the meantime, the respondents were asked if each icon has unique meaning. A respondent wrote down the meaning if any, or kept the answer box blank if there was none. They were also asked if an icon had an identifiable dominant subject. A respondent circled the subject if any or kept the answer box blank if there was none.

THE ANALYSES

The collected data were then undergone a series of analyses. First, Friedman tests were employed to investigate if there truly existed ranking of download preference among the 5 icons for each app category. It was employed because once one design dimension was selected, it could not be considered again so events are not independent from one another. The results showed that ranking did exist for all the 12 app categories.

Then, Wilcoxon tests were employed to actually uncover the ranking. For example, in arcade games, the Wilcoxon test showed the results as in (Table 2). It showed that the ranking is Active = Organic > Complexity > Depth > Balance

Table 2 Wilcoxon test for the arcade game

Attribute	B - A	C - A	D - A	E - A	C - B	D - B	E - B	D - C	E – C	E - D
Z test	-11.361[a]	-6.581[a]	-9.532[a]	-.522[a]	-5.450[b]	-3.915[b]	-10.443[b]	-2.190[a]	-6.399[b]	-8.921[b]
asymptotic Significance (two-sided)	0.000	0.000	0.000	0.602	0.000	0.000	0.000	0.029	0.000	0.000

a. negative rank b. positive rank (A: Active, B: Balance, C: Complexity, D:Depth, E:Organic)

Such practice was repeated for all the 12 categories and the results are summarized in (Table 3).

Table 3 Attribute ranking for app downloads					
	Active	Balance	Complexity	Depth	Organic
Arcade Game	1	5	3	4	1
Brain Game	2	1	4	3	5
Casual Game	1	3	5	3	2
Entertainment	4	2	2	5	1
Tool	1	1	5	1	1
Communication	1	4	5	3	2
Productivity	1	3	5	3	1
Personalization	2	5	2	4	1
Music & Audio	1	3	3	3	2
Social	2	2	5	4	1
Media & Video	1	5	3	3	2
Travel & Local	1	5	3	3	2

The results of the Wilcoxon tests allow us to further analyze the impact of the demographic variables on the rankings of attributes. We need to answer two questions. First, do demographic variables have an effect across all respondents on the ranking of a specific attribute for each type of game? For example, do males consistently rank the active attribute of arcade games higher than females do? An ordered probit was employed because the dependent variable is ranking data, and the regression of gender on the ranking of the active attribute for arcade games is as follows:

$$Y_i=\alpha_0 + \alpha_1 X_{1i} \quad (1)$$

where Y_i is the ranking (from 1 to 5) that respondent i assigned to the active attribute for the arcade games and X_{1i} is i's gender. X_{1i} was coded 1 for males and 0 for females. For example, $Y_i = 4$ and $X_{1i} = 1$ means that a male respondent ($X_{1i} = 1$) ranked the active attribute as the second highest ($Y_i = 4$) for arcade game.

We followed the same convention for the other demographic variables and the other 11 app types. After conducting the ordered probit regressions using SPSS and verifying the results using Stata, we found no impact of the demographic variables gender, age, education, profession, and number of downloads in the past year on the rankings of the active attributes for arcade games. We applied the same technique to other attributes for other apps and found no impact of the demographic variables on the rankings of any of the attributes for any app. Second, do demographic variables affect the rank order generally for each type of game across all respondents? For example, to assess if there is a gender difference in the general rank order for arcade games, we apply the following formula:

$$Y_{ij}=\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2j} \quad (2)$$

where Y_{ij} is the specific ranking that respondent i assigns to attribute j, X_{1i} is i's gender, and X_{2j} is the overall rank order (assigned by all respondents) of the j^{th} attribute for arcade games. This overall rank order was determined by a Wilcoxon test. For arcade games, $X_{2j} = 5$ when the attribute is active (because active attribute is #1 ranking for downloading), $X_{2j} = 5$ when it is organic, $X_{2j} = 3$ when it is balance, $X_{2j} = 2$ when it is depth, and $X_{2j} = 1$ when it is complexity. Rank number 1 is the highest and was thus given a score of 5. For example, $Y_{ij} = 4$, $X_{1i} = 1$, and $X_{2j} = 2$ means that a male respondent ($X_{1i} = 1$) ranked the depth attribute ($X_{2j} = 2$) as the second highest ($Y_{ij} = 4$) for arcade games.

On the other hand, we suspected that the relationship between Y_{ij} and X_{2j} would prove to be asymptotic instead of linear, so we also tested the following regression:

$$Y_{ij}=\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2j}^2 \quad (3)$$

If Equation (3) has higher explanatory power than Equation (2) (by observing adjusted R2), it demonstrates that the relationship is asymptotic.

For the three regressions, we found that, first, any value of a demographic variable did not have more significant effect on ranking than other values for all 12 app categories. For example, we did not find that males consistently rank the active attribute of arcade games higher than females did.

Second, we could not find impact from any demographic variables on overall ranking for the 12 app categories either. For example, we could not find that males showed different rank order for arcade games than females did.

Third, we could not prove that the relation between the attributes and the rank orders was asymptotic. We also tested X_{1i} and X_{2j} for multicollinearity using ordinary regression and found it not to be significant for all 12 categories. There also was no significant heteroscedasticity or autocorrelation, because the error terms for probits or ordered probits are always standard normal.

The next analyses were testing the impact of meaning and dominance on ranking. Another series of ordered probit regressions similar to Equation (1) were employed. Here, X_{1i} is a dummy variable. When it is one, it means that a respondent believe that an icon contains meaning or it has a dominant subject. We concluded that having meaning or having a dominant subject could increase the chance of an icon to be downloaded.

CONCLUSIONS

It is important for practitioners and scholars to know why an app is more likely to be downloaded than others. We found that icons were important. How can an icon foster the downloading? We believe its attribute is the key. For example, for arcade games, if an icon demonstrates active or organic attribute, its app can be more likely to be downloaded than that of depth, complexity, or balance attributes. Likewise, for entertainment apps, organic can be a better design dimension than active. From Table 3, we can tell that active attribute in general is a good design principle. Although active attribute can be the best design dimension for many app categories, it is not always true. For example, following active design principle for entertainment apps can be a wrong decision because Table 3 shows that apps with active icons are ranked number 4 in downloading preference. Therefore, our research is valuable because it clearly shows the ranking of design dimensions for each app category and it tells us that an optimal design choice for one type of app might be a bad design choice for another app type.

A more sophisticated question to ask is why a certain design dimension may foster the download. The key is response dimensions. In this paper, we suggested two response dimensions – meaning and dominance. Our results shows that not only having meaning or having a dominant subject could increase the chance of an icon to be downloaded, but also the impact of design dimensions is by way of meaning and dominance because there exist causality from response dimensions to. Meaning was studied in previous research (Henderson & Cote, 1998; van der Lans, 2009) but dominance was studied first by us.

Regarding the research limitations and future study, one can be the limit of research domain. We conducted our research in Taiwan. Although logo recognition can be universal (van der Lans et. al, 2009), authors have suggested that managers “can optimized logos for specific countries if desired.” Thus, extending our research from Taiwan to other cultures can be beneficial.

In addition, as Henderson and Cote (1998), we examined only logo recognition (Have you seen this logo before?) as opposed to recall (What company does this logo belong to?). Further research can focus on providing managers with guidelines to achieve high recall. Though, this issue may not be significant in mobile app business at this moment because most app providers are too small to make brand recognition important. After mobile app business reshuffles and enter a new era of competition, brand recognition may become an issue.There are more response dimensions as listed by Henderson and Cote (1998).

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Identify Technology Changeover Timing Using Phone Support Services

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ABSTRACT

Rapid increase of technology usage combined with limitedness of capital resources technology managers are forced to come up with optimal strategy for technology implementation. To maintain their competitive superiority managers are expected to increase productivity through reduced technology downtime with improved performance in a limited resource environment. To best achieve this, one option is to replacement of older technologies with current and improved versions in every few years. However, the primary challenge for an organization is to understand and measure the replacement timing for optimum outcomes. To this end, a comprehensive two step statistical process is proposed.

KEYWORDS: Technology changeover, Leading indicator, piecewise regression, technology operations, technology management

INTRODUCTION

Technology is essential in accomplishing the primary organizational operations (Croteau & Bergeron, 2001; Mithas, Ramasubbu, & Sambamurthy, 2011; Tallon, Kraemer, & Gurbaxani, 2000) and has become a tangible resource utilized by organizations to enhance their capabilities. Researchers (Bharadwaj, Bharadwaj, & Konsynski, 1999; Devaraj & Kohi, 2003; Sabherwal & Jeyaraj, 2015) have provided evidence suggesting substantial returns are attained through technology investments along with being a method some organizations have used to create a strategic advantage (Mithas, 2012). Subsequently, investments in technology have been made by organizations' managers with the defined purpose of using technology to attain a competitive advantage (Kohli and Devaraj, 2003; Melville et al., 2004; Piccoli and Ives, 2005). More embedded technology means dependence on technology, and technology dependence challenge managers to address the risk to their company's operations when technology goes wrong. To overcome these challenges increasing interest in finding ways, to promote optimal use of technology, its updates, and the timing of changing technology over to its updates.

Educational technology in the classroom, similar to business organization's use of technology, has become an avenue university administrators use to facilitate innovations (Xu & Meyer, 2007).

Organizations create procedures to address technological disruptions that include analytical practices that assist in continuous monitoring, evaluation, and support services of the technology to minimize technology related interruptions to the operations of businesses and universities. Both types of organizations from time to time make additional technology investment decisions associated with replacing or updating technology. For managers, this is a complicated decision making process, as the producers of the technology make frequent changes and the managers try to accomplish strategic goals for the organization in a constrained resource settings.

As the underlying goal of technology resource management is the optimal usage of technology, determining the best timing of technology changeover becomes the core issue. Technology changeover, the main focus of this study, is different from the replacement of individual technology unit. Technology changeover is a large scale replacement of a technology system adopted by an organization. To implement a technology changeover many organizations rely on historical information and data that is usually subjective in nature. The length of time a technology remains valuable to an organization during the technology's life cycle is uncertain (see, Aytac and Wu, 2013) and therefore predicting the precise timing of changeover is challenging. This difficulty is primarily due to differences in the products' life cycles of various products and integration of multiple technologies in the system that reduces the likelihood a manager could, through subjective means alone, effectively predict the appropriate timing. Analysis of objective data taken from the operations of the technology should make it feasible to determine if the technology changeover adhere in the past fit into a recurring cycle and, if it does, it must also be possible to effectively predict when the organization's technology needs a changeover. To this end, this research contributes by determining if a technology changeover, that has already happened, is able to document through objective analysis and also investigates if any leading indicator(s) exists to identify the changeover timing in advance. Furthermore, this two-step approach combines the information from a leading indicator with an intervention model to predict the timing of technology changeover before it becomes essential. Operations managers could use this process to become more knowledgeable on the dynamics of advance planning for technology changeover to project necessary capital requirement.

LITERATURE REVIEW

Putting technology in the hands of employees where employees have a world of information at their fingertips, collaborate with colleagues across the globe, and deliver products also means employees are dependent upon a certain level of performance from the technology (even as it ages). Strategic standouts with technology, therefore, achieved a level of proficiency that allows them to construct, implement, maintain, changeover, and sun setting technology. Yet, of these areas, a proficiency in determining the timing for technology changeover is among the least researched. Given what we know about the landscape of the digital workforce and the increasing deployment of technology at work, the state of installed technology eventually reaches an operational state where it needs replacement or becomes surpassed by updated versions of the technology. Individual component repair or replacement of a broken unit is indicative of a traditional technology maintenance program, but this does not necessarily represent a state, where much of the organization's technology needs a changeover as discussed in this paper.

Changeovers here represent the replacement of technology and the continued use of this technology in an operationally improved form, and the changeover is a wholesale replacement of the technology. Hence, replacement *en masse* of the technology to newer version that possessed additional features is indicative of a technology changeover. Hallmarks of a technology changeover are an upgrade of a technology system by replacing incompatible units, replacement

of units on an enterprise-wide scale to improve efficiency, and stay current with the technological innovations. Timing this replacement can be a challenge as completing a changeover too early could provide additional improved technology at a higher cost to the organization, but the improvement may provide no additional strategic value. Changeover, instead of repair at a later time, might be beneficial to an organization with some number of aging technologies (e.g., computers) when the updated technology is a better option than the combination of downtime and maintenance costs associated with not updating the technology. Another option might be to delay changeover until the technology cannot effectively meet the expected performance need of users, when it stops working, replacement parts are hard to find, or it becomes totally outdated.

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Identifying risk interdependencies in pharmaceutical supply chains through gamification-enabled structural modelling

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ABSTRACT

We develop an approach for the evaluation of interrelated risks that could compromise a pharmaceutical supply chain's ability to serve patients, whereby experts conduct pairwise-comparisons through an online gamification-enabled platform. Risks categorization based on structural modelling elevates their consideration beyond the single instance in which they are normally evaluated.

KEYWORDS: Multi-method research, Pharmaceutical Supply Chains, Supply Risk Management

INTRODUCTION

The literature on risk management in supply chains has developed substantially in recent years demonstrating the importance of taking a systems perspective on risk. For example, since the seminal work of Craighead, Blackhurst, Rungtusanatham, & Handfield (2007) increasing attention has been paid to the network characteristics of supply chains, and how these characteristics may affect system-wide disruptions. In a similar fashion, the World Economic Forum (2018) highlights that global risk perception should take into account how different risks might influence each other, as if forming a network, rather than evaluating each risk in isolation in terms of frequency and magnitude. Interdependencies between individual risks are sometimes acknowledged (for example, Chopra & Sodhi 2004), but not generally considered. The pharmaceutical sector provides an ideal context to address this methodological gap. Pharmaceutical Supply Chains (PSC) are increasingly exposed to disturbances such as the contamination, adulteration and substitution of pharmaceutical ingredients throughout increasingly global sourcing processes; the intentional and fraudulent production of drugs (counterfeiting); and the manifestation of arbitrage behavior through speculative inventory build-up in secondary distribution channels (Marucheck, Greis, Mena, & Cai, 2011). Due to the fragmented nature of PSCs, it is not common practice to analyze the identified risks in terms of possible interdependencies between them. Rather, the industry's approach to risk management is predominantly concerned with Good Manufacturing Practice (GMP) and regulatory compliance (Friedli, Basu, Bellm, & Werani, 2013, p. 63). Whilst relationships between risks are sometimes defined in hierarchical terms as in Fault Tree Analysis (Rees, 2011, p. 403), these approaches lack consistent analytical counterparts.

Considering the above mentioned gaps, we develop an approach for identifying and evaluating risk interdependencies that could compromise a PSC's ability to serve patients. This is achieved by answering the following research questions:

- RQ1: How can PSC risks be categorized and prioritized while systematically taking into account the interdependencies between them?
- RQ2: Which areas of interventions become more prominent when risk interdependencies are taken into account?

The proposed approach is meant to inform the formulation of mitigation strategies by elevating the consideration of risks beyond the single instance in which they are normally assessed. The reminder of this paper provides an overview of the relevant academic literature; outlines key methodological aspects for the elicitation and analysis of expert knowledge on risk interdependences; and illustrates an initial implementation through a sector case study in the UK pharmaceutical industry. This is followed by a discussion of some preliminary findings, and the expert feedback on how such findings may inform a critical appraisal of current and perspective risk mitigation practices.

LITERATURE REVIEW

Compared to the vast academic literature on Risk Management in Supply Chains (Heckmann, Comes, & Nickel, 2015 provide an overview), relatively little work has investigated the nature and prevalence of risk in pharmaceutical supply. For example, Huq, Pawar, & Rogers (2016) surveyed senior PSC executives on 20 'disturbance factors' in three global pharmaceutical network configurations differing for outsourcing location policy; Panzitta et al. (2017) propose a simplified risk assessment procedure to help regulators to quickly assessing medicine shortage risk in relation to 10 factors potentially affecting manufacturing complexity; Breen (2008) mapped out the PSC underpinning the UK National Health Service and identified 35 aspects of the current 'state-of-the-world' that could negatively affect the movement of medicines and materials, and hence compromise the treatment of patients. Jaberidoost, Nikfar, Abdollahiasl, & Dinarvand (2013) identify 50 vulnerability areas of a PSC by reviewing the literature. While a comprehensive overview of the literature is left outside the scope of this paper for brevity, it is possible to outline broad trends from both a conceptual and a data-driven modelling perspective:

- From a conceptual perspective, a common trait across research carried out to date, regardless of specific applications to PSC, is that the emphasis is placed on identifying and categorizing disturbances, chiefly uncertain and adverse triggering-events and outcomes, which are aggregately addressed with the blanket term 'supply chain risks'.
- From a modeling perspective, there seems to be three incumbent perspectives on data-driven supply chain risk management in PSC, namely:
  - *Statistical inference and predictive analytics*: empirical observations such as time-series or longitudinal data are mined to detect regularities in the occurrence of specific events. With regards to the pharmaceutical industry, regulatory agencies provide public domain datasets regarding, for example, medicine shortages and recalls. The analysis of such data with the aim of identifying trends and developing predictive analytics has received little attention in academia (Aschenbrücker, Löscher, & Troppens, 2013);
  - *Simulation and optimization*: probabilistic and 'snapshot' data (i.e. not historical) concerning the occurrence of identified scenarios are commonly taken into account when optimizing supply network configuration or simulating inventory dynamics in the form of stochastic programming and chance constraint. Applications may include avoiding medicines shortage by optimizing the build-up of buffer inventory as a mitigation strategy. For example Bam, McLaren, Coetzee, & Von Leipzig (2017) apply Systems Dynamics to model shortage risk for tuberculosis medicines;

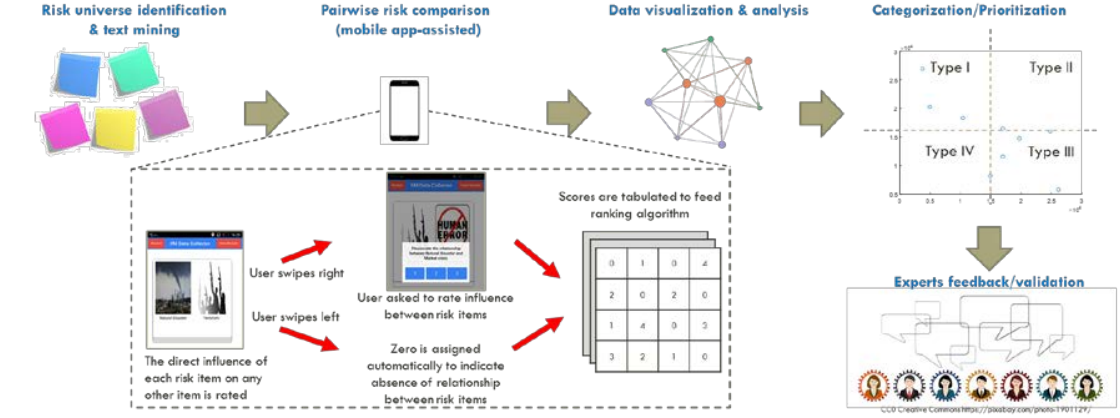
- *Expert judgment*: In the absence of precise quantitative data about specific product supply chains, the two approaches mentioned above cannot be applied. Often, the only source of empirical evidence is the expertise of those 'in the know', which then needs to be appropriately elicited and processed to provide some aid to decision making. Expert judgment may be elicited in the form of qualitative data, as in interviews or panel studies (Breen, 2008); or semi-quantitative data such as scores on ordinal scales as in surveys (Huq et al., 2016) and pair-wise comparisons (Raka & Liangrokapart, 2017).

The last perspective is of particular relevance for this paper, since empirical evidence is gathered chiefly through expert judgment. The reason for this choice is twofold. First, the necessary data for simulation and optimization is often company and product-specific: while providing greater accuracy, this approach may limit *a priori* the possibility to gather a broader, multi-stakeholder perspective on the topic of risk in PSC. Second, most statistical datasets available in the public domain have geographical coverage limited to the United States, and lack an end-to-end supply chain perspective. Rather, these datasets focus on the occurrence and duration of specific events such as shortage and recall of pharmaceutical products, sometimes accompanied by the indication of a single cause for its occurrence (for example, 'manufacturing delay', 'demand variability' etc.).

MATERIALS AND METHODS

The multimethod research approach adopted in this paper for modeling PSC risk is illustrated schematically in Figure 1.

Figure 1: Visual summary of proposed approach



The following sub-sections illustrate the key methodological aspects of the proposed multi-method research approach with regards to terminology and conceptual assumptions; techniques for semi-quantitative analysis; and data gathering process.

Theoretical perspective

In the context of this research, the notion of PSC risk is chiefly associated with the ability or inability to provide patients with the 'right' medicines.

While risk is relatively straightforward to formulate mathematically, it is more difficult to reach agreement on contextual definitions that enable the effective management of risk in supply chains (Kumar, Srai, & Gregory, 2016). A widespread attitude towards the concept of risk is to place the emphasis almost exclusively on what can go wrong, and hence on what supply chain organizations need to worry about (Olson & Wu, 2010). Underneath this common understanding of risk is the belief that unacceptable outcomes must have unacceptable causes, and that these

must be distinct from the causes of acceptable outcomes, thus reflecting an implicit moral codex in which good deeds are rewarded and bad deeds are punished (Hollnagel, 2018). This belief is implicitly endorsed in PSC through commonly adopted managerial practices such as root cause analysis – see for example Friedli et al. (2013). The main methodological implication of this terminological habit is that hunting for broken components within complex socio-technical systems continues to equate with 'good analysis' (Dekker, 2011).
A more nuanced view is that undesired outcomes typically associated with the notion of 'risk' emerge from the behavior of a complex socio-technical system, hence making 'things that go wrong' hardly separable from 'things that go well' (Hollnagel, 2018). Fewer works have brought to the fore the role of structural elements reflecting the system-like nature of supply chains in general, and PSC in particular. For example, Craighead, Blackhurst, Rungtusanatham, & Handfield (2007) associate the occurrence of supply chain disruptions, as well as the ability to respond to such disruptions through mitigation capabilities with structural elements of supply chains across several industries, including pharmaceutical, such as density, complexity, and node criticality.
The terminological caveats examined above lead to the following conceptual assumptions, which are adopted henceforth:

1. The term 'risk' more appropriately describes the exposure to the chance of loss or gain by choice rather than fate: in this way the attention is shifted towards managerial aspects for which decision support tools are needed (Emblemsvåg, 2011);
2. Supply chains being complex socio-technical systems (Pathak, Day, Nair, Sawaya, & Kristal, 2007), focusing on linear cause-effect relationships to understand adverse and disruptive outcomes can be misleading. Rather, it is necessary to pay greater attention to both the relevant system's elements, and the contextual relations among them;
3. Higher-order interactions between ill-defined elements of a complex system are difficult to grasp relying on the individual's bounded rationality. To explore these interactions, experts need to sharpen their perception of the relationships between the system's elements through a formalized structure (Bolaños, Fontela, Nenclares, & Pastor, 2005).

Techniques for semi-quantitative analysis

The theoretical perspective presented above is addressed here through Structural Modeling (SM). A common principle across various SM techniques is to enable a group of experts to formally articulate an ill-defined problem in terms of elements and relationships within a system using the principles of graph theory, while allowing each expert to contribute diverse data, skill, and knowledge – see Lendaris (1980) for a comparative overview.
Specifically, two closely related techniques will be considered here:

- the structural problematique analysis developed within the DEMATEL (Decision Making Trial and Evaluation Laboratory) project (Fontela & Gabus, 1974), and
- the MICMAC (Matrice d'Impacts Croisés-Multiplication Appliquée à un Classement) technique (Godet, 1977).

Both approaches take inexact, subjective inputs with the aim of producing a meaningful, but not precise output by ranking, categorizing, and visualizing the elements included in the system of interest based on how they relate to each other. In both cases, the system's elements are typically qualitative structural variables of memory and experience, anticipation and foresight, or needs and goals; the relationships between such elements are typically relational statements can be definitive, comparative, influential, or mathematical in nature.
The key difference between MICMAC and DEMATEL is in the classification/prioritization and visualization of the elements of the system based on their interrelationships. In particular:

- Visualization facilities: both MICMAC and DEMATEL generate classification planes with specific interpretations for different areas of the plane;

- Computational structure: DEMATEL is based on solving a convergent series the elements of which are powers of a normalized cross-impact matrix. Conversely, MICMAC is based on raising a cross-impact matrix to consecutive powers following specific stopping criteria;
- Procedural consistency: DEMATEL is probably the approach more accurately described since the outset from a computational perspective. The consistent application of MICMAC is difficult to verify, as most works in the literature do not disclose the analytical details of the steps followed (see for example Jain, Kumar, Soni, & Chandra, 2017).
- Synthesis of multiple responses: DEMATEL explicitly provides analytical devices to combine multiple responses obtained from different experts, and to deal with the uncertainty deriving from such variety. In principle, also MIMAC and ISM may involve multiple experts, but it is unclear how this is analytically taken into account.

Based on our literature review, neither DEMATEL nor MICMAC have been applied to evaluate risk interdependencies in PSC. While System Dynamics qualifies as an SM tool (Lendaris, 1980), its applications to PSC are either product-specific (Bam et al., 2017), or purely schematic representations of causal paths and feedback loops (Narayana, Arun, & Rupesh, 2014).

Data gathering process

The identification of relevant risks with specific regards to the PSC was carried out through an iterative process involving multi-stakeholder workshops; qualitative data analyses through text mining; and online collection of semi-quantitative data (ordered-category rating items) through gamification-enabled structural modelling. Workshops were deemed a suitable format to gather reliable data through the active participation of a selected group of individuals sharing common expertise in the domain of interest (Ørngreen & Levinsen, 2017).

The steps of the knowledge elicitation process can be summarized as follows:

- Identification of risk elements to generate a 'risk universe' for a generalized PSC using a standardized PSC configuration map (Srai & Gregory, 2008) within a semi-structured workshop process involving input from multiple experts with extensive experience on risk analysis across the sector. Experts included individuals from two of the largest UK-based medicine manufacturers; a leading specialist healthcare distribution logistics providers; the major pharmacy retailer in the UK; a healthcare consultancy practice providing analytical tools for risk management; and a financial institution specializing in pharmaceutical risk insurance and reinsurance.
- Over 120 hours of expert deliberations on risk events informed the development of a 'universe' or risks, generating 121 risk items (statements) across the end-to-end PSC. In line with the incumbent risk management practice and academic literature alike, the risk universe thus obtained represented a comprehensive list of 'things that can go wrong' in a PSC, each accompanied by a definition and supporting statement of possible root causes. The potential relationships between these items were not identified at this stage;
- Textual data analysis: standard text mining techniques (Provost & Fawcett, 2013 Ch.10) were deployed to evaluate wording similarity and discover possible latent topics across items included in the workshop's risk universe, as well as in relation to 13 similar lists published in the academic literature. Through multiple iterations informed by the text mining results, 74 risk items aggregated in 17 categories were selected as elements of the system of interest to be further analyzed through SM. The items and categories included in this subset of the risk universe are listed in the Appendix;
- Pair-wise comparison of selected risk item: a second data-gathering process involved a group of five experts representing primary and secondary manufacturing; distribution and retail pharmacy, and institutional sector risk consultancy. The experts were required to provide $N = n(n-1)$ scores on a scale from 0 [no influence] to 5 [very strong influence], were $n = 74$ is the number of risks included in the final list. A gamification-enabled online

platform for structural modelling (MATRisk: https://remedies-ifm.azurewebsites.net/) was specifically developed to enable the assessment of the level of interdependence between risks by pair-wise comparison.

Elements of gamification were specifically introduced to incentivize users to engage in the process of collecting data of greater quantity and quality (Seaborn & Fels, 2015). In particular, through the online platform, each respondent scored remotely and in their own time the N pairs of risk items. Each pair was presented on screen as a 'card' containing an iconic representation and textual description of each item. The pairwise comparisons between these items was operated either by simply 'swiping left' to indicate that no association between the items exists, or 'swiping right' otherwise – in which case the respondent is asked to score the magnitude of the association on a 5-point ordinal scale. To expedite the process, experts could swipe groups of items simultaneously by using top-level cards corresponding to the 17 categories previously identified. The second process step in Figure 1 provides an iconic representation of the proposed gamification-enabled pair-wise comparison.

The preliminary data gathered process was carried out over 20 days throughout April 2018, following a webinar organized by the researchers to illustrate the purpose and use of the online platform to the enrolled respondents. At the end of the time window, data was gathered in the form of cross-impact matrices, analyzed by the researchers and the results presented to the respondents for feedback in a follow-up validation workshop.

RELIMINARY FINDINGS

To address RQ1 and RQ2, this section provides insights into the process of generating a classification and prioritization of PSC risks from experts-generated interdependencies scores. For the sake of clarity, the analysis is illustrated through a streamlined example first, and later on applied to actual data obtained from one respondent through the MATRisk online platform. For illustration, assume the risk universe consist of 7 items; then a hypothetical expert response corresponds to a 7 × 7 cross-impact matrix $\mathbf{X}$ like the one depicted in Table 1. (An actual table gathered through MATRisk would have 74 × 74 = 5,476 cells: due to space limitations, such table is not reported in full here, but is available from the authors on request)

Table 1: Hypothetical response numerical example: values are randomly generated for illustrative purposes only

EXP	Influencing risk item	Influenced risk item						
		1	2	3	4	5	6	7
A	1 Critical findings during Quality Audit	0	0	1	0	0	0	5
D	2 Process variability and quality deviation	0	0	0	0	2	5	0
A	3 Final product contamination/degradation	0	0	0	0	0	0	5
B	4 Supplier's understanding of regulatory constraints	3	0	0	0	0	0	0
C	5 Strategic/commercial decision by supplier to discontinue product	0	0	0	0	0	0	0
B	6 Lack of process robustness/process failure/variability of product	0	3	4	0	0	0	0
E	7 Shelf life insufficient for product lifetime/distribution timescales	5	0	0	0	0	0	0

EXP: expert classification by cause/responsibility (A - Failure in Focal Company Quality; B - Failure in Contract Manufacturer quality; C - Inability of supply; D - Process complexity/variability; E - Regulatory Change);

Table 1 shows an example of how most SM techniques, such as DEMATEL and MICMAC, formally articulate the relationships of direct influence between any pair of constituting parts of the problem situation. Each cell in the cross-impact matrix records the expert's assessment of the influence of the item listed row-wise on the item listed column-wise. Hence, the generic element of a cross-impact matrix $\mathbf{X}$ can be interpreted as follows:

$$\mathbf{X} = \left[x_{ij}^{k}\right] = \begin{cases} l, & \text{expert } k \text{ believes that } i \text{ exerts direct influence of magnitude } l \text{ on } j \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

In equation (1), each row and column of $\mathbf{X}$ (hence, each risk item) is indexed as i and j, respectively. The estimate l of the magnitude of a relationship between elements of a problem situation is typically expressed using ordered-category rating items. Unfortunately, there is no consistent use of rating items in the literature. Depending on the individual study, the rating items range from [0, 1], indicating just the absence/presence of an influential relationship (see for example Jain et al., 2017), and up to 5-points ordered-category rating items to indicate very low [1] to very high [5] influence (see for example Rajesh & Ravi, 2017). The latter type of rating item is not be confused with Likert-type scales used in survey research, since it lacks the characteristic of being a bipolar and symmetrically balanced response set, and it is not meant to indicate degree of agreement with a stimulus attitude statement.

For example, $x_{2,5} = 2$ denotes that, in the expert's opinion there is a direct influence between risk item 002 ('Process variability and quality deviations') and risk item 005 ('Strategic/commercial decision by supplier to discontinue product'). While this is not the case the other way round, since $x_{5,2} = 0$. Mutual influences are allowed, but the relationship is not symmetrical i.e., 'A influences B' does not imply that 'B influences A'. In terms of the MATRisk online platform usage, this means that the respondent has 'swiped right' when presented with a the pairwise comparison card stating 'Risk item 002 influences risk item 005', but they 'swiped left' when presented with the card stating the relationship the other way round. Consequently, along any row of matrix $\mathbf{X}$ one reads the direct influence exerted by the corresponding risk item on any other item; along any column, one reads the dependence of the corresponding risk item on any other item. In the example, item 002 directly influences items 005 and 006 ('Lack of process robustness/process failure/variability of product'); and it directly depends on items 005, hence 002 and 005 are said to form a cycle. Matrix $\mathbf{X}$ can, in fact, be interpreted as the incidence matrix of a weighted directed graph. For an actual response, Figure 2 shows the network visualization and descriptive analysis generated using Gephi (Bastian, Heymann, & Jacomy, 2009).

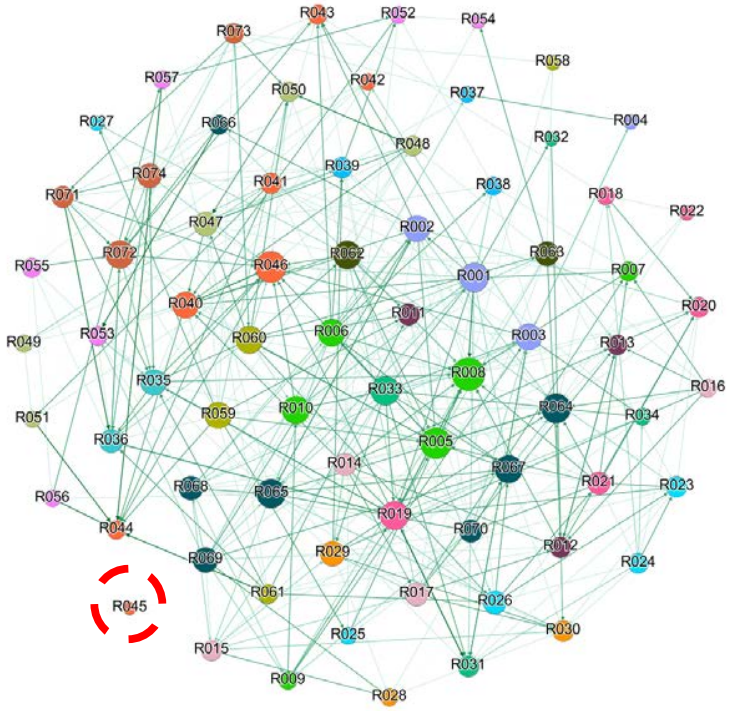
The use of graph-theory to interpret the cross-impact matrix $\mathbf{X}$ is a key principle of SM in general (Lendaris, 1980), and of techniques such as MICMAC and DEMATEL in particular. Both techniques take $\mathbf{X}$ as input, but then process it in a slightly different fashion:

According to the MIMAC technique, $\mathbf{X}$ is raised to successive powers $p = 2,3,\ldots$ to unravel paths of influence beyond the direct connections represented in the corresponding graph. For example, making reference to the hypothetical example in Table 1, risk item 002 does not exert a direct influence on item 003 ("Final product contamination/degradation") but it does so indirectly through item 006, which it directly influences and, in turn, influences item 003. This is known as transitivity. This path can be discovered through the Boolean operation of raising $\mathbf{X}$ to the power $p = 2$, and checking that $x_{2,3}^{(2)} \neq 0$ – here the notation $x_{i,j}^{(2)}$ denotes the element in row i and column j in the Boolean matrix associated with $\mathbf{X}^2$, not $\left(x_{ij}\right)^2$. This leads to the following general formulation:

$$\mathbf{T}^{*} = \lambda \mathbf{X}^{p^{*}} \quad (2)$$

Where $\mathbf{T}^{*}$ is the normalized matrix of total connections, p^{*} is the highest power to which matrix $\mathbf{X}$ is raised; and λ is a normalization factor. Unfortunately, there is no agreement in the literature with regards to the parameters λ and p^{*}.

Figure 2 Network visualization, descriptive analysis of initial response (risks list in Appendix)



Network summary:
- Avg. degree: 5.9
- N = 74; L: = 443
- Density: 0.08
- Avg. path length: 4.12

- Arcs color-coding: weight (the higher the score the darker the arc color)
- Nodes color-coding: categorization in risk universe

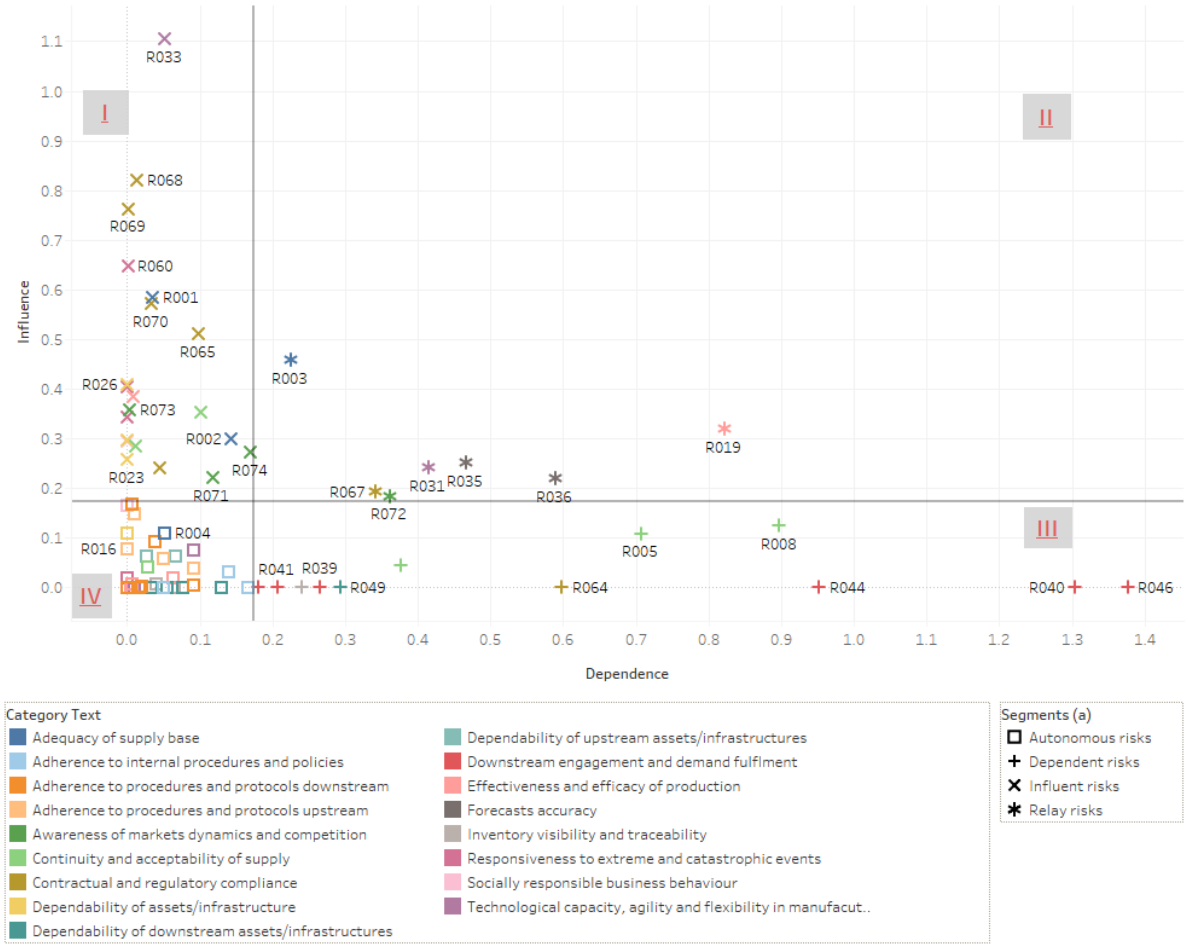
For example, Godet (2007) suggests that p^* is such that greater powers no longer affect the ranking of the vector sums across the columns and rows of $\mathbf{T}^*$, whereas Lendaris (1980) implies that $p^* = n$; in either case $\lambda = 1$. Conversely, (Hachicha & Elmsalmi, 2014) use $\lambda = 10^{-p^*+1}$ but do not provide a general rule. Other applications do not disclose the computational procedure followed in implementing MICMAC. In the simplified example considered here, $p^* = 4$ is found iteratively. It follows that $\lambda = 10^{-3}$ and:

$$\mathbf{T}^* = \begin{bmatrix} 0.625 & 0 & 0.025 & 0 & 0 & 0 & 0.250 \\ 0.500 & 0.225 & 0.300 & 0 & 0 & 0 & 0 \\ 0.625 & 0 & 0 & 0 & 0 & 0 & 0.125 \\ 0.075 & 0 & 0.075 & 0 & 0 & 0 & 0.375 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.100 & 0 & 0.090 & 0.225 & 0.800 \\ 0.125 & 0 & 0.125 & 0 & 0 & 0 & 0.625 \end{bmatrix}; \mathbf{d}^* = \mathbf{1}' \mathbf{T}^* = \begin{bmatrix} 1.95 \\ 0.22 \\ 0.62 \\ 0 \\ 0.09 \\ 0.22 \\ 2.17 \end{bmatrix}; \mathbf{r}^* = \mathbf{T}^* \mathbf{1} = \begin{bmatrix} 0.90 \\ 1.02 \\ 0.75 \\ 0.52 \\ 0 \\ 1.21 \\ 0.87 \end{bmatrix}'$$

Vectors $\mathbf{d}^*$ and $\mathbf{r}^*$ are obtained, respectively, as the column and row sums of $\mathbf{T}^*$, providing for each item in Table 1 a measure of its overall power of influencing or being influenced, directly and indirectly, by any other items. The elements in $\mathbf{d}^*$ and $\mathbf{r}^*$ that correspond to a specific risk item are used as coordinates to graphically represent the item on a Cartesian plane. For an actual respondent, Figure 3 (next page) shows the risk items scatterplot on the influence/dependence plane.

In Figure 3 the risk items are categorized as they fall into specific quadrants of the plane based on whether their coordinates are above or below the average dependence and influence. Proceeding clockwise, each quadrant is interpreted as follows (Godet, 2007):

Figure 3 MICMAC risk categorization for initial response (risks list in Appendix)

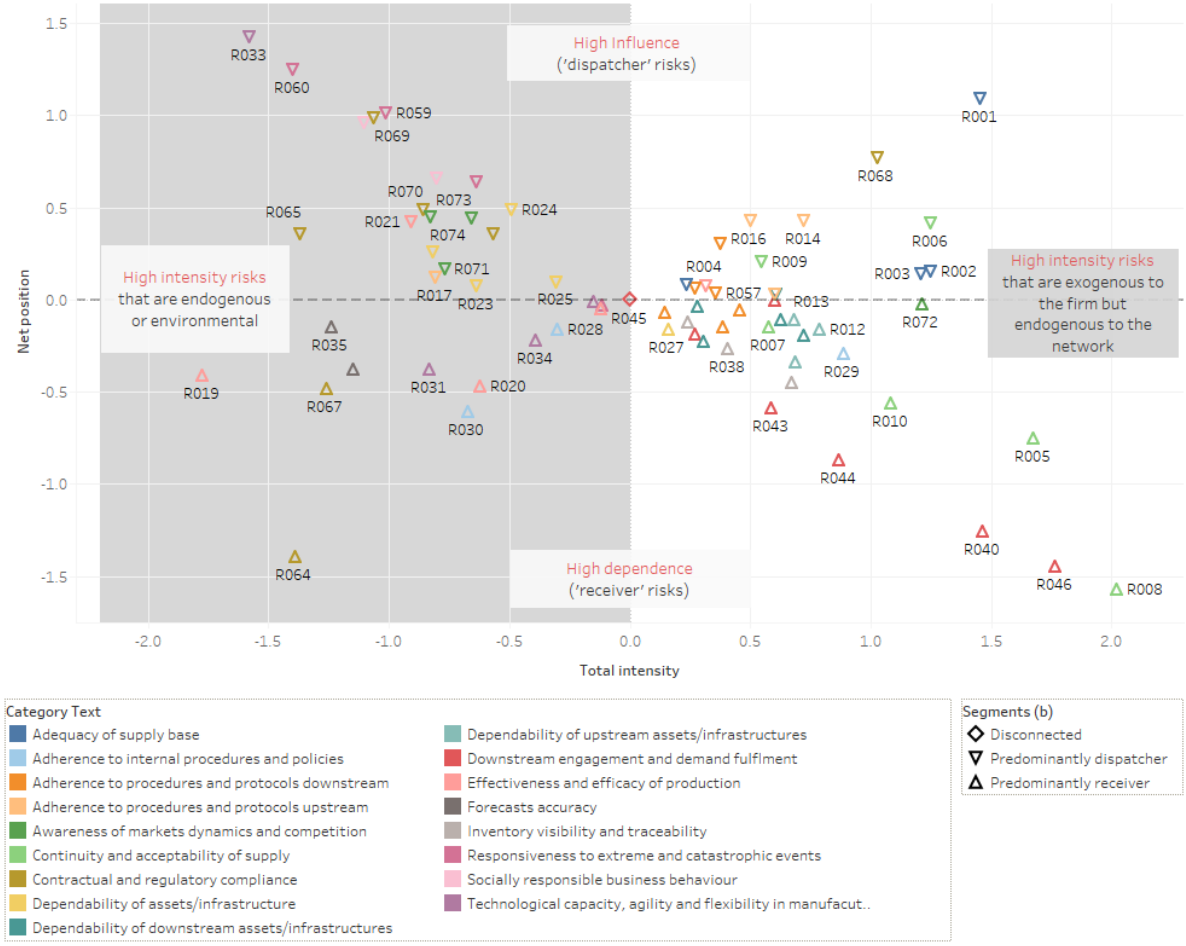


- Quadrant I (upper-left): mostly *influential* items, potentially conditioning and explaining the behavior of the whole system;
- Quadrant II (upper right): gate-keeping or *'relay'* items showing instability, characterized by being both influential and dependent on other items in the system;
- Quadrant III (lower right):mostly *dependent* items, largely resulting from the interactions between those items in quadrants I and II;
- Quadrant IV (lower left): mostly *autonomous* items, that may be expected to have little or no influence on future developments having fewer relationships with the rest of the system. These can be safely discarded from further analysis.

The segments corresponding to each quadrant are visually codified as shapes in Figure 3.
The same matrix-structured dataset gathered through the MATRisk app was analyzed through the DEMATEL technique. A distinguishing feature of DEMATEL is that the total connections matrix $\mathbf{T}^*$ is the result of a convergent series, the element of which are powers of a normalized cross-impact matrix $\mathbf{A}$ obtained by multiplying the raw data gathered in $\mathbf{X}$ by a scalar equal to the reciprocal of the largest row sum of the cross-impact matrix (Fontela & Gabus, 1974):

$$\mathbf{T}^* = \lim_{p\to\infty}\left(\mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \cdots + \mathbf{A}^p\right) = \mathbf{A}(\mathbf{I} - \mathbf{A})^{-1} \quad (3)$$

Figure 4 DEMATEL risk categorization of initial response (risks list in Appendix)



In equation (3), $\mathbf{I}$ is an identity matrix of adequate size, and the superscript "-1" denotes matrix inversion. The aspects of normalization and convergence criteria when computing the total connection matrix as shown in equation (3) are less ambiguous in the literature than in the MICMAC case. As in the MICMAC case, the key metrics of dependence and influence are obtained by summing the elements of the total row and column-wise, respectively. Using the simplified example in Table 1, from equation (3) one obtains:

$$\mathbf{T}^* = \begin{bmatrix} 1.39 & 0 & 0.34 & 0 & 0 & 0 & 1.95 \\ 0.71 & 0.44 & 0.69 & 0 & 0.41 & 1.20 & 1.01 \\ 1.22 & 0 & 0.17 & 0 & 0 & 0 & 1.71 \\ 1.02 & 0 & 0.14 & 0 & 0 & 0 & 0.83 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1.01 & 0.61 & 0.96 & 0 & 0.17 & 0.44 & 1.41 \\ 1.71 & 0 & 0.24 & 0 & 0 & 0 & 1.39 \end{bmatrix}; \mathbf{d}^* = \mathbf{1}' \mathbf{T}^* = \begin{bmatrix} 7.09 \\ 1.06 \\ 2.57 \\ 0 \\ 0.58 \\ 1.47 \\ 8.32 \end{bmatrix}'; \mathbf{r}^* = \mathbf{T}^* \mathbf{1} = \begin{bmatrix} 3.69 \\ 4.30 \\ 3.12 \\ 2.01 \\ 0 \\ 4.62 \\ 3.36 \end{bmatrix}$$

The elements are visualised and categorized by combining the corresponding values in vectors $\mathbf{d}^*$ and $\mathbf{r}^*$ as follows:

- $\mathbf{y} = \mathbf{r}^* - \mathbf{d}^*$: is the "net position" of the risk items. A positive entry in $\mathbf{y}$, indicates that the corresponding risk item is predominantly a "dispatcher", strongly influencing other risks. Whereas, if negative the item is predominantly a "receiver", strongly influenced by other risks.
- $\mathbf{x} = \mathbf{d}^* + \mathbf{r}^*$: is the "total intensity" of the risk items. Similarly to the concept of weighted node degree in a network, larger-valued entries in $\mathbf{x}$ denote risk items of greater overall relevance, considered simultaneously as a dispatcher and receiver.

With reference to the data gathered for an actual respondent, Figure 4 (above) shows an alternative scatterplot of the same risk items according to their net position and total intensity indicators computed according to the DEMATEL procedure described above. In Figure 4, risks regarded as endogenous and environmental are shown with total intensity increasing from right to left (greyed area), whereas risks regarded as exogenous to the individual firm but endogenous to the PSC are shown with total intensity increasing form left to right.

DISCUSSION

Although derived from a limited respondent base, the results illustrated in the previous section already provide some structural insights into the propagation of risks in a generalised PSC when possible interdependencies between risks are explicitly taken into account.

Joint examination of Figures 3 and 4 leads to the following observations:

- Dependent risks (items falling in Quadrant III of Figure 3; bottom half of Figure 4) are mostly located downstream, reflecting a linear upstream-to-downstream flow of influence. For example, almost all the risk items included in the category "downstream engagement and demand fulfilment" exhibit high dependency (bottom-right quadrant in Figure 3; and bottom half of Figure 4). Most of these items are perfectly dependent (nil influence). Those items that more closely reflect the overarching PSC risk concept defined in the theoretical perspective section, namely R046 ("Product shortage prevents patient getting product") and R040 ("Delays in delivery to patient"), exhibit the highest dependence in Figure 3. Whilst these items are still prominent in Figure 4, risks belonging to other categories, namely R008 ("Late or incorrect delivery of materials "") and R064 ("Loss of license to operate") exhibit higher rank in terms of receiver net position and intensity;
- Influential risks (items falling in Quadrant I of Figure 3; upper half of Figure 4) belong to heterogeneous categories. The highest ranking risk in this segment, R033, is technological in nature and related to the increasing complexity of medicines portfolios. Most contractual/regulatory compliance risks, and risks in the category "responsiveness to catastrophic and extreme events" fall in this segment (upper-left quadrant in Figure 3; upper half of Figure 4);
- Relay (unstable) risks (Quadrant III in Figure 3; middle-right/left in Figure 4): the presence of seven items in the upper-right quadrant in Figure 3 suggests some instability in the system, although none of these items scores simultaneously as high in influence and dependence. Relay items are either endogenous to the firm or environmental in nature, including categories such as: process complexity/variability; forecast accuracy; and inability of supply;
- Ambiguous risks: some risks are located in close proximity to the x or y-axis in Figure 3, such as R067 ("Failure/inability to comply with regulatory change") and R072 ("Product diversion e.g. product not being sold in target market in the presence of price differentials"). These risks are more difficult to categorize and require further analysis (Godet, 2007).
- Independent risks (Quadrant IV in Figure 3; close to the centre in Figure 4): Almost half (~46%) of the risk items evaluated falls into the "autonomous" category and hence could be dismissed, as they exhibit weak influence and dependence. For example, two downstream risks have neutral net position, with R045 ("Extended applicability of GDP to handling points in the distribution chain") being perfectly autonomous (graphically positioned at the point of origin in Figure 3 and 4; and a disconnected node in Figure 2).While relevant in terms of risk

identification, these risks might not propagate as pervasively as others, rather, they can be regarded as mostly self-contained and hence not a priority.

Preliminary findings such as those discussed above provided the grounds for an expert-panel discussion in a follow-up workshop. Visual analytics analogous to those shown in Figure 3 and 4 were presented to the participants through interactive dashboards on multi-user touch-screen surfaces to enable further interrogation and exploration of the data as part of a small-group learning activity.

From a mitigation strategy perspective, the analysis lends itself to network theories on contractual relationships and their implications for supply chain management (Kim, Choi, Yan, & Dooley, 2011). More specifically, proposed risk management for networked risks (54% of those identified in our study) would be informed by the identification of influential, informational dependent, and relational mediation characteristics of risks. For independent risks (46% in our study) conventional approaches to manage and mitigate risk such as those prosed by Chopra & Sodhi (2004) and Kumar et al. (2016) would remain appropriate and relevant.

From a computational standpoint, similarities and differences between MICMAC and DEMATEL and the visual-analytical insights they generate are rarely pointed out. Rather, either technique is chosen upfront by individual studies without acknowledging the other. This reflects a more general lack of comparative research on SM approach since seminal works such as Lendaris (1980). For similar reasons, only few works to date address the issue of assessing the reliability and validity of the results obtained through these techniques (e.g., Shieh & Wu, 2016).

CONCLUDING REMARKS

This paper has presented an approach for the evaluation of interrelated risks that could compromise a pharmaceutical supply chain's ability to serve patients. The approach was developed in line with multi-method research, and it encompassed the elicitation of expert knowledge on risk events across the PSC; the development of an online gamification-enabled platform for experts to conduct pairwise-comparisons; and the use of structural analysis methods to categorize and prioritize risks based on their identified interrelationships. These steps have been illustrated throughout the paper with reference to some preliminary results gathered from actual survey responses with a focus on the UK pharmaceutical landscape. Feedback and validation of preliminary findings through industry experts' engagement confirm the utility of the approach in determining risk category clusters where interdependencies elevate their consideration beyond the single instance in which they are normally evaluated.

While existing techniques are employed as part of the proposed approach, its novelty lies in the broader process of expert judgement elicitation, from the identification of a sector-specific universe of risks, through to the analytical evaluation of the possible interdependencies between the identified risks, and up to bringing the analytical insights gathered from individual respondents back to the group for discussion and validation.

The proposed approach promotes the innovative use of gamification-enabled structural modelling, thus explicitly addressing the challenges of engaging experts in a potentially cumbersome data gathering process. The panel discussion provided initial feedback on the respondents' overall experience with the data gathering process, visualisation of results insights on ranking. Overall, the MATRisk app was found to be easy to use, and serving its purpose of expediting a comparison process potentially involving 5,000+ pairs of items.

An obvious limitation of the research presented in this paper is that it relies on preliminary results gathered from a limited set of respondents. However, similar works often present aggregated view through a single super-respondent, or are vague with regards to whether single or multiple experts are involved in a study. Other limitations include the absence of a consistent approach on assessing the reliability and validity of the results obtained through SM techniques. Addressing these limitations calls for further research on this topic.

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APPENDIX – LIST OF RISK ITEMS EVALUATED THROUGH THE MATRisk APP

Item *	Category (based on text analysis and judgment)	Top-level classification (literature)
R001, R002, R003, R004	Adequacy of supply base	Exogenous to the firm, endogenous to the network
R005, R006, R007, R008, R009, R010	Continuity and acceptability of supply	Exogenous to the firm, endogenous to the network
R011, R012, R013	Dependability of upstream assets/infrastructures	Exogenous to the firm, endogenous to the network
R014, R015, R016, R017	Adherence to procedures and protocols upstream	Exogenous to the firm, endogenous to the network
R018, R019, R020, R021, R022	Effectiveness and efficacy of production	Exogenous to the firm, endogenous to the network
R023, R024, R025, R026, R027	Dependability of assets/infrastructure	Endogenous
R028, R029, R030	Adherence to internal procedures and policies	Endogenous
R031, R032, R033, R034	Technological capacity, agility and flexibility in manufacturing	Endogenous
R035, R036	Forecasts accuracy	Endogenous
R037, R038, R039	Inventory visibility and traceability	Exogenous to the firm, endogenous to the network
R040, R041, R042, R043, R044, R045, R046	Downstream engagement and demand fulfilment	Exogenous to the firm, endogenous to the network
R047, R048, R049, R050, R051	Dependability of downstream assets/infrastructures	Exogenous to the firm, endogenous to the network
R052, R053, R054, R055, R056, R057	Adherence to procedures and protocols downstream	Exogenous to the firm, endogenous to the network
R058, R059, R060, R061	Responsiveness to extreme and catastrophic events	Environmental
R062, R063	Socially responsible business behaviour	Environmental
R064, R065, R066, R067, R068, R069, R070	Contractual and regulatory compliance	Environmental
R071, R072, R073, R074	Awareness of markets dynamics and competition	Environmental

*Full description omitted due to space constraints. Details available on request.

DECISION SCIENCES INSTITUTE

Impact of Game-Based Classroom Response System as a Persuasive Technology on Students' Perception of Their Learning Experience:
Case study of Information Systems course for Business Student

ABSTRACT

This survey study measured the effect of game-based classroom response system as a persuasive technology on the students' perception of their learning experience. A group of 108 Business students enrolled in one of the introductory courses of Management Information Systems was selected as a convenient sample. Based on Fogg Behavioral Model, three independent variables were selected, which are Ability, Motivation, and Trigger factors. The effect of these factors on the dependent variable, students' perception of their learning experience, was measured. Multiple linear regression test was used to determine the best-fit models between the independent and dependent variables.

KEYWORDS: Game-based classroom response system, Persuasive technology, Gamification, Fogg behavioral model (FBM), Motivation

INTRODUCTION

There are different types of classroom response systems (CRS) in the new educational era such as Turning Point, Poll Everywhere, Top Hat, Socrative, Clicker, and Kahoot. Mahon (2012) defined classroom response system as "technology that allows an instructor to present a question or problem to the class; allows student to enter their answers into some kind of device; and instantly aggregates and summarizes students' answers for the instructor". The features of game-based learning such as competitive practices, immediate feedback, and classroom monitoring are supported by the newer type of classroom response systems. The purpose of this study is to address the impact of game-based classroom response system (Kahoot) as a persuasive technology on the students' perception of their own learning experience.

Problem Statement

MIS101, Introduction to Information Systems for Management, is the mandatory lower level course for all business students in the College of Business in one of the large-size public universities of northeast California. Two sections of 55 students were assigned to me for the first time to teach in Spring 2018. More experienced colleagues who taught this course in previous semesters informed me that there is a student lack of interest in this class and it is difficult to engage large number of students in the non-specialized courses for their major.
For increasing students' engagement, motivation and learning, we decided to use Kahoot, a multiplatform game-based classroom response system. Kahoot has several advantages compare to its competitors and the most important one is that it's free and can run in a browser without installation. The Kahoot platform was new for me and for the students. Some of them used Clicker or Hat, but almost none of them had the experience of working with Kahoot.
As an instructor of MIS101, my main goals and strategies for using CRS in this class were classroom monitoring, game-based learning, formative assessment, immediate feedback, and equal participation. Monitoring student attendance and participation in large-size classes are not easy tasks (Lander and Stoeckel, 2012). According to Martyn (2007), CRSs support some principles of game-based learning, such as competitive practices and scoreboard system. The game strategy that the instructor used in this class was to ask students to read the assigned

chapter for the class session, then listen to the lecture in the class and take a multiple-choice quiz on Kahoot to stabilize their learning.

LITERATURE REVIEW

Game-based classroom response system

The benefits of CRS according to Martyn (2007), are immediate response and display as well as data analytics for assessments and evaluations. Fies and Marshall (2006) described that the appropriate pedagogy combined with the classroom response systems can promote learning. Other studies such as those of Simpson and Oliver (2007) and Stowell and Nelson (2007) disclosed that classroom response system by making an interactive and dynamic environment could make the class more fun and enjoyable for both students and instructor. Lander and Stoeckel (2012) and Caldwell (2007) discussed the disadvantages of CRS. Based on their studies, making quality questions which are aligned with learning objectives of the course, unfamiliarity of instructors and students with the CRS interactive environment, and the unstable or disconnected internet connections are some of the disadvantages that need consideration before applying CRS in the classroom.

Kahoot is one of the game-based classroom response systems (GCRS) that for the first time was introduced in 2013 (Wang and Zhu, 2016). While Bring You Own Device (BYOD) and technology tools have been widespread in the modern classroom, the classroom response system (CRS) has shifted from Clickers or Zappers to more game-based classroom response system (GCRS), such as Kahoot or Socrative (Wang, 2015). With Kahoot, students can use their cellphone or tablet to open the web browser, connect to the Kahoot game landing page, enter the game pin and start answering the questions in a game-show like situation. Instructor is the game show host and students are the competitors. Question will be displayed on the classroom screen with different graphical user-interface, audio, and time limit. The instructor can control the pace of play. If students answer the question correctly, they will be awarded points and students' points will be displayed on the screen and this could be exciting for the students.

THEORETICAL FRAMEWORK: GAMIFICATION AND PERSUASIVE TECHNOLOGY

Huotari and Hamari (2012) defined gamification as "a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation". In gamification, the game elements are applied in an unlikely context, such as education, health, management, or marketing. According to Gartner, gamification motivates a target audience to higher and more meaningful levels of engagement. The stimulating elements of gamification, such as immediate feedback, feeling of achievement, and challenge make it valuable in the field of education (Kapp, 2012). Because of these stimulating features, game-based response systems can be used as "persuasive technology" within the classroom environment.

Fogg (2002) defined persuasive technology, as a technology that is designed to change user attitude and behavior through persuasion and social influence. Fogg (2009) explained that persuasive technologies are ubiquitous. People can experience them through the web, video games, mobile phones applications, and consumer electronic devices. He introduced the best practices for developing new digital experiences that could influence people. Furthermore, he described the eight-step design process for creating successful persuasive technologies. He believed that three factors, lack of motivation, lack of ability, and lack of a well-timed trigger to complete the task may result in an unpleasant digital experience (Fogg, 2009). Also, the lack of these three factors could prevent audience from performing the target behavior. In this study,

the Fogg model was applied to the game-based classroom response system (Kahoot) and its users (students here).
In this study, the Ability, Motivation, and Trigger factors were used as independent variables. Therefore, Ability, Motivation, and Trigger scales were designed for the purpose of this study. Here each of the three factors as defined in the Fogg Behavioral Model (FBM) are explained.
In Fogg Behavioral Model, Ability is sometimes replaced by Simplicity. Based on his model, if persuasion designers focus on Simplicity of the target behavior, they will increase the Ability. Fogg (2009) defined Simplicity as "the minimally satisfying solution at the lowest cost". Also, he mentioned that time, money, physical effort, brain cycles (think a lot for the long time), social deviance (going against the norm), and non-routine tasks are the elements of Ability.
Fogg (2009) observed that the core motivators are central to human experience. Three core motivators in his study are sensation, anticipation, and belonging. Each of these has two sides--pleasure/pain, hope/fear, and acceptance/rejection. Fogg's keynote at Health User Experience Design Conference clarified that when motivation is high, you can get people to do hard thinks (Fogg, 2012). Also, his model shows that by motivating people, we can facilitate changes in their behavior.
Fogg (2009) gave different names to Triggers such as cue, prompt, call to action, request, and so on. Based on his study the target action sometimes needs an internal or external trigger, such as, a ringing alarm. There are three types of Triggers--facilitator, signal, and spark. The designers should use the Trigger type that best matches their target user's context. Further information of these constructs as applied in this study will be provided in the methodology section.

METHODS

This study used cross-sectional methodology. Cross-sectional is a subset of survey research methodology in the quantitative strategy category [16]. This study investigated the extent to which differences in students' Motivators (Motivation), Simplicity factors (Ability) and different types of Triggers (Facilitators) are related to differences in the students' perception of their learning experience.

Population and sample

A convenience, non-probability-based sampling method was used in this research (Creswell and Creswell, 2017). The sample comprised business students who were enrolled in the Introduction to Information Systems (MIS101) course in Spring 2018 at one of the large-size public universities in northeast California. All students in this study are business undergraduate students with different concentrations such as accounting, business, management, marketing, finance, management information systems, human resources, and entrepreneurship.

Data collection and response rate

The tool for collecting data in this study was an online questionnaire. The total number of questions was 30 plus 11 demographic questions. Students took 5-10 minutes to fill out the questionnaire. As an instructor of the course, I explained in the face-to-face class that this is the first semester that I am using mobile-based response system (Kahoot) in MIS101 and would like to know how this technology tool affects their learning experiences. It was mentioned in the class that survey is located on the Google Form. The link to the survey was provided in Canvas (Student Learning Management System) and was also emailed to them. Participants were informed about the subject of the study and could ask any questions regarding the research.

Their participation was voluntary, and they were offered an extra credit if they filled out the survey. At the end of the semester, they were assigned two different types of extra credit activities and they had an option to choose between them. Since the survey was anonymous, there was no fear of revealing the participants' identity. The data collection process took two weeks. A sample survey will be provided upon the request of the reviewers.
Out of 108 face-to-face registered students in two different sections, all of them filled out the online survey. Therefore, the response rate was 100%.

Descriptive Sample Information

Table 1 shows the sample demographic information. his includes gender, age, international/domestic student, ethnicity, class level, full-time student, major, studying and working per week.
Most of the sample members are male (66.7%); the female population is 33.3%. Students' ages are between 19-above 42 but most students are in the age range of 19-24 years old. Three main ethnic groups are Asian (26.9%), Hispanic or Latino (20.4%), and White (28.7%). Around 75% of the sample populations are in their junior year at college and 94.4% of them are full-time students. Finance concentration has the highest rate of enrollment, business administrative with 21.3% stayed in the second rank and accounting with 17.6% placed as a third popular concentration. Also, around 45% of them are working full time and 40% of the students are studying between 6-20 hours during a week.

Instrument Validity and Reliability

The validity of the instruments was examined by content validity. After extensive literature review and consulting with experts in the field, the main scales for Motivation, Ability, Trigger, and perception of learning experience factors in this study were designed. Two experts from the School of Business and two experts from the College of Technology at the large-size public university in northeast California reviewed the questionnaire and gave their professional opinions. Furthermore, Forgg (2002) study provided a comprehensive viewpoint and applicable guide to develop the scales. Several items of Motivation and Trigger scales were adapted from Bicen and Kocakoyun (2018) and Zarzycka-Piskorz (2016) and modified for this study. All four scales are based on a 5-point Likert scale and five anchors (1=strongly disagree to 5=strongly agree).
Perception of learning experience scale included seven items and was intended to measure the student's perception of their learning via the mobile-based classroom response system. The Cronbach's alpha for this scale was solid and 0.94. The students' perception of their learning experience construct included the following questions:

1. Information can be recalled more easily thanks to Kahoot
2. Use of a learning method blended with a Kahoot help me to understand the lesson better
3. Playing Kahoot improves my learning
4. Kahoot enables active learning
5. Kahoot provides permanent learning in classroom activities
6. Playing Kahoot made me think more during
7. Playing Kahoot makes my learning process faster and easier
8. Overall, how would you rate your learning performance playing with Kahoot?

The simplicity (ability) scale in this study was intended to measure how easy or simple it is for students to work with Kahoot. In another word, how simple setup of Kahoot can increase the ability of students to work with. This scale included seven items. When students see Kahoot

application easier to setup and use, the scale values are more positive; if they find Kahoot application difficult to set up and hard to use, the direction tends to be negative. The Cronbach's alpha for this scale with the value of 0.717 was meaningful. The Ability construct included the following question:

9. It is fun to compete against other students
10. I like to see myself on the Kahoot Podium at the end of the game
11. The Kahoot music on the background while I am answering a question, makes me nervous
12. I like to put funny avatar for my Kahoot nickname
13. The color harmony of the buttons in the application is nice
14. Kahoot point-system makes me excited for playing it
15. I think my reputation in the classroom improves with the badges I win through Kahoot

The motivation scale in this study was intended to measure the students' motivation for using Kahoot in the classroom. This scale included eight items. When students are motivated to use Kahoot, the scale values are more positive; if they don't have enough motivation, the direction tends to be negative. The reliability test for this scale was solid and 0.88. The motivation construct included the following questions:

16. Playing Kahoot decreases my stress for taking other quizzes (such as midterm and final exam)
17. My fear of taking exams decreases by playing Kahoot in class
18. Seeing the answer of the test immediately increases my motivation to focus
19. Playing Kahoot can increase my class attendance rate
20. I wish Kahoot! Was used in other lectures
21. I enjoy playing Kahoot
22. I engage more in class while playing Kahoot
23. Each question I correctly answer improves my self-confidence

The Trigger (Facilitator) scale in this study was intended to measure the Kahoot's facilitator tools to attract students to engage in the class. This scale included seven items. If facilitator tools could engage more students in the class, the scale values are more positive and if they don't, the direction tends to be negative. The reliability test for trigger scale was 0.74 and acceptable.

The Trigger construct included the following questions:

24. It is fun to compete against other students
25. I like to see myself on the Kahoot Podium at the end of the game
26. The Kahoot music on the background while I am answering a question, makes me nervous
27. I like to put funny avatar for my Kahoot nickname
28. The color harmony of the buttons in the application is nice
29. Kahoot point-system makes me excited for playing it
30. I think my reputation in the classroom improves with the badges I win through Kahoot

Data analysis

Multiple linear regression was utilized for analyzing quantitative data in this study to determine the strength and direction of the relationships between the motivation, ability, and trigger scales and students' perception of their learning experiences. Scale reliability was examined by the Cronbach's alpha. Multiple linear regression was used to build a model and discover the best predictors for the students' perception of the learning experience; statistically-insignificant

variables were not included in the model. All statistical procedures were performed using SPSS (Version 25).

Table 1: Demographic Information		
DEMOGRAPHIC	FREQUENCY	PERCENT
Gender		
Female	36	33.3
Male	72	66.7
Age		
19-24	71	65.7
25-30	16	14.8
31-36	7	6.5
37-42	4	3.7
Above 42	10	9.3
International/Domestic		
International	3	2.8
Domestic	105	97.2
Ethnicity		
American Indian or Alaska Native	2	1.9
Asian	29	26.9
Black or African American	6	5.6
Hispanic or Latino	22	20.4
Native Hawaiian or other Pacific Islander	2	1.9
White	31	28.7
Other	2	1.9
I prefer not to respond	14	13
Class Level		
Freshman	2	1.9
Sophomore	1	0.9
Junior	81	75
Senior	24	2.2
Full-time Student		
Yes	102	94.4
No	6	5.6
Major		
Accounting	19	17.6
Business Administrative	23	21.3
General Management	10	9.3
Marketing	8	7.4
Finance	24	22.2
Information Systems	14	13
Human Resources/Entrepreneurship	9	8.3

RESULTS AND DISCUSSION

The two important questions that were studied in this research are:

1. How game-based classroom response system (Kahoot) as a persuasive technology can affect the students' perception of their learning experience?

2. What are the most important factors that change students' perception of their learning experience? Motivation, Ability, or Trigger?

A multiple linear regression was used to determine the best-fit models between the dependent and independent variables. The R square value of 76.2% of the observed variability in students' perception of their learning experience is explained by the three independent variables. The R with the value of 0.873 shows the good correlation coefficient between the observed value of the dependent variable and the predicted value based on the regression model. The observed value of 0.762 is large enough and indicates that the linear regression model predicts well (Table 2). Table 3 shows that the coefficient for ability and motivation scales are not zero ($p<0.05$); therefore, the null hypothesis is rejected. However, the null hypotheses for trigger scale cannot be rejected and the coefficients for the scale may be zero. In fact, this result does not mean that Trigger is a not good predictor alone or in combination with other variables, it just does not contribute significantly to the model being considered (Norusis, 2006).

Table 2: Model Summary

R	R Square	Std. Error of the Estimate
0.873[a]	0.762	2.645

Table 3: Coefficient

Model	Unstandardized Coefficients	Standardized Coefficients	Sig.
	B	Beta	
Constant	-4.763		.056
Ability	.476	.310	.001
Gamification	.131	.119	.084
Motivation	.469	.508	.000

LIMITATION AND FUTURE RESEARCH

This study has several limitations that are worth considering for future studies. One of the limitations was the sample. The selected population included 108 Business students, enrolled in MIS101 in Spring 2018 at a public university in northeast California. Providing a bigger sample with more variety of students in different majors and courses may affect the results of this study. The impact of aforementioned independent variables on the students' perception of their learning experience in this study may be different among different course subjects and students who are using Kahoot.

We acknowledge that this is only a preliminary study. We did not examine the extent to which students' gender, age group, and ethnicity affect the relationships between the ability, motivation, trigger factors and the students' perception of their learning experience. Also, the influence of the study and work hours per week as a moderator variable is worth examining in a future study.

Certainly, different factors may affect the students' perception of the learning experience by Kahoot application. These factors could be reviewed in future studies. Also, the comparison of Kahoot, Top hat, and other classroom response systems and their effects on students' learning experience is worth studying in the future.

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DECISION SCIENCES INSTITUTE
Impact of Regulation on the Information Systems arena: Study of Sarbanes-Oxley Act

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ABSTRACT

Over the past several decades, Information Systems have become a vital component for organizations to operate and compete in the industry. The design, development, and use of Information systems are also influenced by governmental regulations. For example, Sarbanes-Oxley (SOX) Act that was enacted in the year 2002 had a widespread impact on the IS field. This study systematically reviews existing research on SOX and its impact on the field to present the results. Findings of the study will be useful in seeing the role of government regulations and provide pointers on how regulations may impact other areas of the IS field.

KEYWORDS: SOX, Laws, regulation in IS, and Review

INTRODUCTION

Information systems have become the cornerstone of modern organizations, and are used in a multitude of ways by organizations functioning in diverse areas. Owing to its impact, sporadically we see regulations to impact the field. For example, airline reservation systems in the 1980s (Copeland & McKenney, 1988) and computer operating systems in the 1990s (Economides, 2001). In these cases, the effect of the action was on the organizations involved alone. In some other cases such as the copyright laws (Elkin-Koren, 2007), or healthcare information/privacy the impact was on select sectors of the economy. Likewise, the data protection regulations (Cornock, 2018) in Europe is geographic specific. However, unlike other fields such as finance, accounting, the field of information systems is not under the purview of widespread regulations. The lack of regulations has enabled the field to rapidly grow (Anderson, Block, DiLorenzo, & Mercer, 2001) unfettered in the various areas impacting the society in a wide range of ways.

Promulgation of SOX Act of 2002 had a widespread impact on the public corporations and required robust internal controls that many times were effected by the information systems. SOX impacts various aspects of the information systems discipline, such as project management, software development, IT governance, and data/information (Dhillon & Mishra, 2006). Owing to this SOX had a major impact on the way organizational information systems are designed, developed, and operated. IS researchers have been exploring ways in which SOX regulations are affecting the use of information systems in organizations. In the past Cleven and Winter (2009), carried out a literature analysis of regulatory compliance in information systems. This

study extends this line of work by not limited to one area alone but to the broader aspects of SOX on IS. Focusing on the wider ramifications of the regulation will helps us to understand the impact of it in a more holistic manner.

Findings of this study are important in many ways. First, it has been 15 years since SOX was introduced and it is an opportune time to take stock of the research on it in the IS field. Second, with more widespread use of technologies in our daily life, there will be calls for regulations in other areas of IS (e.g., data privacy/protection in the US, artificial intelligence, self-driving cars, etc.) and the research on SOX can shed light on the kind of impact new regulations can have on the IS field. Third, research on the compliance with regulations effected by IS is not that frequent, and this study will help in identifying gaps and future research directions for research.

The rest of the paper is organized as follows: The next section presents SOX act its provisions that affect IS area. Next, we discuss the methods used in this study to gather research on SOX and Information Systems. We then summarize the findings of the past research and present results. The final section provides directions for future research and concludes the study.

Sarbanes-Oxley Act 2002

Sarbanes-Oxley (SOX) Act was enacted in 2002 after the prominent financial scandals came to light in Enron, WorldCom, Adelphia, and others. The Sarbanes–Oxley legislation, officially called the Public Company Accounting Reform and Investor Protection Act of 2002, was designed to fix auditing of U.S. public companies (Coates & John, 2007). SOX is aimed at strengthening the internal controls and ultimately increase accountability. SOX has sets of mandates that increase the role of auditors in enforcing laws against at public companies (Coates & John, 2007). Eleven sections of SOX define auditor and corporate responsibilities in various areas (Brown & Nasuti, 2005). For example, Section 302 requires the CEOs and CFOs to certify the financial statements filed with the SEC. Likewise, Section 906 specifies the accountability/liability for the accuracy of the financial and the officers' knowledge about it (Volonino, Gessner, & Kermis, 2004). Section 404 deals specifically with the management's assessment of internal controls. Section 401 and 409 deals with the disclosure of information that may have a material effect on the financial health of the company (Volonino et al., 2004). Section 201 restricts organizations auditing organizations from carrying out non-audit services such as the design and implementation of financial systems for their audit clients (Levy, 2016).

Since financial reporting processes are driven by information systems, they too need to be assessed, documented, and tested to achieve compliance with SOX (Damianides, 2004). Some of the sections of the law had specific implications on the information systems used by the organization or the information systems field itself. Section 802 requires authentic and immutable record retention and IT plays a major role in data management, system security and business recovery practices(Brown & Nasuti, 2005). These requirements necessitate IS professionals to design, develop, and adopt systems that can provide accurate, visible, and timely information while ensuring that company's information assets are secure (Damianides, 2005).

METHODOLOGY

Following the prescriptions of Webster and Watson (Webster & Watson, 2002) in reviewing the existing research, as the first step, we searched EBSCO's Business Source Complete and ABI-Inform database for research on SOX and Information Systems. We used the search string "Sarbanes-Oxley" and "Information Systems" to retrieve relevant research articles. We restricted

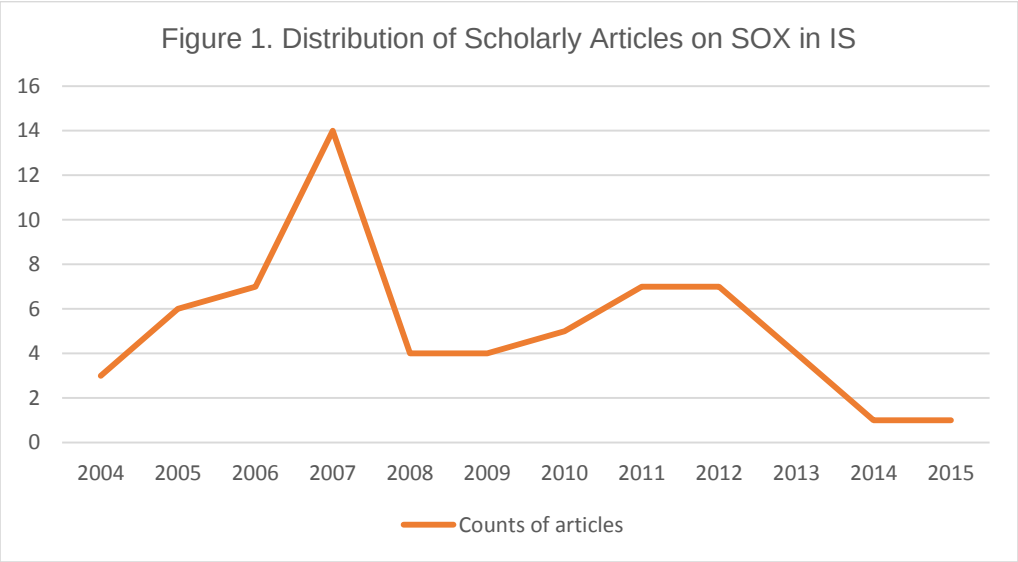
the study to focus on the peer-reviewed scholarly journals and included research until 2017. As the second step, we scanned the search results and selected the articles that focused on the information systems areas and its domains. This step eliminated articles that made passing reference to either SOX or Information Systems. We also excluded pedagogical related articles.

Table 1 presents the distribution of SOX-related research in IS from various journals. As can be seen, two journals specializing in Accounting Information Systems are namely the International *Journal of Accounting Information Systems* and *Journal of Information Systems* has published a greater number of research on SOX in IS. However, a variety of IS journals have also published research on SOX but to a lesser extent.

Table 1. SOX-related IS articles in Journals

Journal Title	Number of articles
Communications of the ACM	3
Communications of the Association for Information Systems	7
Information Management & Computer Security	2
Information Systems Management	6
International Journal of Accounting Information Systems	10
Journal of Information Systems	9
MIS Quarterly	3
Other journals	23
Total	63

Figure 1 presents the distribution of SOX-related research in IS from various journals during the period in review. Though the SOX act was promulgated in 2002, research on it in the IS area took a while to peak in 2007. From then on, there is a steady stream of research that has tapered in the recent times.

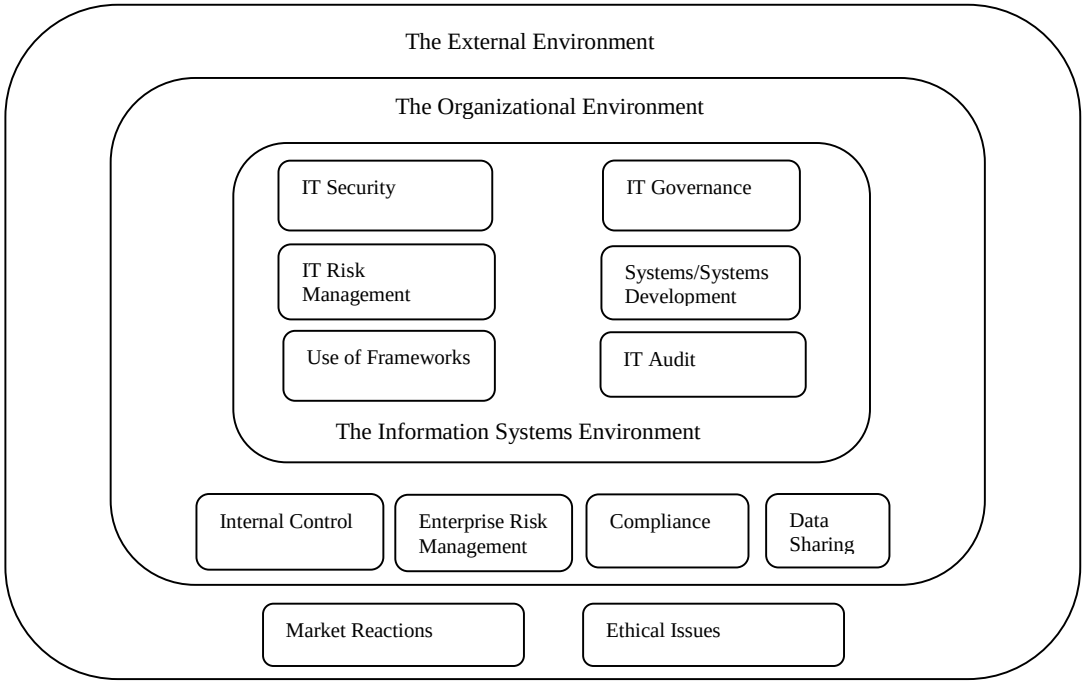


The selected articles were individually examined and categorized into various focus areas of research. Then using the IS research model(Ives, Hamilton, & Davis, 1980), these categories were classified into IS environment, organizational environment, and the external environment to understand the nature of research done in the field.

FINDINGS

Ives et al. (1980) developed a comprehensive framework for understanding and classifying research in Information Systems. According to the authors, IS research is the systematic investigation of the development, operation, use, and impact of an information (sub) system in an organizational environment and an external environment. This framework allows us to classify the various research in the SOX-related information systems research and also find gaps in the existing research. Figure 2 presents the key areas of research on SOX and Information Systems.

Figure 2. Scholarly Research on SOX and Information Systems



The Information Systems Environment

IS environment is concerned with the development, management, and use of information systems in organizations. Since this study focused on IS area, obviously found this domain to have the bulk of the studies included in the review. Various dominant themes within the IS environment explored by the researchers are indicated below:

IT Governance

This area is widely studied in the context of SOX and its need for prudent governance of IT. Studies have explored the use of IT Governance frameworks to facilitate the compliance needs of SOX. Damianides (2005) describe how Control Objectives for Information and related

Technology (COBIT) for IT governance provides the necessary information for management to provide reasonable assurance of the IT control structure for complying with Section 404 of SOX and also provide an illustration with a case study on a financial institution. Trites (2004) examine the director's responsibility for IT governance in light of the SOX and state that the directors, in general, do not have an understanding of IT. Hence they provide a list of considerations for various areas of IT in an organization. Bowen, Cheung, and Rohde (2007) stress the importance of IT Steering committee in fostering SOX compliance and use a case study to examine specific propositions.

IT Security and Risk management

SOX has requirements for the external reporting of adverse events an organization faces and hence IT security and risk management is also a focus of attention. For example, the security control activities and user participation is the focus of one of the studies (Spears & Barki, 2010). Likewise, the most and least used controls, and the variations in the type and size of the organization have also been studied (Wallace, Hui, & Cefaratti, 2011). Since the Committee on Sponsoring Organizations (COSO) considers security as a critical variable in enterprise risk assessment, the effective security governance is important for SOX compliance (Brown & Nasuti, 2005).

Systems and Systems Development

Development of systems is impacted owing to the need for internal control. There are studies that examined the use of frameworks such as COBIT in the systems development process so that the SOX compliant needs could be met (Mishra & Weistroffer, 2007). Likewise, the impact of SOX on outsourcing systems requirements have been examined. Hall and Liedtka (2007) discuss the implications of large-scale IT outsourcing and the weakening of financial controls and reduction in accuracy and clarity of financial reports. Systems such as enterprise resource planning have been shown to reduce the reported internal control weakness of firms (Morris, 2011).

IT Audit

SOX regulations had an impact on internal audit and consequently on the IT audit. For example, auditor independence and the audit quality has been explored (Wright & Capps, 2012). Use of appropriate technology for internal audit to increase the efficiency and effectiveness is also highlighted (Weidenmier & Ramamoorti, 2006). Likewise, systems development for audit using simulations for the audit objectives has been proposed (Borthick & Bowen, 2008). Chang, Wu, and Chang (2008) describe the development of a computerized auditing system to comply with SOX Section 404 and validate it using an ISO model.

Frameworks

Frameworks help in implementing compliance mechanisms for the regulations. Haworth and Pietron (2006) highlight how an organization implementing the ten categories of IT control provided by ISO 17799 will be compliant with SOX. Likewise, Wallace et al. (2011) study how well the controls suggested by ISO 17799 framework has been incorporated in internal control environments of organizations. COSO is also explored in the context of the weakness of IT and non-IT related components of an organization (Klamm & Watson, 2009).

The Organizational Environment

Organizational environment pertains to the internal environment of the organization. Compliance with SOX required a focus on the organization's internal processes and requires necessary organizational structures. Information systems play a major role in creating such a compliant environment. Following topics were explored by IS researchers in the past.

Compliance

Many studies have explored the aspect of organizational compliance with the requirements of SOX. For example, institutional pressures such as coercive pressure, mimetic pressure, and normative pressure have been found to influence compliance with Section 404 of the act (Braganza & Desouza, 2006). Further, Braganza and Hackney (2008) highlight the role of senior authorities, financial and resource subsidies, and standards in complying with the Section 404 requirements. Also, patterns for enforcing compliance in the business processes has also been explored (Elgammal, Turetken, & Van Den Heuvel, 2012).

Internal control

SOX has called for better internal control mechanisms and IS plays a major role here. Perceptions about IS reliability in the section 404 disclosure has been explored on analyst stock price predictions (Arnold, Bedard, Phillips, & Sutton, 2011). IT is also proposed to be used to identify internal control weaknesses in organizations (Boritz, Hayes, & Lim, 2013). Li, Peters, Richardson, and Weidenmier Watson (2012) mention about the importance of IS controls and the reporting of material weakness and found evidence that management forecasts were less accurate for a firm with information technology material weakness in their financial systems.

Enterprise Risk Management

Apart from IT risk management, enterprise risk management has also been studied as there mandated SOX requirements on it. Organizations with stronger strategic enterprise risk management experienced less difficulty in meeting the SOX mandates (Arnold, Benford, Canada, & Sutton, 2011). Integrated information systems have also been shown to increase strategic flexibility and performance through enterprise risk management (Arnold, Benford, Canada, & Sutton, 2015). Likewise, an enterprise risk management system is also claimed to improve compliance with SOX (Kusserow, 2007).

Data Sharing

SOX regulations require data/information sharing with the stakeholders on a timely basis. These data/information sharing may use information systems or the information sharing itself is about information systems. This has prompted research on the data models for data sharing (Kim, Fox, & Sengupta, 2007) as well as the sharing of financial information with stakeholders (Biot-Paquerot & Hasnaoui, 2009). Moreover, the quality and reliability of the data itself is also a focus of a study (Krishnan, Peters, Padman, & Kaplan, 2005). There also studies that have explored information sharing as a result of cyber-attacks (Hausken, 2007).

The External Environment

External environment pertains to the factors that are outside of the organization and may have a bearing on the functioning of the organization. As with any regulation, SOX and its compliance by the organization had an external impact, and explored by various researchers as shown below:

Ethical issues

The act itself was brought to improve corporate governance and ethical business practices in organizations. Mingers and Walsham (2010) state that the relevance of ethics in IS is not restricted to SOX and highlight the need for IS professionals to understand the ethical imperatives of SOX in their work. Likewise, the ethics of dissemination of financial information with the stakeholders is subject of a study that states that typically this aspect is missed by research with focusses only technical and technological issues in information sharing (Biot-Paquerot & Hasnaoui, 2009).

Market reactions

Some of the studies have examined on the market reactions to internal control weakness, and some studies have found negative effects of it (Stoel and Muhanna 2011). However, there seems to be an influence based on the type of investors used in the study as not all may have information on the internal control weakness reports(Arnold, Benford, et al., 2011). Benaroch, Chernobai, and Goldstein (2012) conceptualized IT operational risk evens as an internal control weakness and examined the market reactions to IT failures. They found that investors to penalize firms more strongly for events compromising the availability of systems. Market reactions regarding bid-ask spread have been found to reduce with compliance (Dobre, 2011).

Discussion and Future Research Directions

This study systematically reviewed the SOX-related IS research that appeared in the scholarly journals. Findings of the study provide a glimpse of the areas that are of focus when researching SOX in the context of IS. SOX had a profound impact on the public corporations in general and IS in specific areas. Review of the research shows some of the unique IS aspects considered in compliance with SOX.

Findings of this research could be used to examine the impact of future regulations in the IS area. For example, in the IS environment, IT governance will play a major role in light of any future regulations as the compliance with the law/regulations will require more directed efforts in the development and use of information systems. Likewise, frameworks that aid in the adherence to the laws/regulations could be developed or used by organizations to facilitate the requirements of such regulations. In the organizational environment, compliance will be a major area of research. Organizations should have to evolve adequate mechanisms/processes to comply with the requirements of the law/regulations. In a similar fashion, data sharing with the organizational stakeholders (e.g., customers, suppliers, regulatory bodies, etc.) will be vital as the organization tries to meet the requirement of the new law/regulations. In the external environment area, ethics play a major role as a particular segment of operation is regulated. Usually, the laws take time to get enacted and till then the ethics play an important part in evaluating and determining appropriate actions by organizations.

This study also found some gaps in the existing research. For example, the issues surrounding non-compliance with the provisions of SOX and the role of IS is not much explored. Sometimes, IS/IT itself may create issues in the compliance of SOX mandated requirements. Likewise, the effects of regulations on the IS systems design/development is not that much examined in the past. Requirements of the regulations are taken into account in how a system is designed and developed.

In the future, research could be undertaken to examine the impact of SOX on some of the under-explored areas such as the role of regulations and the requirements for compliance with systems design and development. Moreover, the study sample could be enhanced to include

conference publications. This study used SOX as an avenue for studying the impact of regulations on the IS field. Findings of this study could be used to frame research questions for future regulations in the IS field. For example, many of the themes found in the SOX research such as compliance, security, systems development, and frameworks could be used in studying the effects of future regulations.

Conclusions

Research on the impact of SOX on Information Systems is found in both Information Systems as well as accounting journals. SOX had a multi-level (IS, Organizational and Environmental) impacts on organizations and the extant research highlight this. Compliance and internal control were some of the major themes in the research done in the past and IS role is often stressed. Many IS specific areas such as IT security, IT audit, systems development also focuses of the studies.

SOX and its provisions had an impact on the IS field in many ways, and it provided a classic example to study the impact of regulations on the IS area where regulations are only sporadic. (Smith & McKeen, 2006) claim that the IS field of the future will be increasingly controlled, standardized, and bureaucratized due to regulations. Already, we see calls for regulations such as on privacy on the Internet, artificial intelligence applications, and self-driving cars. Examining the research themes in the advent of SOX will afford us with the opportunity to see the impact of regulations on the IS domain. This study highlights some of the dominant areas that were impacted and future research and practice can use it as they navigate through regulations in any specific IS area.

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DECISION SCIENCES INSTITUTE

Impact of supply chain practices on micro-entrepreneurs' purchasing performance in base-of-the-pyramid markets

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ABSTRACT

Need for creation of inclusive business opportunities while considering base of the pyramid (BoP) markets makes it a sound starting point for evaluating how supply chain practices impact the firm's purchasing performance in business-to-business (B2B) markets of BoP. A structured questionnaire was used to collect data from indigenous micro-entrepreneurs operating in a BoP setting while factor analysis and linear regression are used to investigate the findings of the empirical research. (S)SCM construct of supply chain partner development is found to have the significant positive impact on the purchasing performance of indigenous firms in B2B supply chains. With earlier empirical works in BoP literature mainly focused on business-to-customer linkages, this paper while aiming at business-to-business interactions in emerging economies will enrich the understanding of the base of the pyramid business environment.

Keywords: Base-of-the-Pyramid, (Sustainable) Supply Chain Management, Empirical, Regression Analysis, Supplier Development, Buyer-Supplier Interaction.

INTRODUCTION

Emerging economies are increasingly considered as sources of learning and innovation for driving firm performance(Kaplinsky, 2011; Murphy, Perrot and Rivera-Santos, 2012). Novel solutions are required in milieu of their unique and predominantly informal business environment (Poetz and Prügel, 2010). In this context, the supply chain practices which contribute to the achievement of new performance and innovation frontiers need to be explored carefully. Since its emergence in a little more than the past decade, base of the pyramid (BoP) literature has been dominated by two debates: first, a more conceptual debate contemplating BoP business strategies either from a consumer, producer, or partner oriented perspective (Prahalad, 2006; Karnani, 2007; London *et al.*, 2010). Second, a more strategic BoP debate "focused on product and distribution strategies tailored to consumers in these markets" (Arnould and Mohr, 2005). This paper tries to explore the operational dynamics of BoP supply chains which advance indigenous firms' purchasing performance. While following a partner oriented BoP approach, the paper presents results of a quantitative survey conducted in Pakistan, focusing on business-to-business (B2B) supply chains.

The unique business environment of informal markets requires a reconsideration of the contemporary supply chain knowledge to fulfil the exclusive demands of BoP supply chains (Sesan *et al.*, 2013). Furthermore, the call for the development of inclusive business models

(Halme *et al.*, 2012; Kolk *et al.*, 2014) for BoP, necessitates the examination of purchasing issues in greater detail. In this context the core research question of the study can be stated as: Which of the respective (S)SCM constructs substantially affect the purchasing performance of micro-firms in B2B supply chains at the BoP? The (S)SCM constructs have been derived from published (S)SCM literature deductively. The respondents of the study were selected from manufacturing and retail sectors without specifying any industry in particular. The constructs representing both process and strategic dimensions of supply chain management have been employed to assess their effect on purchasing performance of BoP entrepreneurs. Furthermore, in line with the arguments of (Ahlstrom, 2010) for the crucial nature of integration in BoP, this paper, while contemplating work of Chen and Paulraj (2004) and Vachon and Klassen (2006), further explores *supplier* and *customer* dimensions of technological integration in driving the BoP supply chains. The strategic part of BoP supply chains is signified by constructs of supply chain partner development and supply network structure constructs (Chen and Paulraj, 2004). The process part of the supply chain is represented by such constructs as strategic purchasing and communication and coordination with suppliers.
Concerning the organization of this paper, the next section presents a brief literature review on the subject matter and introduces BoP and the core (S)SCM constructs used in the paper. Section three elaborates the research methodology. The succeeding section four presents findings of the empirical survey followed by a discussion presented in section five. The conclusions are drawn in the last section.

LITERATURE REVIEW

Base of the Pyramid (BoP)

Potentially lucrative informal markets of developing world have started gaining attention of intellectuals and practitioners (Kolk *et al.*, 2014). The informal markets of developing countries in particular, and the respective societies served by these markets in general are referred to as base of the pyramid (BoP) in contemporary management literature (the word pyramid implies ‘world income pyramid’). The apparent little consensus on a concrete definition of the base of the pyramid (BoP) in literature is quite in line with the argument by Gladwin *et al*. (1995, p. 876) who maintains “definitional diversity is to be expected during the emergent phase of any potentially big idea of general usefulness”. While some scholars used an income yard stick for defining BoP (Arnold and Williams, 2012), the authors of this paper follow the arguments of Hart (2010) and London and Hart (2011) and consider all the participants of informal markets who are “generally excluded from the current system of global capitalism” as part of BoP.
“Ingrained in notion of inclusive capitalism”, the BoP literature argues for an enterprise-driven strategy for the creation of economically viable business models to kick start economic activity in BoP markets (Ansari *et al.*, 2012). From a strategic perspective BoP literature can be generally divided into three sub-streams. First, a *consumer centered* BoP approach presents BoP markets as a long forgotten potentially lucrative market of billions of “value conscious consumers”(Prahalad, 2006; Weidner, Rosa and Viswanathan, 2010; Arnold and Williams, 2012). Second, a *producer centered* BoP strategy, while appreciating the BoP population as potential suppliers, producers, co-owners and/or customers, considers BoP markets as a “hot bed” for future innovations (Karnani, 2007; Agnihotri, 2013). Third, a recent *partner oriented* BoP strategy contemplates a holistic perspective while calling for taking on-board all the traditional and non-traditional stakeholders to formulate economically viable business strategies for the BoP which aim at poverty elimination (London *et al.*, 2010). Nevertheless, there remains

a consensus in the BoP literature concerning the centrality of the business in designing poverty alleviation strategies.

BoP research contemplates business operations on the integration of disadvantaged parts of societies as part of production or distribution processes. This highlights the criticality of a sustainable management of the respective supply chains (Gold *et al.*, 2013). Calls for the creation of inclusive business opportunities by considering BoP as potential source of suppliers in the respective literature highlight the crucial role of purchasing in informal markets (Halme *et al.*, 2012). "The growing importance of supply chain management has led to an increasing recognition of the strategic role of purchasing, which has recently evolved and expanded from buying to procurement and supply management" (Paulraj *et al.*, 2006). The involvement of BoP actors in upstream (as producers) or downstream (as distributors) supply chains in informal markets of developing countries is particularly challenging from a supply chain management perspective, as it implies dealing with a "large number of small transactions", thereby tremendously increasing the transaction costs (Sodhi and Tang, 2014). Devising a mechanism to ensure fair distribution of supply chain surplus among the disadvantaged supply chain actors on account of illiteracy and poor market power is yet another steep hill to climb for supply chain researchers (Sodhi and Tang, 2016). These obstacles to inclusive business opportunities in the BoP, however can be tackled by formulating strategies of "establishing cross-sector partnerships" and taking a wide array of traditional and non-traditional stakeholders on board (Hill, 2010; Matos and Silvestre, 2013). (S)SCM with a rich tradition of stakeholder focused research can help to provide useful insights for the development of inclusive business models to address social, economic and environmental issues on sustainable basis at the BoP (Meixell and Luoma, 2015). While (S)SCM research can potentially provide viable answers to certain challenges faced by BoP scholars, a research gap is evident since "… current research on the interface between supply chain management and BoP business operation is lacking" (Gold *et al.*, 2013).

Furthermore, in the context of the relationship based business environment of the BoP (Kistruck *et al.*, 2011; Ansari *et al.*, 2012), the accumulation of relational capital (Kale *et al*., 2000) should be seen as a crucial part of the firms' long-term business strategy in BoP. Earlier BoP-related studies suggested the firms who remain successful in building their relational capital in BoP communities would reap benefits in the long run (Galariotis *et al.*, 2011; London and Anupindi, 2012). Therefore relationship building not only remains a business qualifying criteria, but also has strategic implications for focal firms' sustainable performance in BoP supply chains (Hall and Matos, 2010).

Additionally, the relationship based business environment of BoP can be explained by acknowledging the resource scarce nature of BoP. One should also keep in mind the fact that the BoP firms have to interact with their external environment not only to fulfil their operational resource requirements but also for compensating the evident institutional voids (Rivera-Santos, Rufín and Kolk, 2012; Van den waeyenberg and Hens, 2012). While the relationships with traditional business stakeholders can fulfil the operational needs of businesses, effects of institutional voids can be counterbalanced by engaging with non-traditional stakeholders (Reficco and Marquez, 2012).

In such a backdrop the extent paper intends to explain the impact of supply chain practices on the purchasing performance of the BoP organizations.

Core (S)SCM constructs

Supply chain management (SCM) appreciated as the management of all the various actors and processes involved in the movement of products and services from an ultimate supplier to an

ultimate consumer (Chen and Paulraj, 2004), has certain contingencies with the BoP related literature (Khalid and Seuring, 2017). Correspondingly, the sustainability part of supply chain management dealing with the integration of triple bottom line concepts in the supply chain management discourse also speak about many issues apparently part of the traditional BoP debate (Gold *et al*., 2013). While defining sustainable supply chain management (SSCM), Pagell and Wu (2009) argue that a sustainable supply chain is "one that performs well on both traditional measures of profit and loss as well as on an expanded conceptualization of performance that includes social and natural dimensions". Since this paper discusses constructs taken simultaneously from SCM and SSCM literature and because of the evident overlaps in both of the concerned theories (e.g. in case of constructs of supply chain integration), the paper for sake of convenience refers to both of the respective theories together as (sustainable) supply chain management (S)SCM.

The (S)SCM constructs used in the paper have been selected considering their relevance to the propositions of relationship building with various supply chain actors. Furthermore, the respective constructs are defined as they have been presented in the respective key papers which are presented in Table 1. It is worthwhile to indicate here that the supply chain partner development construct in this study is a cumulative construct representing the respective constructs of long term relationship development (Chen and Paulraj, 2004), supplier operations (Carter and Rogers, 2008), and investment in human capital (Pagell and Wu, 2009). The supply chain partner development concept is further enriched based on the arguments by Wagner (2011) and considered in this study as a buyer-supplier relationship management paradigm. The strength of a buyer-supplier relationship is therefore taken as a moderator impacting a focal firm's supply chain partner development activities to increase its purchasing performance. Furthermore, buyer – supplier interaction is signified by the construct of communication and coordination with suppliers. *Appendix B* indicates that the construct connotes an exchange of business related sensitive information among the interacting partners.

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Table 1**:** Brief explanation of (S)SCM constructs taken up in the study

(S)SCM CONSTRUCTS	SOURCE	DESCRIPTION
Strategic purchasing	Chen and Paulraj, 2004	The construct is "conceptualized by its proactive as well as long-term focus, its contributions to the firm's success, and strategically managed supplier relationships".
Communication and coordination with suppliers	Seuring and Müller, 2008; Chen *et al.*, 2004	The efficient exchange of critical and sensitive information related to operational and strategic issues and collaborative relationship maintained by the focal firm with its various suppliers
Technological integration	Vachon and Klassen, 2006	The construct represents "the tacit knowledge sharing taking place between a buying and a supplying organization in strategic areas like product development, process reengineering, and technical training".

Supply chain partner development	Chen and Paulraj, 2004; Carter and Rogers, 2008; Pagell and Wu, 2009 and Wagner, 2011	The process by which buying firm strives to develop its suppliers as strategic partners by developing their operational and human capabilities based on intensity of mutual business relationships
Supply network structure	Chen and Paulraj, 2004	The construct explains "non-power based relationships and inter-firm coordination as well as the informal social systems that are linked through a network of relationships".
Purchasing performance	Wagner, 2011 and White, 1996	Performance indicates purchasing performance of focal firm in a dyadic buyer-supplier relationship context.

THEORY AND HYPOTHESIS

Relationship between SCM Practices and Purchasing Performance in Context of BoP

The relationship based business environment of the BoP demands firms to invest heavily in building and maintaining relationships (Ansari *et al.*, 2012). Though trustworthy long-term relationship development with indirect supply chain actors has also been emphasized in related literature, efficient connections with direct supply chain partners in the context of the social nature of business in BoP remain business qualifying criteria in the BoP (Calton *et al.*, 2013). Extensive relationship building evident in BoP, therefore is a consequence of its special indeterminate external business environment (Ghauri *et al.*, 2014). Furthermore, one can infer that with increasing uncertainty in the firm's external business environment, an increase in width and breadth of inter-organizational relationships will be evident (Pfeffer and Slancik, 1979). The highly social nature of business in BoP thereby is also an indication of its extreme uncertain business environment. BoP firms in order to build and maintain these relationships can therefore be anticipated to become actively engaged in activities that foster long term relationship development (Khalid *et al.*, 2015). Practices like joint product development, supplier integration, partner development by investing in ones' human and operation capabilities and other related activities, can therefore assumed to be evident in BoP business relations (Elaydi and Harrison, 2010). Business performance of BoP firms is thereby highly dependent upon the extent to which a firm engages in activities related to fostering relationship development with other supply chain actors (Arnould and Mohr, 2005).
In line with the aim of the study and focusing on purchasing performance, we can anticipate that indigenous BoP firms will actively engage in relationship development related activities in order to decrease uncertainty in their purchasing related practices. Uncertainty reduction in purchasing activities will thereby help respective firms to boost their purchasing performance (McMullen, 2011). As mentioned in section 2.2, the supply chain partner development construct in this paper represents various relationship development related practices. We can therefore say:

> ***Hypothesis 1:*** *A BoP firm's engagement in inter-organizational relationship development related activities (represented by the supply chain partner development construct in this study) significantly influences respective firm's purchasing performance.*

The volatile business environment tends to lure firms to manage their supply lines on strategic basis. Operating in highly uncertain markets, BoP firms thereby take efforts to strengthen their relationships with their immediate suppliers in order to decrease the supply related uncertainty (Carter and Rogers, 2008; Gold, Seuring and Beske, 2009). Strategic purchasing has been conceptualized by Chen and Paulraj (2004) in context of supplier relationships. Trust based carefully managed supplier relationships remain a precondition to pursue purchasing activities on strategic basis (Hahn and Gold, 2014). A strategically managed, secure, and dependable supply line not only helps firms run their internal business operations more smoothly but may also be a source of competitive advantage in its own right in volatile markets (Busse, 2016). By helping reduce supply related uncertainty strategic purchasing can be envisioned to have a direct impact on purchasing performance of BoP firms. In backdrop of such an association between strategic purchasing and purchasing performance second hypothesis of the study can be stated as:

> ***Hypothesis 2:*** *Strategic purchasing significantly influences purchasing performance of micro-entrepreneurs in BoP.*

Chen and Paulraj (2004) refer to supply chain management as a study that involves "collaborative advantage". In other words, collaborative advantage involves building a strong correspondence between buyer and suppliers in order to get benefit from one another's strengths. Within this collaborative paradigm, the firms need an efficient communication and coordination framework at place within their buyer-supplier relationship. Moreover, the communication and coordination is essential to increase the performance of the firms (Prahinski, & Benton, 2004).
Volatile business environment makes it crucial for indigenous BoP firms to actively communicate and coordinate with their suppliers (Webb *et al.*, 2010; Kistruck *et al.*, 2013). Through active engagement BoP firms also intend to retain the suppliers of critical products. This supplier retention strategy through active coordination also helps firms strategically managing their supply base (Chen and Paulraj, 2004).
Furthermore, due to their capricious nature, information related to both operational and strategic issues needs to be shared among the dyadic actors. Efficient exchange of information leads to mutual trust in the buyer-supplier dyad (Reficco and Márquez, 2012). Accordingly, maintaining good communication and coordination will help foster the purchasing activities of the firm. Therefore, it can be hypothesized that:

> ***Hypothesis 3:*** *Active communication and coordination with suppliers significantly effects purchasing performance of micro-entrepreneurs in BoP.*

Relationship based business environment of BoP also highlights the need of prudent flow of tactical information between various actors of supply chain. Vachon and Klassen (2006) defines the concept as technological integration. Technological integration includes "strategic knowledge sharing between the buying and a supplying organization in areas like product development, process reengineering, and technical training" (Vachon & Klassen 2006). The extent paper looks into both supplier and customer dimensions of technological integration, while working with two separate constructs i.e. technological integration with suppliers and technological integration with customers. Technological integration with customer includes involvement of customers into the process. On the other hand, technological integration with suppliers accentuates the knowledge sharing with the key suppliers of the firm.

Researchers have shown that a positive relationship exist between technological integration and performance of the firm (Prajogo, & Olhager 2012). The inconsistent business environment of BoP firms call for the tactical knowledge sharing, which will further enhance their purchasing performance. In this backdrop we propose that:

> ***Hypothesis 4:*** *A BoP firm's technological integration with suppliers significantly influences its purchasing performance.*
>
> ***Hypothesis 5:*** *A BoP firm's technological integration with customers significantly influences its purchasing performance*

Supply chain network concept in BoP entails how non-power based relationships, inter-organizational coordination, and informal social systems are linked within a supply chain (Calton *et al.*, 2013). Supply network structure highlights the firm's relationship with traditional and non-traditional stakeholders, and explains how flourishing them impacts the overall performance of the organization. However, within the BoP business environment, establishing such relationships require craftsmanship. Personal ties with key personnel and institutions like local political leaders, banks, tax officials, local administration, NGO's etc. are fruitful for a firm in long run (Ghauri, Tasavori and Zaefarian, 2014). These relationships can impact the purchasing performance of the respective firm as they account for the alliances with institutions and personnel making up the social capital that remains vital for doing business in BoP markets. Networks by helping respective firms bridge institutional voids in BoP and securing their supplies can potentially have a direct impact on purchasing performance (Webb *et al.*, 2010). Within the horizon of this study, we therefore propose that:

> ***Hypothesis 6:*** *Supply network structure significantly influences respective firm's purchasing performance.*

RESEARCH METHODOLOGY

The BoP research has mainly dealt with business-to-consumer issues (Kolk et al., 2014). The evolving state of BoP research in general and novelty of focusing on B2B issues in BoP in particular, allows to employ exploratory research techniques to generate new ideas or hypotheses (Neuman, 2012). Furthermore, since the primary data of the study is collected from indigenous micro-entrepreneurs by administering personal interviews, the study follows an exploratory research approach.

Survey Instrument

A seven point Likert scale structured questionnaire was used to collect the data for this research in face-to-face personal interviews. While administering the interviews, other relevant information was also sought and recorded by taking field notes. The side line information gathered like this, helped to reveal a clearer picture of the subject matter and thus further enriched the survey findings.

Survey Design

Concerning the sampling design, the data for this study was gathered from micro-entrepreneurs operating in Pakistan without specifying any particular industry to focus on. An employee size of

less than 15 was one defining criteria for the inclusion of firms in the sample. However, it is worthwhile to mention here that in most of the cases the employee size of sample firms was less than 10. The data was collected between November 2015 and March 2016. In absence of any reliable and up-to-date databases of indigenous SMEs in the country, a snowball sampling technique was employed to collect data. The sample was drawn from the micro-entrepreneurs having their operations in three cities of Pakistan i.e. Lahore, Rawalpindi and Islamabad. A total of sixty interviews was conducted with entrepreneurs in manufacturing and retail sectors. The respondents interviewed for this study represented such industries as garments, home appliances, auto spare-parts, steel, wooden furniture, marble tiles and electrical equipment. A typical interview lasted for about 30-45 minutes, with the interviewee filling in the questionnaire and interviewer assisting him for clarifying any ambiguities.

Data Analysis

After completing the data collection phase of the study, the interview results were first coded and later analyzed using SPSS. First of all, the reliability of the constructs used in the study was tested by calculating Cronbach's alpha (α) value for individual constructs. Constructs with α-values greater than 0.6 were taken as being significant (Table 2) (Hair, 1998, pp. 207-219). Following this, an exploratory factor analysis was conducted for respective significant constructs to check the reliability and validity of the items formulating individual constructs used in the survey. A threshold value of 0.450 was used and all the items with factor loadings less than the threshold value were considered as insignificant and therefore discarded (in total twelve items were rejected). The two purification procedures left us with *seven* constructs (one *dependent* and six *independent*) and *twenty-six* items (Table 2).
Finally, correlation and regression analysis being "statistical tools for the investigation of relationships between variables" (Sykes, 1993) were used. In line with the aim of this study, purchasing performance was taken as dependent variable while conducting regression analysis. The effort helped to identify the particular (S)SCM constructs which have the most significant impact on and are responsible for the considerable variation in purchasing performance of firms in a BoP setting.

Reliability and Validity

"Reliability is the degree of dependability, consistency or stability of a scale" (Wen-li *et al.*, 2003). As mentioned above the internal reliability of the study was ensured by calculating α-values. Only the particular constructs with α-values greater than 0.6 are used in the study (Bagozzi and Yi, 1988; Cohen, 1992) . Furthermore, Composite reliability was calculated to confirm the consistency of the scale. The results of Cronbach alpha and composite reliability are presented in tables 2 and 3 below.

Table 2: Internal Reliability test results

CONSTRUCTS	CRONBACH ALPHA
Strategic Purchasing (SP)	0.835
Tactical Purchasing (TP)	0.697
Supply Network Structure (SNS)	0.711
Communication (COMM)	0.768
Technological Integration with Supplier (TIS)	0.782

Technological Integration with customer (TIC)	0.667
Purchasing Performance (PP)	0.951
Supply chain Partnership Development (SCPD)	0.944

Table 3: Convergent Validity and Composite Reliability test results

CONSTRUCTS	AVERAGE LOADING	VARIANCE EXTRACTED	CONVERGENT VALIDITY ESTABLISHED	COMPOSITE RELIABILITY VALUE
Strategic Purchasing	0.9264	0.8583	Yes	0.9237
Tactical Purchasing	0.7905	0.6249	Yes	0.8363
Supply Network Structure	0.6748	0.4553	Questionable	0.9062
Communication	0.7674	0.5888	Yes	0.8519
Technological Integration with Supplier	0.8346	0.6965	Yes	0.8734
Technological Integration with customer	0.7932	0.6292	Yes	0.8391
Purchasing Performance	0.9340	0.8723	Yes	0.9654
Supply chain Partnership Development	0.9272	0.8597	Yes	0.9609

(Acceptable values = AVE > 0.5, Average loading > 0.7, Composite reliability > 0.7)

Convergent validity was established for the constructs having average loading greater than 0.7. Similarly, composite reliability was established for the constructs having values greater than 0.7 (Fornell and Larcker 1981). Only supply network structure had values of AVE and average loading below the threshold of 0.5 and 0.7 respectively.

TABLE 4: DISCRIMINANT VALIDITY TEST RESULTS

AVE	SP	TP	SNS	COMM	TIS	TIC	PP	SCPD
SP	-							
TP	0.7416	-						
SNS	0.6568	0.5401	-					
COMM	0.7236	0.6069	0.5221	-				
TIS	0.7774	0.6607	0.5759	0.6427	-			
TIC	0.7438	0.6271	0.5423	0.6090	0.6629	-		
PP	0.8653	0.7486	0.6638	0.7306	0.7844	0.7508	-	
SCPD	0.8660	0.7423	0.6575	0.7243	0.7781	0.7444	0.8660	-

Table 5: Discriminant Validity test results

CORRELATION SQUARE	SP	TP	SNS	COMM	TIS	TIC	PP	SCPD
SP	-							
TP	0.0004	-						
SNS	0.0063	0.1391	-					
COMM	0.0036	0.1936	0.0492	-				
TIS	0.0144	0.0858	0.0269	0.5112	-			
TIC	0.0924	0.0104	0.0008	0.1954	0.1505	-		
PP	0.0068	0.0231	0.0042	0.0310	0.0002	0.0016	-	
SCPD	0.0095	0.0586	0.0103	0.0539	0.0015	0.0005	0.8501	-

The validity of the results presented in this paper are confirmed by assessing the *content*, *construct, and discriminant* validity. The content validity of the study was ensured first by collecting all the different supply chain constructs used in the paper via conducting a comprehensive literature review and second by consulting two experienced researchers to avoid any ambiguities in items and in the questionnaire (Chen *et al.*, 2004). The construct validity was assessed based on the factor loading values of the items used to collect the data related to individual constructs. Not only the items with cross-loaded values but also those having factor loadings less than 0.450 are not taken into account while cumulating results of the study. Similarly, discriminant validity was calculated to ensure that the constructs used in the study are statistically unrelated. Average variance extracted AVE and squared correlation were calculated to establish the discriminant validity between constructs, the results are presented in table 4 and 5 above. The discriminant validity was established as the Average variance extracted between all the constructs is greater than their squared correlation.

FINDINGS

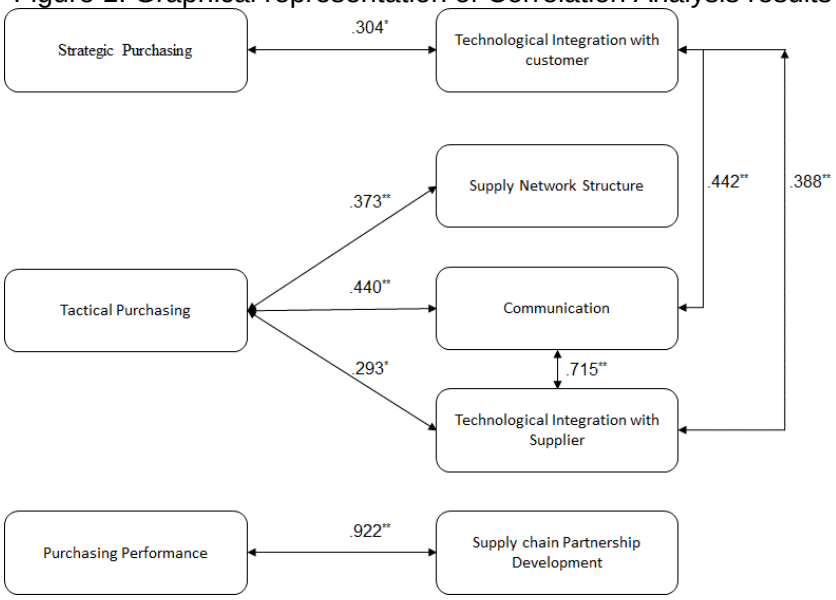
"The BoP approach, … can be thought of as an emergent 'metanarrative'— a grand synthesizing framework which provides scholars and practitioners at diverse sites with a template for future research and action aimed at creating market based solutions for poverty eradication" (Chatterjee, 2014). This section of the paper presents the results of the correlation and regression analysis and comments on the hypothesis presented earlier.
The correlation of the constructs is presented to find the degree of associations between them. Positive correlation indicates a reciprocal association and vice versa.

Table 6: Correlation Analysis

	SP	TP	SNS	COMM	TIS	TIC	PP	SCPD
SP	1							
TP	.020	1						
SNS	-.080	.373**	1					
COMM	.060	.440**	.222	1				
TIS	.120	.293*	.164	.715**	1			

TIC	.304*	.102	-.028	.442**	.388**	1		
PP	.082	-.152	-.065	-.176	.013	-.039	1	
SCPD	.098	-.242	-.101	-.232	-.038	-.022	.922**	1

Figure 1: Graphical representation of Correlation Analysis results



* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed).

Table 6 presents the correlation analysis results. Supply chain partnership development and purchasing performance have highest correlation of 0.922, which is also statistically significant at 0.01. However, strong correlation between two constructs can raise the issue of multicollinearity, however, discriminant validity was established between two in previous section. Therefore, it can be concluded that, BoP firms which are engaged in partnership development activities are more likely to get benefit in their purchase related activities. A positive correlation exists between strategic purchasing and purchasing performance, however, the value remains statistically insignificant. Besides, the association between other independent variables and purchasing performance has not been established as has been anticipated.
As far as correlations among other constructs are concerned, positive and significant associations have been analyzed between tactical purchasing and supply network structure, communication, and technological integration with suppliers. Similarly, another positive association has been observed between communication and technological integration. The positive correlation signifies that the BoP firms who communicate and coordinate with their suppliers are more likely to practice tactical knowledge sharing. Though the results are beyond the scope of this study, however the correlations established among the constructs remain constructive and offer useful foundation for further research on the topic. Further, the results are analyzed in light of regression model.

The regression model has brought forth the construct of *supply chain partner development* (the process by which buying firm strives to develop its suppliers as strategic partners by developing their operational and human capabilities based on intensity of mutual business relationships) as the one responsible for significant variation in the purchasing performance of BoP micro-entrepreneurs in dyadic buyer – supplier interactions (Table 3 and Table 4).

Table 7: Model Fit Summary

Model	R	R Square	Adjusted R Square	R Square Change	Sig. F Change
1	.926[a]	.857	.838	.857	.000

a. Predictors: (Constant), Supply Chain Partner Development, Technological Integration with Customer, Supply Network Structure, Strategic Purchasing, Technological Integration with Supplier, Tactical Purchasing, Communication

Table 7 elaborates the model fit summary. The prominence of the (S)SCM practices in explaining the variation in a focal firm's performance is indicated by the respective values of R. As shown in Table 7, all independent variables account for 86% of variation in firm's purchasing performance. The model presented above is also statistically significant, thus the model is a good fit.

As indicated in Table 8 only supply chain partner development construct shows a significant association (positive) with the purchasing performance of micro-entrepreneurs in BoP. The association between the two constructs denotes the fact that more a firm engages in supplier development related activities more it will benefit in terms of improvement of its purchasing related activities.

The regression analysis results signifying correlation between purchasing performance and supply chain partner development lead to acceptance of Hypothesis 1. We thereby conclude that supply chain partner development significantly effects the purchasing performance of BoP firms. The construct is also therefore responsible for significant variation in the purchasing related performance of indigenous micro-entrepreneurs.

Having said that the statistical results lead us to reject Hypothesis 2,3,4,5 and 6, since significant influence of none of the other constructs upon the purchasing performance could be established. The results are interesting as some of the otherwise seemingly relevant constructs appeared to become irrelevant as far as their association with purchasing performance is concerned.

Table 8: Regression model

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-1.001E-013	.052		.000	1.000
Strategic Purchasing	-.004	.056	-.004	-.073	.942
Tactical Purchasing	.068	.063	.068	1.091	.280
Supply Network Structure	-.004	.057	-.004	-.072	.943
Communication	-.004	.086	-.004	-.047	.962
Technological Integration with Supplier	.049	.077	.049	.641	.524
Technological Integration with Customer	-.042	.062	-.042	-.665	.509
Supply Chain Partner Development	.938	.056	.938	16.788	.000

a. Dependent Variable: Purchasing Performance

DISCUSSION

"Purchasing has increasingly assumed a pivotal strategic role in supply-chain management", and today is considered as a seminal pillar of a firm's business strategy (Chen et al., 2004, p. 505). Relationship based business environment renders indigenous BoP firms largely dependent on other supply chain actors for getting their supplies; may they be small scale producers, wholesalers or manufacturers. Evaluating the factors effecting the purchasing performance of these indigenous micro-entrepreneurs therefore becomes crucial if one has to develop respective supply chains on a sustainable basis while creating inclusive business opportunities for BoP communities.

Earlier BoP literature has dealt with the issues mainly falling within B2C domain of supply chain (Kolk, Rivera-Santos and Rufín, 2014). The extent paper by focusing on the B2B interactions in BoP will help in further advancement of knowledge and understanding of BoP business environment. The survey methodology employed in the study will also aid in bridging the apparent research gap, since the BoP literature mainly comprises of case studies and conceptual articles (Kolk, Rivera-Santos and Rufín, 2014; Khalid and Seuring, 2017). Furthermore, the subject of the paper also seems justified and timely when seen in context of calls for creation of inclusive business opportunities for BoP (Halme, Lindeman and Linna, 2012). The results of the study contribute towards evaluating the factors contributing towards integration of BoP micro-entrepreneurs in regional and global supply chains.

In such a context the results of the study depict a reciprocal relationship between the constructs of *supply chain partner development* and *purchasing performance*. The result indicates that the indigenous micro-entrepreneurs in BoP, by capitalizing on their relational capital and partner development related activities can increase their purchasing performance (Arnould and Mohr, 2005). BoP micro-entrepreneurs are normally devoid of capital, technological and human resources enabling them to optimize their business processes. Investing in developing the manufacturing and technological capabilities of these micro suppliers enable them to upgrade their manufacturing processes (Elaydi and Harrison, 2010; Hahn and Gold, 2014). Since supply of inconsistent quality products remains one among the major obstacle hampering the smooth

integration of BoP suppliers in global supply chains. The up-to-date manufacturing technology enables micro-entrepreneurs produce quality products with the specifications aligned with what their customers demand. Such supplier development activities thereby have a direct positive impact on purchasing performance of businesses in BoP. Furthermore, involvement in such supplier development related activities also fosters relational capital of respective firms by nurturing trust based relationships (Pagell and Wu, 2009).

Importance of developing human resource of suppliers to strengthen management related capabilities have also been highlighted in the empirical research (Lim, Han and Ito, 2013). Illiterate personal managing the micro-businesses usually lack proper training and knowhow of advanced process management techniques. Coaching and efficient exchange of information related to process management techniques help in joint development. Micro-entrepreneurs were found not capable enough to hold formal training sessions for their suppliers, therefore, most of the supplier development initiatives falling under the realm of human resource remain of informal nature. Frequent visits of each other's facilities and informal discussions between the buyers and suppliers help the dyadic actors explore avenues of further improvement and knowledge sharing (Murphy, Perrot and Rivera-Santos, 2012).

Knowledge sharing by helping sort out the human and process related deficiencies of interacting actors, fosters innovation capabilities (Murphy, Perrot and Rivera-Santos, 2012). Though the product related innovation capabilities remain very frugal in nature. However, better than nothing, the meager innovations help keep the businesses running by enabling them offer final customers with an assortment of products (Esko, Zeromskis and Hsuan, 2013). It was learned during the course of the empirical research that the innovation in BoP markets mainly centers products/services, with business processes largely considered an out of bound area for the subject. Micro-entrepreneurs were found to be apt with traditional ways of doing businesses and consider no need of bringing any change in the way they are running their business operations. Innovation related partner development endeavors therefore remain focused at nurturing product development capabilities among the interacting actors.

Logistics, particularly inventory management appeared as another area benefiting from partner development activities. Efficient exchange of information among buyers and suppliers enable them to establish a smooth flow of products characterized by short replenishment times and low levels of inventory. Usually 3PLs are hired for physical transport of products from supplier's premises to buyers' facility. Respondents of the study noted that developing manufacturing and human capabilities particularly aids in reducing replenishment times.

The results of the study thereby conclude that partner development practices related to and by ensuring consistent quality of products purchased, fostering management, innovation and logistics related capabilities have greatest impact on purchasing performance of micro-entrepreneurs in BoP.

CONCLUSION

Considered as a notion advocating for "privatisation of poverty reduction" (Arora and Romijn, 2012), "the BoP approach, … can be thought of as an emergent 'metanarrative'—a grand synthesizing framework which provides scholars and practitioners at diverse sites with a template for future research and action aimed at creating market based solutions for poverty eradication" (Chatterjee, 2014). The paper presents the results of a survey aimed at highlighting the supply chain practices which have a significant impact on indigenous micro-entrepreneurs purchasing performance in B2B supply chains of the BoP. The supply chain partner development construct (signifying long term relationship and supplier development related activities) is found to be the construct having a significant impact on the purchasing

performance of the firm. A reciprocal relationship between supply chain partner development and purchasing performance is revealed by the results of the regression analysis. Correlation analysis results also highlight potential areas for future studies in B2B domain of BoP. For example, positive and significant relationship between communication and coordination with supplier and technological integration signifies that the firms who communicate and coordinate with their suppliers are more likely to practice tactical knowledge sharing. Though the relationship is beyond the scope of this study, it is more appropriate for future studies to explore the area in detail.

Consistent with earlier studies, empirical results of the extent paper highlight the frequent informal interactions among buyers and suppliers a distinguishing characteristic of business in the BoP and a prerequisite of establishing long term relationships. The interest in building trust worthy relationships is mirrored in firm's urge of long term commitment and investment in supplier development. The interactions not only intensify mutual business relationships but also serve to improve business processes. The results remain also crucial from practitioner's point of view as they provide a holistic view of enhancing purchasing efficiency when considering BoP firms as suppliers.

The study results also enable us to explore how potential win-win situations can be achieved while working in a dynamic business environment like BoP. Incorporating these synergic impacts into the goals of the firm may then serve as starting point for adequate business process improvements.

APPENDIX A

Strategic Purchasing

SP1	Purchasing for critical products is done from selected group of suppliers
SP2	Non-critical items are purchased from wherever we get quality products at competitive price

Communication and coordination

CM1	We share sensitive information (financial, production, design, research, and/or competition) with our suppliers
CM2	Suppliers are provided with any information that might help them improve their performance
CM3	We keep each other informed about events or changes that may affect the other party
CM4	We exchange business performance feedback with our suppliers

Technological integration with customers

TIC1	We involve key customers in product design and development stage
TIC2	Our customers assist us in improving our operational technology (machines etc.)
TIC3	We involve our key customers in business and strategy planning

Technological integration with suppliers

TIS1	We involve key suppliers in product design and development stage
TIS2	We involve our key suppliers in business and strategy planning
TIS3	We collaborate with our suppliers in improving mutual operational technology (machines etc.)

Supply chain partner development

Our firm has undertaken supplier development through

SPD1.1	Giving manufacturing related advice (e.g. processing, machine process, machine setup)
SPD1.2	Giving technological advice (e.g. materials, software)

By improvement of supplier capabilities through development of supplier

SPD2.1	He was able to strengthen his management capabilities
SPD2.2	He was able to strengthen his manufacturing capabilities
SPD2.3	He was able to strengthen his logistics capabilities
SPD2.4	He was able to strengthen his product development capabilities

Supply chain network structure

SNS1	We consider doing business in networks more productive
SNS2	I think I will be helped in difficult times by other business owners in vicinity
SNS3	We try to establish trust based long term relationships with our suppliers
SNS4	Our relationship with other business players can be termed as supportive instead of competitive

To what extent do you think you have maintained any personal relationships with following

SNS5.1	Buyers
SNS5.2	Suppliers
SNS5.3	Competitors
SNS5.4	Logistic service providers

To what extent do you think you have maintained any personal ties with following

SNS6.1	Local political leaders
SNS6.2	Banks
SNS6.3	Tax officials

SNS6.4	Local administration
SNS6.5	Local communities
SNS6.6	NGOs

Purchasing performance

Improving product and delivery performance through development of supplier has improved/reduced

PP1.1	The quality of products purchased from supplier
PP1.2	The replenishment lead time of the products purchased from supplier
PP1.3	The service of supplier deliveries
PP1.4	The reliability of supplier deliveries

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IMPACT OF STOCKOUT COMPENSATION FOR THE SUPPLIER AND ETAILER IN E-COMMERCE DROP-SHIPPING SUPPLY CHAIN

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ABSTRACT

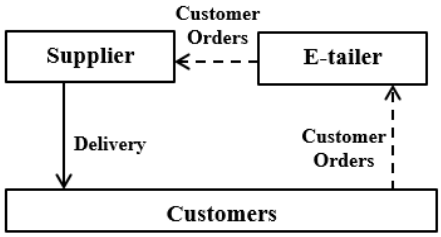
Using simulation methodology, our research is the first study to investigate the impact of equal stockout compensation strategy (E-SC) compared to no stockout compensation strategy (N-SC) on supplier's profits and etailers profits in a dropshipping supply chain. Results from our study shows that on average, the profit difference in E-SC compared to N-SC is less than 4.0 percent of overall profits for both the supplier and etailer. Also, this study shows that demand variability, production capacity and service level have a significant impact on both the supplier's profits and etailer's profits in E-SC compared to N-SC.

KEYWORDS: E-Commerce, Dropshipping, Stockout Compensation, Variable Demand, Simulation Modeling

INTRODUCTION

In recent years, due to ease of online shopping, there is significant increase in online sales and continues to increase. Market research firm eMarketer estimates online sales of $1.91 trillion in 2016 and projects to exceed $4.00 trillion by 2020 (eMarketer 2016). However, many online retailers have realized that the integration of front-end order taking process with back-end order fulfillment process is challenging, with order fulfillment process being regarded as the weakest link. To overcome this challenge, many online retailers have adopted dropshipping strategy, solely or in combination with their in-house order fulfillment strategy (Khouja 2001, Netessine et al. 2002, Gan et al. 2010, Chen et al. 2011, Cheong et al. 2015). In drop-shipping order fulfillment strategy, as shown in Figure 1, the online retailer (here on referred to as etailer) takes on-line orders from their customers and requests their supplier (manufacturer or distributor) to ship these orders directly to their customers. For example, eBags.com carries very little inventory and use dropshipping extensively to sell more than 12,000 different bags online which are shipped directly by their suppliers to their customers. Large online retailers like Amazon and eBay also use dropshipping to fulfill some of their customer orders (Cheng et al. 2015). In dropshipping strategy, the etailer benefits by transferring inventory management and shipping responsibilities to the supplier, while the supplier benefits with increased demand and the ability to charge higher wholesale prices.

Figure 1. Drop Shipping Supply Chain



However, in a variable demand environment with production (and/or supply) capacity constraints, there are risks to this zero-inventory order fulfillment strategy for the etailer. They are usually vulnerable, especially when the dropship supplier is unable to fulfill customer orders due to stockout situations. As etailers are in direct contact with their customers, they are ultimately held responsible for any unfulfilled customer orders. If orders are not fulfilled on time, customers may cancel their orders or leave negative reviews that will impact the etailer's current and future business. (Kim and Lennon 2011). In a recent study, using 14 months of empirical sales data for an online retailer selling non-perishable items, Jing and Lewis (2011) found that approximately 25.4% of all online orders were imperfectly filled due to stockouts. Similarly, another study by Accenture found that despite best efforts to improve online order fulfillment during the busy season, more than 12% of the orders were not delivered on time (Enos 2010). When online retailer Value America declared bankruptcy, it cited the inability of its dropship suppliers to fulfill their customer orders on time. Similarly, in its early days, online retailer Zappos.com carried very little inventory and used dropshipping extensively to fulfill their customer orders. However, they soon stopped using dropshipping due to poor order fulfillment by their suppliers (Hsieh 2010). As most dropship suppliers do not pay any penalty for late orders, there is less incentive for them to improve their inventory management and order fulfillment rates (Yao et al. 2008, Gan et al. 2010).

So, in a dropshipping supply chain, unfulfilled customer orders during stockout can be a huge obstacle for etailers to pursue dropshipping strategy. In an online retailer setting (without dropshipping), Bhargava et al. (2006) analyze stockout compensation policy during inventory stockouts and conclude that it helps to increase customer retention, improve demand rate and decrease average inventory costs. However, to the best of our knowledge, there are no research studies that investigate the impact of stockout compensation on supplier's profits and etailer's profits in a dropshipping supply chain. In our research study, we propose that both the supplier and etailer share the risk of stockout and equally pay stockout compensation in a dropshipping supply chain. The etailer generates continuous demand and therefore the supplier should consider sharing the risk of stockout to avoid losing future business with this etailer. So, if stockout compensation is to be considered in a dropshipping supply chain, some of these questions arise. What will be the impact on supplier's profits and etailer's profits when both equally share stockout compensation (E-SC) compared to no-stockout compensation policy (N-SC)? In E-SC stockout compensation strategy, what will be the impact on supplier's profits and etailer's profits under different supply chain parameters? Using simulation modeling, our research aims to answer these questions by investigating the impact of E-SC compared to N-SC on the supplier's profits and the etailer's profits in a dropshipping supply chain.

LITERATURE REVIEW

Academic research in online retailing has largely focused on the marketing aspect, and is mostly qualitative in nature (Gulati et al. 2000, De Koster 2003, Jiang et al. 2005, Anderson et al. 2007, Baier et al. 2010, and Rafiq et al. 2013). Academic research in online retailing with operations consideration (production, inventory, dropshipping, etc.) is relatively new and growing in importance. Many online retailers have realized that the integration of front-end order taking process with back-end order fulfillment process is quite challenging, where order fulfillment is regarded as the weakest link.

First, we will review the studies related to dropshipping in online retailing. Next, we will review the studies related to stockout compensation in online retailing. The following studies are related to our research in online retailing using dropshipping. Using a single period model framework, Khouja (2001) formulate a model to identify the optimal mix of in-house inventory and dropshipping to meet customer demand, where capacity of drop-shipping option is unlimited. Using empirical data, Netessine et al. (2002) discuss the advantages and disadvantages of dropshipping for the etailers (they use the term virtual order fulfillment for dropshipping). Netessine and Rudi (2004) develop a model to analyze the interaction between a wholesaler and an online retailer in a dropshipping supply chain. They propose a profit sharing contract where both the wholesaler and online retailer should share the profits and expenses of acquiring customers and fulfilling customer orders. Bailey and Rabinovich (2005) develop an analytical model for an internet book retailing, where both in-house inventory and dropshipping option can be used to fulfill customer orders. They discuss how the product's popularity or frequency of ordering affects the decision of either using in-house inventory or dropshipping option. Netessine and Rudi (2006) model a supply chain with multiple retailers and a wholesaler with dropshipping contract. They provide recommendations where dropshipping or a traditional channel should be preferred from the perspective of inventory risk pooling. Using Monte Carlo simulation, Ayanso et al. (2006) determine a threshold level of inventory for online retailers to switch from internal inventory stocking to dropshipping option for different demand priorities and different lead times. Using a Stackelberg game, Yao et al. (2008) explore how an online retailer (leader) can give the supplier (follower) appropriate incentive to improve the level of delivery reliability in a dropshipping supply chain. Khouja and Stylianoua (2009) develop two (Q, R) inventory models for an online retailer with both in-house inventory and dropshipping option. Their results suggest that dropshipping should be used in case of inventory shortage during the lead time. Chiang and Feng (2010) consider an EOQ game model with pricing and lot-sizing decisions to investigate the advantages of dropshipping over the traditional shipping channel. They identify conditions under which the dropshipping channel produces more profit than traditional shipping channel.

Gan et al. (2010) propose a commitment penalty contract in a dropshipping supply chain with three different parameters under asymmetric demand information. They propose that the supplier should receive demand information from online retailer to maximize the expected profit. Cheong et al. (2015) develop an analytical model for a two-level supply chain to study impact of information discrepancies on both the drop-shipper and online retailer. Their study concludes that both parties can achieve substantial cost reductions if information discrepancy is eliminated. Using mathematical models, Cheng et al. (2016) investigate different order fulfillment strategies for an e-tailer and show that dropshipping model and hybrid channel with inventory rationing model are optimal choices for the e-tailer. Yu et al. (2017) consider a dual-channel supply chain with a manufacturer selling a product through a traditional retailer and online retailer using dropshipping. Their study show that dropshipping benefits both the manufacturer and online retailer, when the online retailer has relatively low market power compared to the traditional retailer.

There are some studies in online retailer setting that consider consumer behavior during stockouts. However, there are limited studies in online retailing that consider some form of financial compensation during stockouts. Using EOQ type inventory modeling framework with deterministic demand in an online retailer setting (without dropshipping), Bhargava et al. (2006) analyze profit difference between stockout-compensation backorder policy and no-stockout-compensation backorder policy. They conclude that stockout compensation policy results in more efficient operation which helps to increase customer retention, increase demand rate and lower average inventory costs. Breugelmans et al. (2006) investigate the impact of an online retailer's stock-out policy on the consumer's category purchase and choice decisions. Their results from an online grocery shopping experiment reveal that suggesting a replacement item during stockout helps to substantially increase consumer's probability of purchasing the suggested item. Kim and Lennon (2011) investigate how consumers respond to online apparel stockouts and found that negative emotions evoked by stockouts create a depressed perception of store image, lowered decision satisfaction, and reduced behavioral intent of buying. They show that financial compensation was most effective in mitigating the negative impact of stockouts.

Previous studies in online retailing using dropshipping have identified some factors that help the supplier and etailer to pursue dropshipping strategy, where most studies consider unlimited capacity for dropship supplier. However, the literature related to stockout compensation in online retailing is relatively small and to the best of our knowledge, there are no studies that consider impact of stockout compensation on supplier's profits and etailer's profits in a dropshipping supply chain. Using simulation modeling, our study is the first paper to consider impact of equal stockout compensation strategy (E-SC) on supplier's profits and etailer's profits compared to no-stockout compensation strategy (N-SC) in a variable demand dropshipping supply chain. These are the two different scenarios considered in our research study.

Scenario 0 (N-SC): This is Base Scenario. During stockout, the customer orders are backordered with 'no stockout' compensation. Customers are willing to wait for their orders to be delivered.
Scenario 1 (E-SC): During stockout, the customer orders are backordered with a 'stockout' compensation. Both the supplier and etailer 'equally share' stockout compensation, and the wholesale price is the same as in the Base Scenario (N-SC).

We investigate the following research questions in this study.

1. On average, what is the impact of E-SC compared to N-SC on the supplier's profits and etailer's profits?
2. What is the impact of E-SC compared to N-SC on the supplier's profits and etailer's profits under different supply chain parameters?

Our research will expand the existing literature (Netessine and Rudi 2004, Bhargava et al. 2006, Yao et al. 2008, and Gan et al. 2010, Kim and Lennon 2011) in the area of online retailing and dropshipping by investigating the impact of stockout compensation in a dropshipping supply chain. The contributions of our research to the literature are three-fold. First, our research is the first study to consider impact of stockout compensation on the supplier's profits and etailer's profits in a dropshipping supply chain. Second, using simulation modeling we consider the impact of equal stockout compensation strategy (E-SC) compared to no stockout compensation strategy (N-SC) on the supplier's profits and etailer's profits in a dropshipping supply chain under different supply chain parameters. Third, our study aims to provide managerial insights for both the supplier and etailer on the impact of E-SC under different supply chain parameters.

RESEARCH METHODOLOGY

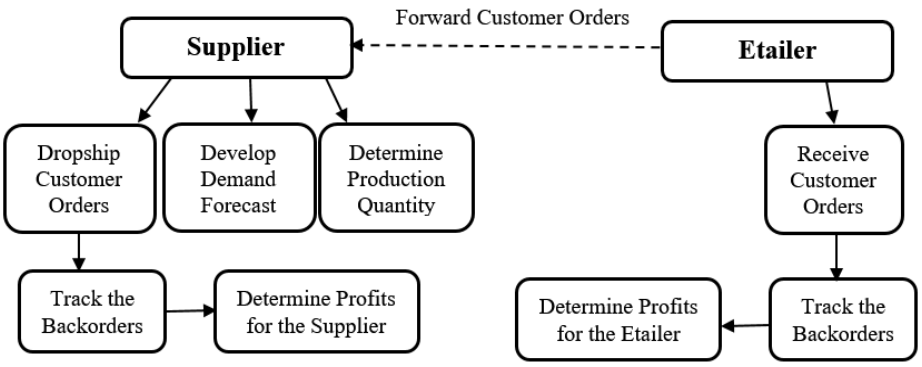
Discrete event simulation (Arena software from Rockwell automation) is used to develop the simulation model for the dropshipping supply chain. Simulation method is appropriate to study the dynamic and time varying behavior of a dropshipping supply chain in a variable demand environment with production capacity constraints. Simulation helps to provide insight into the cause and effects of different supply chain parameters on the performance measures. Simulation approach has been used in many studies for analyzing supply chain systems, including dropshipping and online retailing (Ayanso et al. 2006, Mathien and Suresh 2015).

Simulation Modelling

The conceptual model used to develop the simulation model for dropshipping supply chain is a two-echelon production-inventory system with a make-to-stock manufacturer (i.e. supplier) and an online retailer (i.e. etailer). Periodic review policy is used where all decisions by the supplier and etailer are made at the end of each period, where review period is one week. Demand forecast for supplier is developed using exponential smoothing forecast technique and smoothing parameter is selected based on minimizing forecast error. Periodic review order-up-to policy is used to determine production quantity during each period. Safety stock for supplier is determined using service factor (based on service level) and standard deviation of demand. The supplier uses lot-for-lot production policy with a lead time of one week and has production capacity constraints.

During each period, the customers place their orders online and the etailer forwards these orders to supplier at the end of each period. The supplier's warehouse receives shipment from their production plant at end of each period and their inventory level is updated. From this available inventory, the supplier dropships the customer orders received from etailer, and any demand not met is backordered. In N-SC, customer orders are backordered without a stockout compensation, and in E-SC they are backordered with a stockout compensation. Next, the supplier forecasts demand for next period, calculates order up-to inventory level to determine production quantity. The production quantity during each period is the difference between order-up-to inventory level and current inventory position. The production starts at the beginning of next period and the production quantity along with current inventory is available for dropshipping at the end of next period. Finally, the revenues and expenses are calculated to determine the supplier's profits and etailer's profits during each period. The decisions made by the supplier and etailer during each period in the dropshipping supply chain are shown in Figure 2.

Figure 2. Drop Shipping Supply Chain Setting



Model Notations

P	Retail price per unit (paid by customer)
W	Whole sale price per unit (paid by etailer)
T	Dropshipping cost per unit (paid by etailer)
E	Etailer cost (website, marketing, etc.) per unit
F	Fixed cost of production per period
C	Variable cost of production per unit
H	Inventory holding cost per unit per period
S_s	Supplier stockout compensation cost per unit per period
S_e	Etailer stockout compensation cost per unit per period
d	Customer orders per period
q	Production quantity per period
i	Average inventory of supplier per period
b	Backorder quantity (due to stockout) per period
EP	Etailer profits per period
SP	Supplier profits per period

Profits for Supplier and Etailer in N-SC strategy

$EP = (P - W - T - E)*d$
$SP = W*d - (F + C*q) - H*i$

Profits for Supplier and Etailer in E-SC strategy

$EP = (P - W - T - E)*d - S_e*b$
$SP = W*d - (F + C*q) - H*i - S_s*b$

Experimental Design

The purpose of an experimental design is to develop a methodology to track changes in performance measures by varying factors under study during the experimental runs. According to Law and Kelton (2000), “One of the principal goals of experimental design is to estimate how changes in input factors (control variables) affect the performance measures (response variables) in the experiment.” The main motivation for this research is to investigate the impact of equal stockout compensation strategy (E-SC) compared to no stockout compensation strategy (N-SC) in a dropshipping supply chain under different supply chain parameters. So four independent variables (control variables) with three levels each and two dependent variables (response variables) are considered for this study. All factor combinations of these independent variables are used to investigate impact on dependent variables in N-SC and E-SC stockout compensation strategies.

Table 1. Control Variables for this Research

Control Variables	Details for Variables
Demand Variability (DV)	Low Demand Variability, σ = 100 Med Demand Variability, σ = 200 High Demand Variability, σ = 300
Production Capacity (PC)	Low Production Capacity, 1.10 Med Production Capacity, 1.25 High Production Capacity, 1.40
Service Level (SL)	Low Service Level, 90.0 % Med Service Level, 95.0 % High Service Level, 99.0 %
Inventory Holding Cost (HC)	Low Inventory Holding Cost, $1 Med Inventory Holding Cost, $2 High Inventory Holding Cost, $3

Table 2. Response Variables for this Research

Response Variables	Details
Etailer Profits per Period (EP)	Etailer Revenues minus Expenses
Supplier Profits per Period (SP)	Supplier Revenues minus Expenses

As shown in Table 1 and Table 2, four control variables and two response variables are used to investigate the impact of E-SC compared to N-SC on supplier's profits and etailer's profits in a dropshipping supply chain. Variable demand, production capacity, service levels, and inventory holding costs are used as control variables, as these are important factors that will impact profits for both the supplier and etailer. In this study, auto-correlated demand pattern with three levels of demand variability is considered. The customer demand during each period of the simulation run is generated as shown: $D_t = d + \rho D_{t-1} + \varepsilon_t$ where ρ = correlation factor, d = initial mean, and ε_t = error that is normally distributed with mean zero and standard deviation σ. The initial mean is 500 units with a correlation factor of 0.5 to generate an average demand of 1000 units per period. Three levels of demand variability are generated by varying σ in the above equation.

To investigate the impact of production capacity, three levels of production capacity with different levels of capacity cushion based on average customer demand are considered. Additionally, three levels of service levels to determine the safety stock inventory and three levels of inventory holding costs for supplier are considered. The retail price is assumed to be $100 per unit and the wholesale price per unit is as follows: When demand is less than 900 units per period, the wholesale price is $61 per unit; when demand is 900 to 1100 units per period, the wholesale price is $60 per unit and when demand is more than 1100 units per period, the wholesale price is $59 per unit. The shipping cost charged by supplier to etailer for dropshipping the item is as follows: When inventory holding cost is $1 per unit per period, shipping cost is $5.00 per unit; when inventory holding cost is $2 per unit per period, shipping cost is $5.50 per unit and when inventory holding cost is $3 per unit per period, shipping cost is $6.00 per unit. The stockout compensation cost is assumed to be 10% of retail price and no customer order returns are considered in this dropshipping model. Most studies in dropshipping use retail price minus wholesale price as profit

measure for etailer (Netessine & Rudi 2006, Chiang & Feng, 2010) and do not consider any expenses incurred by the etailer. However, the etailer incurs some expenses for online retailing such as cost of website, marketing, etc. and so our study considers etailer's expense as $3 per unit to generate the customer demand.

Table 3. Production Capacity and Unit Production Cost

Production Capacity	Fixed Production Cost per Period	Var. Production Cost per Unit	Avg. Production Per Period	Avg. Production Cost Per Unit
1.10	$4,000	$22.00	1000	$26.00
1.25	$5,000	$20.00	1000	$25.00
1.40	$6,000	$18.00	1000	$24.00

Generally, the production cost per unit decreases as production capacity increases, so our study considers the production cost details as shown in Table 3. Initial inventory of 2000 units (2 times average demand) is used for supplier at start of simulation run. The supplier profit and etailer profit are used as performance measures and calculated based on revenues minus expenses during each period.

To eliminate the impact of random variations of input data, the same random number sequence is utilized in simulation model to generate the same customer demand data in N-SC and E-SC strategies for all factor combinations. In addition, to reduce variance of output data, a sample size of 60 replications is considered in this study. Generally, stochastic processes for most real systems do not have a steady state distribution, since parameters of the system may continue to change over time. In this research, customer demand for etailer varies from period to period, and therefore the steady state parameters are not well defined or do not exist. In this situation, there will be a fixed amount of data describing how the input parameters can be varied over some time duration. This in effect provides a terminating event for simulation and thus analysis techniques for terminating simulation will be appropriate (Law and Kelton 2000). To determine performance measures for a terminating simulation, the initial conditions should be representative of the actual system. In our study, the simulation model for all factor combinations is run for a total of 1144 periods, with the first 104 periods used to initialize the system (warm up period), and remaining 1040 periods (equal to 20 years) is used for analysis. Increasing warm up period will not have a significant impact, as output values from the simulation model are relatively stable for different warm-up periods. Microsoft Excel and statistical software "Minitab 18" are used for results and discussions.

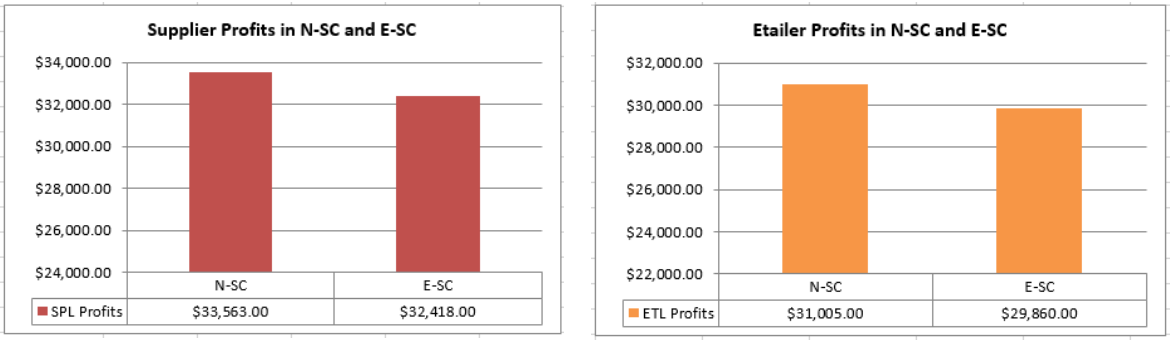
RESULTS AND DISCUSSION

The output data (supplier's profits and etailer's profits) from the simulation model is analyzed to determine the impact of equal stockout compensation strategy (E-SC) compared to no stockout compensation strategy (N-SC). First, the impact of E-SC compared to N-SC on the supplier's profits and etailer's profits for all factor combinations is investigated. Next, the impact of E-SC compared to N-SC on the supplier's profits and etailer's profits under different supply chain parameters is investigated. Some of the main results of this research study are shown below.

Impact of Stockout Compensation Strategy

To determine the impact of E-SC compared to N-SC on supplier's profits and etailer's profits in a dropshipping supply chain, the output data from the simulation model for all factor combinations are plotted as shown in Figure 3. When both the supplier and etailer pursue E-SC, on average, the supplier's profits decrease from $33,563 to $32,418 (i.e. by 3.42%) and etailer's profits decrease from $31,005 to $29,860 (i.e. by 3.69%) compared to N-SC. So, based on the dropshipping supply chain considered in our research study, on average, the profit difference in E-SC compared to N-SC is less than 4.00% for both the supplier and the etailer. This amount of money, which is less than 4.00% of overall profits is surely worth spending to keep the customers happy, which in turn can help in maintaining or even increasing the overall demand and overall profits for both the supplier and the etailer.

Figure 3. Impact of Different Stockout Compensation Strategies

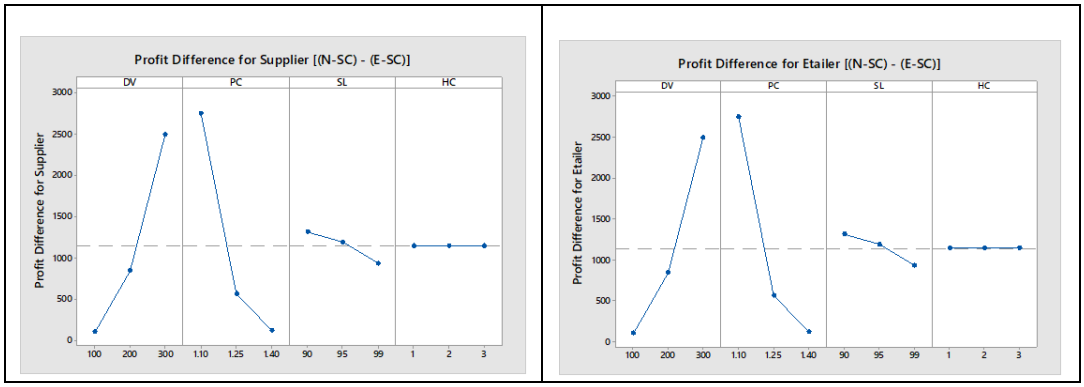


To determine if the difference between means for supplier profits and etailer profits in E-SC and N-SC are statistically significant in a variable demand environment, we use ANOVA to compare p-value to significance level ($\alpha = 0.05$) as shown in Table 4. In E-SC, both the supplier and etailer equally pay stockout compensation, and so the profit difference for both the supplier and the etailer between E-SC and N-SC will be the same. In addition, profit difference for the supplier and etailer between E-SC and N-SC for different supply chain factors is shown in Figure 4.

Table 4. ANOVA of Profit Difference between N-SC and E-SC

Source	DF	Sum of Squares	Mean Squares	F	P
DV	2	80845559	40422780	2398.78	0.000
PC	2	106221592	53110796	3151.71	0.000
SL	2	2026614	1013307	60.13	0.000
HC	2	0	0	0.00	1.000
DV*PC	4	65954297	16488574	978.47	0.000
DV*SL	4	1172861	293215	17.40	0.000
DV*HC	4	0	0	0.00	1.000
Error	60	1011084	16851		
Total	80	257231736			

Figure 4. Profit Difference for Supplier and Etailer between N-SC and E-SC

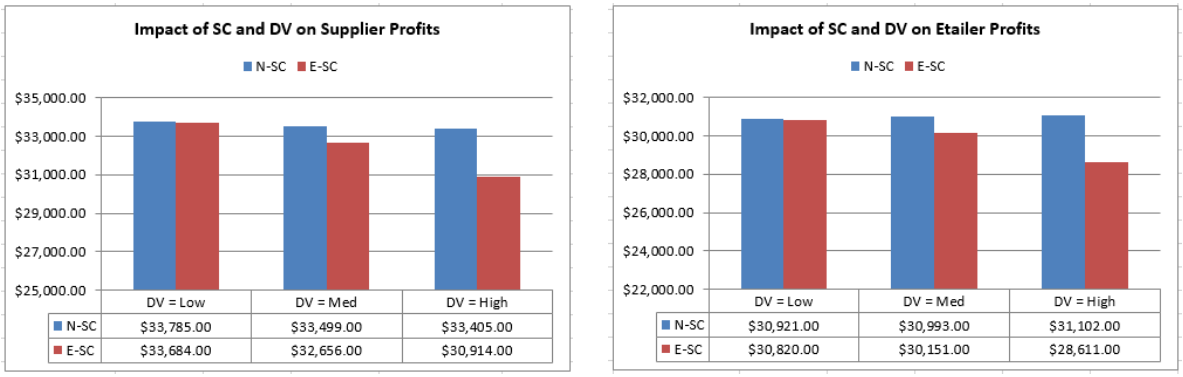


From Table 4, the p-value is less than the significance level, and so we conclude that there is a statistical significant difference for the supplier profits and the etailers profits between N-SC and E-SC for different DV (demand variability), PC (production capacity) and SL (service level). However, it is interesting to see that there is no statistical significant difference in supplier profits and etailer profits between N-SC and E-SC for different HC (inventory holding cost). The likely reason is that same amount of inventory is held by the supplier in both the N-SC and E-SC strategies under different inventory holding costs. Also, only the supplier holds inventory in a dropshipping supply chain, and so inventory holding cost does not impact the etailer's profits.

Impact of Stockout compensation (SC) and Demand Variability (DV)

Demand variability can play an important role on impact of E-SC compared to N-SC on both the supplier profits and etailer profits in a drop shipping supply chain. In this research, the customer demand for etailer is varied during each period of the simulation run. The supplier profits and etailer profits under different demand variabilities and stockout compensation strategies in a dropshipping supply chain are shown in Figure 5.

Figure 5. Impact of Stockout Compensation (SC) and Demand Variability (DV)



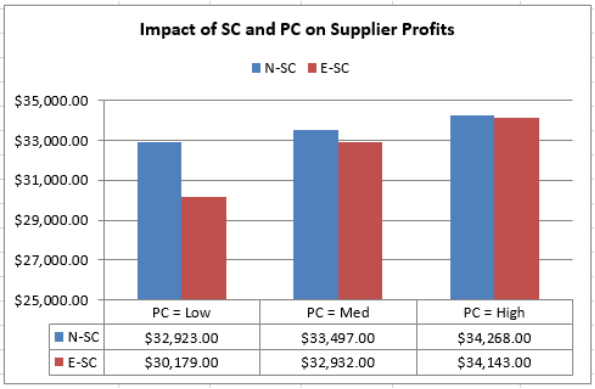
When demand variability is low, the supplier's profits decrease only by 0.30% and etailer's profits decrease only by 0.33% in E-SC compared to N-SC. It means that when demand variability is low, the profit difference for E-SC compared to N-SC is less than 0.50% for both the supplier and etailer. This is because when demand variability is low, the supplier is able to accurately forecast

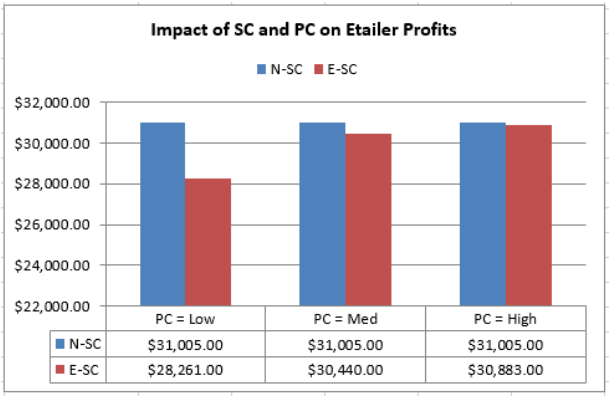
demand and have enough production capacity to fulfill almost all customer orders with very little stockout. However, when demand variability is high, the supplier's profits decrease by 7.46% and etailer's profits decrease by 8.01% in E-SC compared to N-SC. When demand variability is high, the supplier may not be able to accurately forecast demand and may not have sufficient production capacity resulting in higher profit difference in E-SC compared to N-SC due to higher stockout. Our results are similar to the study by Bhargava et al. (2006) who show an increase in profit difference for an online retailer with stockout compensation (without dropshipping) when demand rate increases. The results from this study show that demand variability does have a significant impact in E-SC compared to N-SC on both the supplier's profits and the etailer's profits. If feasible, the etailer should try to reduce demand variability to help increase the profits in E-SC for both the supplier and the etailer.

Impact of Stockout compensation (SC) and Production Capacity (PC)

Production capacity helps to determine if the supplier has enough capacity to produce during each period to meet the customer demand. So, production capacity can play an important role for both the supplier and etailer in E-SC compared to N-SC. The supplier profits and etailer profits under different production capacities and stockout compensation strategies in a dropshipping supply chain are shown in Figure 6.

Figure 6. Impact of Stockout Compensation (SC) and Production Capacity (PC)



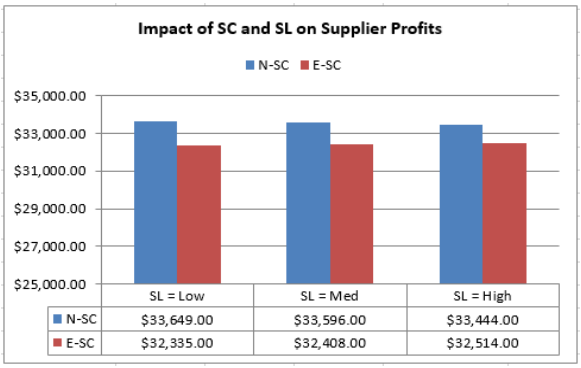


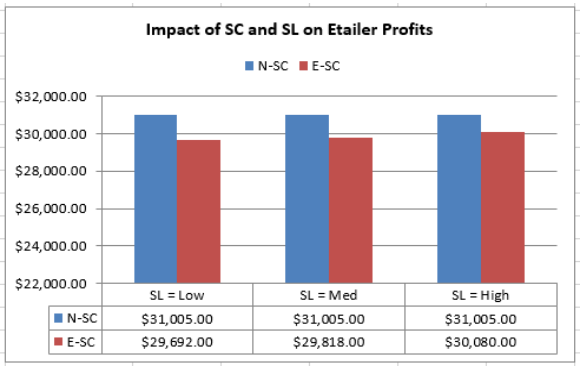
When production capacity is high, the supplier's profits decrease only by 0.36% and etailer's profits decrease by 0.39% in ESC compared to N-SC. It means that when production capacity is high, the profit difference in E-SC compared to N-SC is less than 0.50% for both the supplier and etailer. This is because when production capacity is high, the supplier may have enough capacity to produce and fulfill almost all customer orders with very little stockout. However, when production capacity is low, the supplier's profits decrease by 8.33% and etailer's profits decrease by 8.85% in E-SC compared to N-SC. When production capacity is low, the supplier may not have enough capacity to produce and fulfill the customer orders resulting in higher stockout. The results from this study show that production capacity does have a significant impact in E-SC compared to N-SC on both the supplier's profits and the etailer's profits. So, in a variable demand environment, the supplier should increase production capacity which will significantly reduce cost of stockout compensation in E-SC and increase overall profits for both the supplier and etailer.

Impact of Stockout compensation (SC) and Service Level (SL)

Service level used to determine the safety stock for supplier can play an important role on the impact of E-SC compared to N-SC for both the supplier and etailer in a drop shipping supply chain. The supplier profits and etailer profits under different service levels and stockout compensation strategies in a dropshipping supply chain are shown in Figure 7.

Figure 7. Impact of Stockout Compensation (SC) and Service Level (SL)



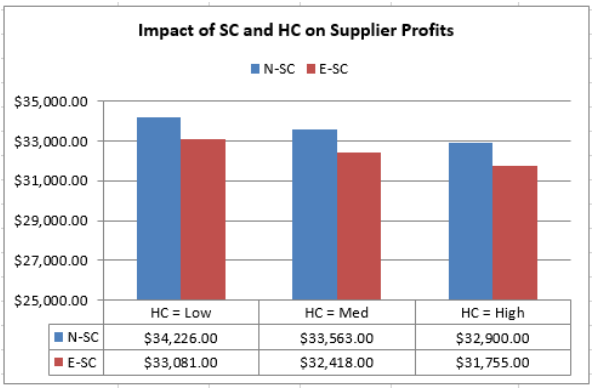


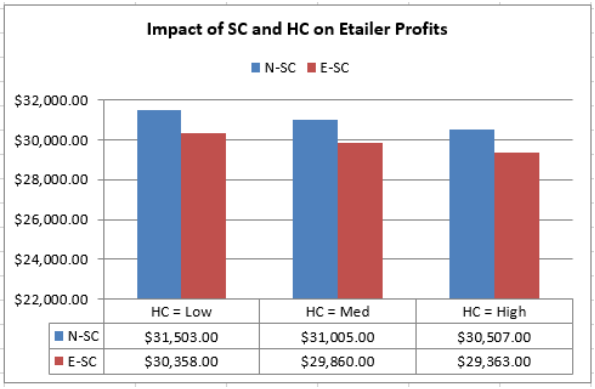
When service level is high, the supplier's profits decrease by 2.78% and the etailer's profits decrease by 2.98% in E-SC compared to N-SC. It means that when service level is high, the profit difference for E-SC is less than 3.00% for both the supplier and etailer. With higher service level the supplier carries more safety stock inventory which helps to fulfill customer orders with less stockout. However, when service level is low, the supplier's profits decrease by 3.91% and the etailer's profits decrease by 4.23% in E-SC compared to N-SC. It means that when service level is low, the profit difference for E-SC compared to N-SC is more than 3.00% for both the supplier and etailer. With lower service level the supplier carries comparatively less safety stock inventory which increases the stockout rate. The results from this study show that service level does have a significant impact in E-SC compared to N-SC on both the supplier's profits and the etailer's profits. Ideally, in a variable demand environment the supplier should maintain higher service level to help reduce the stockout compensation in E-SC which will help to increase the overall profits for both the supplier and the etailer.

Impact of Stockout compensation (SC) and Inventory Holding Cost (HC)

Even though the profit difference for the supplier and etailer is same between N-SC and E-SC strategies under different inventory holding costs, however the supplier profits and etailer profits are not the same in E-SC compared to N-SC under different inventory holding costs. The supplier profits and etailer profits under different inventory holding costs and stockout compensation strategies in a dropshipping supply chain are shown in Figure 8. In this study, for every dollar increase in inventory holding cost per unit per period, an additional cost of $0.50 per unit is charged to etailer for dropshipping the customer orders, which will help the supplier to offset their higher inventory holding cost. In a dropshipping supply chain, only the supplier holds inventory, and so they should be able to charge slightly higher price to etailer which will help to offset their higher inventory holding cost.

Figure 8. Impact of Stockout Compensation (SC) and Inventory Holding Cost (HC)





When inventory holding cost is low, the supplier's profits decrease by 3.35% and etailer's profits decrease by 3.63% in E-SC compared to N-SC. It means that when inventory holding cost is low, the profit difference for E-SC compared to N-SC is less than 4.00% for both the supplier and etailer. Similarly, when inventory holding cost is high, the supplier's profits decrease by 3.48% and etailer's profits decrease by 3.75% in E-SC compared to N-SC. It means that when inventory holding cost is high or low, the profit difference for E-SC is less than 4.00% for both the supplier and etailer. So, the results from this study show that inventory holding cost does not have a significant impact in E-SC compared to N-SC on both the supplier's profits and the etailer's profits. This is because, the supplier is able to charge higher dropshipping cost to etailer, which will help the supplier to offset their higher inventory holding cost.

CONCLUSION

In a dropshipping supply chain, unfulfilled customer orders during inventory stockout can be a huge obstacle for online retailers (i.e. etailers) to pursue dropshipping strategy. Using simulation modeling, our research is the first study to consider stockout compensation in a dropshipping supply chain. We investigate impact of equal stockout compensation strategy (E-SC) compared to no-stockout compensation strategy (N-SC) on supplier's profits and etailer's profits in a variable demand dropshipping supply chain. The conceptual model is a two-echelon production-inventory system with a make-to-stock manufacturer (i.e. supplier) and an online retailer (i.e. etailer).

The results from this study suggests that on average, the supplier's profits decrease by 3.42% and the etailer's profits decrease by 3.69% in E-SC compared to N-SC. So, based on the dropshipping supply chain considered in our research study, on average, the profit difference for both the supplier and etailer is less than 4.00% of their overall profits in E-SC compared to N-SC. This amount of money, which is less than 4.00% of their overall profits, is worth spending to keep the customers happy which in turn can help in maintaining or even increasing the overall demand and profits for both the supplier and etailer in a dropshipping supply chain. Demand variability, production capacity, and service level have a significant impact on both the supplier's profits and the etailer's profits in E-SC compared to N-SC. When demand variability is high, production capacity is low, service level is low and inventory holding cost is high, the impact on the supplier's profits and etailer's profits in E-SC compared to N-SC is higher (i.e. decrease in profits is higher in E-SC compared to N-SC). However, when demand variability is low, production capacity is high, service level is high and inventory holding cost is low, impact on supplier's profits and etailer's profits in E-SC compared to N-SC is comparatively lower.

Limitations and Future Research

Although valuable insights can be gained from this research study to understand the impact of equal stockout compensation strategy (E-SC) compared to no-stockout compensation strategy (N-SC) on the supplier's profits and etailer's profits in a variable demand dropshipping supply chain, however, it is recognized that the conclusions provided here is limited to the dropshipping supply chain setting considered in this study. In this research, a single supplier and a single etailer with periodic review policy (R, S) is considered for the dropshipping supply chain. Demand variability, production capacity, customer service level and inventory holding costs are used as the control variables. A fixed retail price and one set of stockout compensation cost is considered in this study. So, there are many opportunities to evaluate and strengthen these insights by investigating other parameters to determine the impact of E-SC compared to N-SC on the supplier profits and etailer profits in a dropshipping supply chain. Future studies can investigate the impact on supplier's profits and etailer's profits when only the supplier pays the stockout compensation (S-SC) and in addition, determine the appropriate wholesale price the supplier can charge in the S-SC strategy to offset their stockout compensation cost. Also, future studies can investigate how different sets of stockout compensation costs, retail price and profit margins will impact supplier profits and etailer profits in E-SC and S-SC compared to N-SC. Another area of future research is to consider the impact of E-SC and S-SC on supplier profits and etailer profits with multiple suppliers and/or multiple etailers. In addition, it would be valuable to extend this study to investigate the impact of E-SC and S-SC on the supplier profits and etailer profits by considering other inventory management policies like (s, S) and (R, Q) policies in a dropshipping supply chain.

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Impacts of Stimulation Approaches on Online Learning Achievement: A Case Study

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ABSTRACT

This study has adopted academic motivation theory to implement a stimulation strategy with a teacher-stimulated approach and a teacher-guided approach in an online undergraduate computer literacy course. Hypothesis testing utilizes the performance records of 2,500 students to exam students' learning performances and achievements of each approach in two consecutive semesters.

KEYWORDS: Online learning; Learning motivation; Learning achievement

INTRODUCTION

The affordable of advanced information and communication technologies have nourished the popularity of online learning in the current digital age. Organizations and higher education institutions have permanently incorporated this into its traditional classroom learning approach. It is a cost effective for having the ability to communicate and educate vast number of distance students at anytime and anywhere in the universe. The limited resources and funding constraints have also prompted the College of Business Administration (CBA) to transform a high enrollment undergraduate computer literacy course (MIS 123) from the traditional face-to-face classroom teaching to a student self-pulled online learning.

Under the new learning approach, students have the total control and freedom of their studying time, place, and pace to access a courseware over the Internet. The course instructor acts as a course administrator to define structure, prepare syllabus, submit grades and solve problems. Students have to pull themselves together to figure out the entire learning process without any push from the instructor. Unfortunately, this approach has produced a high dropout rate and a low passing rate as revealed by numerous academic researches. It is due to some students lacking self-managed and self-motivated ability to study as required in an isolated online learning environment. An urgent responsibility of the instructor is to figure out a stimulation strategy that utilizes academic motivation theory to persuade students to engage in the online learning process.

MIS 123 adopted a stimulation strategy of 20 extra reward points based on ARCS motivation model and self-determination theory (SDT). It utilized two implementation approaches for a stimulation strategy including teacher-stimulated and teacher-guided to motivate students in their learning process and reducing online learning pitfalls. Every student received the same lessons, assignments, and final exam via a commercial online courseware. Hypothesis testing utilizes the performance records of 2,500 students to exam the effectiveness of each approach in two consecutive semester.

LITERATURE REVIEW

In general, the student satisfaction is a critical successful factor to improve learning effectiveness, passing rate and dropout rate as suggested by many researchers and educators (Allen & Seaman, 2013; Castillo-Merino & Serradell-Lopez, 2014; Eom & Ashill, 2016; Jung, Choi, Lim & Leem 2002; Collins, Deck & McCrickard 2008; Manochehri & Young, 2006; Mashaw, 2012; Wu, Tennyson & Hsia, 2010; Zhao, Lei, Yan, Lai & Tan, 2005). A well-designed courseware and instructor's motivation strategy are the two major determinants for fabricating students' satisfaction. An effective courseware should have multiple course delivery formats such as reading, watching and practicing to fit student's learning style. Its structure has to be easy navigating, interactive and multimedia presentation for reducing the isolated learning feeling. In addition, it should provide instant learning feedback for quick performance improvement (Nemanich, Banks & Vera, 2009; Neuhauser, 2002; Ozdemir & Abrevaya, 2007).

The instructor's stimulation strategy utilizes academic motivation theory to persuade student in the learning process for a better learning outcome (Deci, Vallerand, Pelletier & Ryan, 1991; Guay, Morin, Litalien, Valois & Vallerand, 2015; Herath, 2016; Keller, 1987; Ryan & Deci, 2009). One motivation theory is ARCS model that proposes four elements including attention (A), relevance (R), confidence (C) and satisfaction (S) to design a motivation strategy for achieving better learning outcomes by students (Keller, 1987). The attention focuses on persuading students to put in effort in acquiring knowledge. The relevance makes students to realize that knowledge is a useful and valuable tool for their study and professional career. The confidence helps students to build self-assurance for completing learning tasks. The satisfaction stresses a desired learning outcome for students by finishing their course assignments.

The SDT includes autonomous motivation and controlled motivations (Deci, Vallerand, Pelletier & Ryan, 1991; Ryan & Deci, 2000). An autonomous motivation comprises intrinsic motivation and extrinsic motivations that give reward to students as a stimulation strategy for their learning accomplishment. A controlled motivation builds rules and guidance to put pressure and requirement on students for their achievement.

The instructor can establish a stimulation strategy based on ARCS model to motivate and inspire students for mastering course knowledge. The implementation of the stimulation strategy can utilize either an autonomous motivation or a controlled motivation as stated in SDT. The studying efforts and outcomes of students are according to their assessment value of a stimulation strategy. The instructor can identify an appropriate and effective stimulation strategy approach.

COURSE BACKGROUND

MIS 123 is a prerequisite requirement for students before declaring a major in CBA. There are two objectives of this course. First, it is to provide students with advanced microcomputer software knowledge and skills for helping their studying in other courses and/or facilitate their work in professional areas. Second, it is to initiate their lifelong self-learning ability. Course materials include Microsoft Office for its popularity usage in the business world and availability in the form of commercial online courseware. The course includes three one-unit, credit/no credit, and sequenced five-week long sub courses in a semester. Windows, Internet Explorer and Outlook are subjects for MIS 1. Comprehensive Excel is the only subject for MIS 2 due to its complexity and usefulness in the business field. Comprehensive Word and PowerPoint are two subjects for MIS 3. Results of a student survey regarding MIS 1 is the easiest and least useful one. MIS 2 is the hardest one but most valuable to find a job. MIS 3 is the most usefulness in other courses for writing papers and conducting presentations.

Only one instructor was responsible for administrating MIS 123. Each sub course's homepage had a detailed syllabus to provide students with information including learning objectives, contents, learning methodology, technical support, course materials, final exam (date, procedure and regulations), grading policy, office hours and communication with instructor.

There was no class meeting on campus. Same lessons and assignments were available (except final exam date) for students via an online courseware 24x7 during every semester. Students could take each lesson in three different learning methods at their own preferences. "E-text" word-by-word online lessons describe tasks, "watching video" online step by step demonstrations show tasks, and "hand-on practicing" step-by-step allows students to complete tasks. Each chapter had a comprehensive assignment for students to study and prepare for final exam. Students could view the correct assignment question answer after entering three wrong entries. Consequently, students could obtain a high assignment correction rate if they put in adequate studying time and effort.

Students took the same online final exam in an executing format that was scheduled from 8 a.m. to 4 p.m. Pacific Standard on the last Friday of the fifth week for each sub course. Exam parameters were 50 minutes, 1 attempt, 30 random sequenced questions, 30 attempts for each question and no makeup. Grading policy was at least 70 points for receiving one unit credit.

Students could take final exam at any remote location via their own computer facilities and Internet connection without supervision. To reduce misconducts, lessons and assignments were not available to students on the final exam date. Access to the courseware using the same student identification number via different computers at the same time was disabled. A study has revealed that there is no significant difference of average final exam score between a supervision and no supervision testing environments (Tsai; 2016).

STIMULATION STRATEGY IMPLEMENTATION

As suggested in the ARCS motivation model, an effective strategy ought to include tactics such as granting reward to persuade active participation, give learner control, and perceive present worth. In addition, two critical elements to increase passing rate and dropout rate are encouraging students to carefully studying lessons first, then correctly completing assignments on time. Accordingly, a stimulation strategy gives extra 20 points reward to students if they could achieve 90% correction rate for every assignment within five weeks of each sub course. This stimulation strategy might motivate students to improve their learning behavior and achievement for several reasons. First, students could view reward value as an incentive to study harder. Second, students had control to complete assignments for the reward. Third, students would assess reward as an attainable value and compliment to pass a sub course with 20 points less. Finally, students would be better prepared to pass their final exams.

Teacher-stimulated Approach

In the first semester, students in each sub course had five weeks to study lessons and drill assignments at their choices of learning method, time and place. There was no learning guidance from the instructor except syllabus and offering a reward motivation to students. Earning extra 20 points was an option for students if they can complete every assignment on or before the last Friday of fifth week of each sub course. Students could earn one unit credit if their sub course score (sum of final exam score and extra points) was 70 points or higher. The entire studying process solely depended on students to motivate, discipline, and commit to their

own education for achieving their own learning objectives. This was a teacher-stimulated online learning approach that offered a reward opportunity to students without any instructor's push as an implementation of autonomous motivation stated in the SDT.

Teacher-guided Approach

In the second semester, the syllabus of each sub course included two weekly lesson and assignment completion schedules defined by the instructor. The assignment correction rate (90% or higher) was 20% (20 points) of sub course grade. Students received a weekly announcement with an email that urged them to do their weekly lesson and assignment on Monday. Furthermore, instructor generated a correction rate report of assignment on every Thursday night. The report always showed that less than 25% of students would complete their assignment for every sub course. Based on the report, students without a 90% correction rate received a warning email that served as a reinforcement to complete assignment within the next three days. The second report generated on deadline (midnight of Sunday) that indicated 80% of students with 90% correction rate. Around 55% of students would put in their studying efforts during the last three days. This was a teacher-guided online learning approach that instructor employed rules and encouragements to push students completing their assignments for getting the reward. It was an implementation of controlled motivation stated in the SDT.

DATA ANALYSIS

The statistical analysis of collected data for these two stimulation implementation approaches reveals the degree of impacts on students' learning behavior (lesson completion rate and assignment correction rate), achievement (final exam score) and engagement (passing rate and dropout rate). It uses two tails hypothesis testing at 99% (2.58 Z value) and 95% (1.96 Z value) confidence levels for the analysis (Spurr & Bonini 1973). The independent variables are the reward stimulation approaches to detect changes in the three dependent variables including lesson completion rate, assignment correction rate, and final exam score. Last, a descriptive discussion addresses changes of learning engagement via passing rate and dropout rate.

Hypothesis 1: There is no statistical significant difference of student's online learning behavior measured by the average lesson completion rate between two approaches.

Table 1: Z-value of the Average Lesson Completion Rate between Two Approaches

Class Name	Teacher-stimulated			Teacher-pushed			Z-Value
	No. of Student	Average Completion Rate	Standard Deviation	No. of Student	Average Completion Rate	Standard Deviation	
MIS 1	420	89.37	28.99	390	89.33	28.78	-0.02
MIS 2	421	88.72	28.39	404	85.49	32.65	-1.51
MIS 3	394	89.46	20.76	362	88.22	30.49	-0.64

Outcomes: Accept the no difference hypothesis at both 99% and 95% confidence levels for every sub course as illustrated in Table 1.

Findings: The average lesson completion rates of every sub course are slightly higher under the teacher-stimulated approach. According to ARCS model, students will not put in extra efforts to complete lesson since their lesson assessment value is less than their time and efforts. The students' learning behavior measured by the average lesson completion rate stays the same

regardless the reward implementation approaches (either an autonomous motivation or a controlled motivation).

Hypothesis 2: There is no statistical significant difference of student's online learning behavior measured by average assignment correction rate between two approaches.

Outcomes: Reject the no difference hypothesis at both 99% and 95% confidence levels for every sub course as illustrated in Table 2.

Table 2: Z-value of the Average Assignment Correction Rate between Two Approaches

Class Name	Teacher-stimulated			Teacher-guided			Z-Value
	No. of Student	Average Correction Rate	Standard Deviation	No. of Student	Average Correction Rate	Standard Deviation	
MIS 1	420	73.06	36.83	390	83.88	30.05	4.59
MIS 2	421	39.72	41.07	404	78.89	31.96	15.32
MIS 3	394	40.78	41.36	362	76.31	34.68	12.83

Findings: It is interesting to note that average correction rates of every sub course are much higher under teacher-guided approach. Clearly, this is due to the assignment score is a part of the course grade and students either are willingly or forced to put in the extra efforts to correctly complete the assignment under teacher-guided approach. According to ARCS model, students will finish assignment since their assignment assessment value is worthwhile of their time and efforts. The students' learning behavior measured by the average assignment correction rate does change significantly under the teacher-guided approach (a controlled motivation).

Hypothesis 3: There is no statistical significant difference of the students' online learning outcome measured by the average final exam score between two approaches

Outcomes: Reject the no difference hypothesis at both 99% and 95% confidence levels for every sub course as illustrated in Table 3.

Table 3: Z-value of the Average Final Exam Score between Two Approaches

Class Name	Teacher-stimulated			Teacher-guided			Z-Value
	No. of Student	Average Score	Standard Deviation	No. of Student	Average Score	Standard Deviation	
MIS 1	420	77.66	16.24	390	80.23	7.86	2.90
MIS 2	421	62.76	23.84	404	67.29	22.83	2.79
MIS 3	394	69.60	20.06	362	73.96	18.82	3.08

Findings: Students in every MIS 123 sub course have achieved a higher average final exam score under teacher-guided approach. Obviously, these results closely related to its superior average assignment correction rate. Students have well prepared for the final exam by finishing the required assignment under teacher-guided approach. The students' learning achievement via average final exam score does show a significant improvement under teacher-guided approach (a controlled motivation).

Table 4 presents the statistical summary of the total number of enrollment, the total number of student taking the final, the total number of student passing the final, the final passing rate and

the drop rate for both approaches. The final passing rate is the total number of student receiving "credit" divided by the total number of student did take the final exam. The drop rate is the total number of student did not take the final exam divided by the total number of enrollment.

Clearly, there is a substantial higher final passing rate increased ranging from 24% to 10% among the three sub courses under teacher-guided approach comparing with teacher-stimulated approach. MIS 1 passing rate has a 10% increase from 78% to 89%. MIS 2 passing rate has a 22% increase from 54% to 76%. MIS 3 passing rate has a 20% increase from 63% to 83%. MIS 2 and 3 have generated 20% or higher increasing for the passing rate. These results indicate that students require more learning guidance for harder and useful subjects as MIS 2 and 3 under teacher-guided approach.

Table 4: Drop and Passing Rate of Two Approaches

	Student Enrollment	Student Took Final	Student Passing Final	Final Passing Rate	Drop Rate No Final
MIS 1. Operating Systems and Electronic Communication					
Teacher-stimulated	464	420	330	0.79	0.09
Teacher-guided	462	390	346	0.89	0.16
MIS 2. Spreadsheets					
Teacher-stimulated	503	421	229	0.54	0.16
Teacher-guided	495	404	309	0.76	0.18
MIS 3. Word Processing and Presentation Graphics					
Teacher-stimulated	488	394	250	0.63	0.19
Teacher-guided	491	362	299	0.83	0.26

However, the drop rate is higher under the teacher-guided approach. MIS 3 has the highest drop rate that 26%. In addition, the drop rate is higher toward the mid and end of the semester (MIS 2 and MIS 3). It is also interesting to note that the average drop rate of the three sub courses is around 20% that is corresponding to the overall 20% of students do not put in their time and effort to do the assignment for preparing their final exam. There are four factors related to this drop issue. First, students would drop if they could not meet the deadline of the weekly assignment requirements. Second, each MIS 123 sub course is a 1-unit independent "Credit" and "No Credit" course. Receiving a "No Credit" will not affect a student's grade point average (GPA). Third, a student will neglect the MIS 123 when there are more studying pressure from other courses between the 2nd five weeks of MIS 2 and the last five weeks of MIS 3. Last, a student will more likely to drop a sub course such as MIS 3 if it has two major subjects including Word and PowerPoint.

CONCLUSION

The students' online learning behavior measured by assignment correction rate, the achievement measured by the average final score, and final exam passing rate have sufficiently supported that teacher-guided approach (a controlled motivation) is a more effective and promising motivation approach comparing with teacher-stimulated approach (an autonomous motivation). These positive and fruitful results reveal a successful online learning approach required not only reward strategy for persuading students' learning engagement, but also an instructor's heavily involvements in the isolated, distance and virtual Internet learning environment as in the traditional face-to-face classroom. In general, the instructor's guidance,

encouragement, and motivation strategy do positively increase students' satisfaction and results a better online learning behavior and a higher achievement.

As online learning becomes an important part of higher education system in the current digital era, educators need to conduct further researches in order to refine the online learning experiences for students. It is a critical success factor for an instructor to design a sound stimulation strategy with proper implementation approach based on educational motivation theory under isolated online learning environment. Students can then perform well under the instructor's learning motivation, regulation and guidance. The future researches can extend to other areas. First, how to reduce the high student drop rate in the online learning. Second, how to virtually encourage and guide the student mastering and completing the course material when there is some studying pressure from other classes. Third, the most suitable course subject using the online teaching/learning. Last but not the least, the best student classification (freshman, sophomore, junior or senior) in the higher educational system to adopt the online learning.

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DECISION SCIENCES INSTITUTE
Importance of Course Relevance to Enhance Learning in Business Statistics

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ABSTRACT

Although the American Statistical Association's guidelines for instruction stress the importance of topic and application relevancy, the traditional business statistics course covers a broad spectrum of topics with applications across functional areas. This paper questions whether a discipline-specific focus would enhance learning by increasing the perceived relevance of course material.

KEYWORDS: Business Statistics, GAISE College Report, Learning

INTRODUCTION

Over the years, too many undergraduate students have found their core-required introductory business statistics class to be anxiety-producing, and this feeling detracts from proactive engagement and learning (Simmons, 2014). Therefore, if students can perceive the course to be more appealing, it will likely enhance motivation, proactive engagement, and opportunities for learning.

The recently updated Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report (Carver et al, 2016), sponsored by the American Statistical Association, once again stresses the pedagogical importance of topic and application relevancy. Not only must topics and applications be relevant, the student audience must perceive them as so. With respect to *how* to teach, the GAISE College Report's focus is on the use of real data with a context and purpose; this lends itself to classroom projects employing structured data sets that can be used to demonstrate the integration of topics covered throughout the course (Gould, 2010).

Current Practice

In schools of business, the content of the introductory statistics course is typically more general, covering topics and applications across all business disciplines. A literature review of available text titles reveals a near absence of discipline-specific offerings; the only undergraduate-level text that we find with a true single-discipline focus is one book in marketing (Mazzocchi, 2008). The question that needs to be addressed is whether the current, traditional delivery of the introductory course is best practice.

A Proposed Solution: Offering Dedicated Discipline-Specific Statistics Courses

Berenson et al. (2018) opine that offering discipline-specific introductory business statistics courses would increase motivation for learning because the course topics and applications would be in the area of career interest to that student audience. A course dedicated specifically to finance majors is thoroughly described, and the hypothesis is put forth that such students would have more motivation to study and come to class because they would feel the course is more important and more relevant to their future goals.

To test the hypothesis that dedicated course delivery will enhance learning in introductory business statistics, two studies were conducted simultaneously: one study assessed overall performance across chosen majors in finance and accounting-oriented sections of statistics, and one study evaluated overall performance across chosen majors in marketing-oriented sections. The remaining sections of this paper will describe the methodology used in the aforementioned studies, present preliminary findings, and outline the major analyses and their implications.

STUDY METHODOLOGY

One faculty member taught two sections of the introductory business statistics course with a focus on finance and accounting (F&A) topics and applications, while another faculty member did the same with a focus on marketing (MKT) topics and applications. The four sections, out of a total of 13 offered, were given in 75-minute sessions on Tuesdays and Thursdays.

All students were informed of the course foci in writing both prior to registration and during the first two weeks of the semester when students maintain the opportunity to enter or switch classes. It was strongly suggested that students with specific interest in the F&A and MKT disciplines enroll in one of the dedicated sections; however, it was made clear that if their schedules precluded such enrollment they could take any of the other nine sections that covered a broader set of applications across the business disciplines. Likewise, students who were undeclared or had specific interest in other disciplines were encouraged to enroll in a general section, but permitted to join one of the dedicated sections. In the four study sections combined, 31% of the students had discipline-specific course majors, 16% were undeclared, and 53% selected the section for their own convenience, having already chosen a major not aligned with their section's focus.

A waiver from the university Institutional Review Board was obtained for this joint study because there were no course interventions that would require subject consent. Historically, as long as overall course goals are met in core-required courses with multiple sections, instructors have liberty to design and conduct their specific courses as they deem pedagogically fit; moreover, it was made clear in advance to all students that the intent was to focus on discipline-specific topics and applications in the four study sections. Additionally, the key topic coverages of fundamental numeracy, descriptive statistical methods, inferential statistical methods, and an introduction to regression analysis that are common to all one-semester undergraduate business statistics courses were to be maintained in the discipline-specific sections.

As shown in the Appendix, the distinctions between the discipline-specific course sections and the more general course sections were primarily in the topics selected, the depth and breadth given to each, and the applications taught using methods best suited for those applications. The

MKT courses were concept- and definition-oriented with limited algebraic formulas and mathematical symbols. The F&A courses, taught at a higher expectation of numeracy, placed more emphasis on formulas and symbols. Both types of courses were heavily dependent on analysis and interpretation of results through computer printout, and both had projects requiring written and oral presentation.

Development

What are the factors that determine success in a statistics course? Johnson and Kuennen's (2006) research indicates that very basic mathematics skills are among the most important indicators of student success, even in a statistics course where many of the skills directly assessed (such as analyzing data with descriptive statistics, hypothesis testing, or linear regression) are not necessarily of a basic skills nature. On the other hand, they found that neither taking calculus nor the ACT Math score (measuring higher mathematics skills such as algebra, geometry, and trigonometry) had a significant effect on course performance. This was true across different teaching methodologies and course structures, regardless of the level of mathematics presented or the relative emphasis on computation versus interpretation. Their findings are consistent with Ben-Zvi and Garfield's (2004) research which revealed that difficulties with underlying math concepts interfered with a student's ability to grasp statistical concepts.

Given the importance of basic math skills in learning statistics, and the fact that these skills vary across students, a 25-question mathematics assessment quiz (MAQ) reviewing topics first learned in fourth through ninth grades was administered in the four class sections at the beginning of the semester to evaluate students' current understanding of prerequisite material for the courses. If appropriate, the plan was to use these scores as a covariate when assessing differences in student performance by selected major at the end of the semester. Students were unaware that the MAQ was going to be administered, precluding the possibility of any intentional refreshment of mathematical skills prior to the assessment.

The MAQ sheets were graded on a scale from 0 to 25 that corresponded to number of correct answers and then returned to the students with an aligned list of Khan Academy videos that would help them refresh on questions they missed.

The Data

The obtained dataset was based on information collected from 52 students enrolled in two finance and accounting-oriented course sections (28 in Section 02, 24 in Section 06) and 62 students enrolled in two marketing-oriented course sections (33 in Section 04 and 29 in Section 16).

Aside from collecting the MAQ results as well as information on what major the students had selected (i.e., course discipline-specific, other major, or undeclared), the only other data that were recorded for the purpose of this research were the midterm and final exam scores, which were given equal weight in the overall course average.

The Outcome Measure for the Study

Assessment of learning is based on course performance, and the outcome measure TAvg is selected as the most appropriate proxy for course grade. TAvg is the standardized average of

two equally weighted course assessments, a midterm and final exam, given in each section of the two study groups – the finance and accounting-oriented courses and the marketing-oriented courses. Since the two types of courses had very different topic emphasis there was no reason to directly compare overall course performance between the two study groups and the use of the overall standardized (*Z*) scores over the combined sections within each study group provides a monotonic transformation, preserving the rank ordering of students' performance.

The Intended Analyses

Aside from an analysis of covariance (ANCOVA), a set of orthogonal contrasts was initially planned so that the primary overall comparison could be made between the performances of those students who had selected the major corresponding to the course orientation versus the other majors combined. The secondary comparison would be between the performance of students majoring in the "opposite" course orientation against those who have chosen other majors along with students who were undeclared. The final, but nevertheless important comparison in this orthogonal set, would be to assess whether there were significant differences in student performance between those who had declared "other" majors versus those who were undeclared. This latter comparison was of particular importance to the university administration who have opined that students who are able to select a major demonstrate more incentive toward their studies and outperform their peers who remain undeclared.

If the research hypothesis holds, the respective end-of-semester ANCOVA along with the aforementioned set of planned orthogonal contrasts and some additional non-orthogonal comparisons (Dunnett, 1955) should indicate that those students with selected majors aligned to the course orientation will outperform those who are undeclared or those who have selected other disciplines as their major. Such separate findings could then be synthesized and strengthened through a meta-analysis (e.g., Stoufer et al., 1949; Rosenthal, 1991; Shadish & Haddock, 2009).

In addition to this, one of the planned orthogonal contrasts should also be able to confirm or refute the administration's claim that undeclared students are significantly weakest with respect to overall course performance.

EXPLORATION AND DISCOVERY: PRELIMINARY RESULTS

Descriptive Summary Statistics for Outcome Variable TAvg

Table 1 displays key summary statistics for the outcome variable TAvg for each chosen major category based on course orientation.

Table 1: Summary of TAvg Descriptive Statistics by Chosen Major and Course Orientation

Marketing-Oriented Courses:

Major	*n*	Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Skewness
F&A	12	0.173	1.117	-2.043	-0.520	0.424	0.904	1.657	-0.73
MKT	13	0.530	0.696	-0.701	-0.102	0.532	1.095	1.585	-0.06
OTH	29	-0.057	0.931	-2.152	-0.755	-0.048	0.750	1.548	-0.28
UND	8	-0.914	0.959	-2.551	-1.771	-0.755	-0.075	0.170	-0.72

Finance and Accounting-Oriented Courses:

Major	*n*	Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Skewness
F&A	22	0.473	0.852	-1.905	-0.135	0.683	0.984	1.810	-1.11
MKT	7	0.349	0.993	-0.667	-0.540	0.000	1.143	1.842	0.47
OTH	13	-0.357	0.962	-2.032	-0.826	-0.286	0.460	1.207	-0.39
UND	10	-0.822	0.710	-1.746	-1.326	-0.984	-0.365	0.635	0.77

Student Persistence

Student persistence is defined as the percentage of enrollees who complete the midterm and final exam. The two marketing-oriented course sections respectively began and ended with 33 and 29 students, a 100% persistence rate. On the other hand, the two finance and accounting-oriented course sections began with 34 and 31 students, respectively, and ended with 28 and 24 students, a persistence rate of 80%.

The observed significant difference in the persistence rates may be attributable to a number of factors. With respect to the finance and accounting-oriented sections, one student could not complete the course because of a family emergency. Among the remaining 12 students who did not finish the course, four (33.3%) withdrew in the first four weeks and eight (66.7%) did so immediately after learning their midterm test results. Possible reasons for these withdrawals include a realization of limited mathematical preparation for a more rigorously-conducted course, a realization that finance or accounting was not going to be a career objective, or a desire to change into a more generally-oriented course section.

Table 2 provides key MAQ summary statistics for this group and it should be noted that the mean MAQ score of 11.77 is only 73 percent as high as the MAQ score of 16.12 obtained by the 52 F&A students who completed the courses.

Table 2: Key MAQ Descriptive Statistics for Students Not Finishing the F&A Courses

n	Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Skewness
13	11.77	4.83	4.00	7.00	13.00	14.00	20.00	0.03

Other factors that may have affected the persistence rates could be teacher likeability and course interest. Perception is key here. If a student feels more comfortable relating to a particular instructor there should be less likelihood for course withdrawal. Additionally, if a student feels a particular course format is more interesting and relevant there should be less likelihood for course withdrawal. With respect to the latter, students taking a marketing-oriented business statistics course may more readily relate to topics pertaining to advertising, retailing, and consumer behavior, regardless of whether they have chosen marketing as their major. On the other hand, non-major students taking a finance and accounting-oriented course may not feel the same kind of connection with the course. Even those who have declared finance or accounting as their chosen major usually have limited-to-no background in these business disciplines when they enroll in the statistics course, typically in their freshman or lower sophomore semesters.

The Class Section Breakdowns

The four classifications of major used here are F&A (finance and accounting), MKT (marketing), OTH ("other" major), and UND (undeclared). Using the chi-square test for independence, there was no indication of a significant enrollment pattern by chosen major across the four class sections ($\chi^2 = 12.890;$ *p*-value = 0.168.). Moreover, within each course orientation there was no evidence of a difference in student major based on the section they enrolled in (for F&A: $\chi^2 = 2.083;$ *p*-value = 0.555; for MKT: $\chi^2 = 0.632;$ *p*-value = 0.889.). However, when collapsing class sections based on course orientation, there is evidence of a significant difference in student major by course orientation and this is what was intended and expected ($\chi^2 = 10.260;$ *p*-value = 0.016).

Justification for Combining the Sections

The following summaries in Table 3 provide justification for combining the two marketing-oriented sections and the two finance and accounting-oriented sections.

Table 3: Summary of Key Descriptive and Inferential Comparisons Between Class Sections

Marketing-Oriented Sections:

Variable	Section	*n*	Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Skewness
MAQ	S04	33	16.545	4.273	9.000	12.500	17.000	20.000	24.000	-0.15
	S16	29	15.340	5.540	6.000	10.000	16.000	20.000	24.000	0.09
TAvg	S04	33	-0.206	1.045	-2.551	-0.683	-0.048	0.514	1.585	-0.49
	S16	29	0.235	0.907	-1.463	-0.356	0.351	0.913	1.657	-0.31

Comparisons in MKT Sections	**Separate-Variance *t* Test**	***p*-Value**
MAQ Means in S04 vs S16	*t* = 0.95	0.349
TAvg Means in S04 vs S16	*t* = -1.78	0.080

Finance and Accounting-Oriented Sections:

Variable	Section	*n*	Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Skewness
MAQ	S02	28	16.214	3.823	8.000	14.250	17.000	19.000	25.000	-0.31
	S06	24	16.000	3.683	7.000	14.250	16.000	18.000	22.000	-0.61
TAvg	S02	28	-0.218	1.062	-2.032	-0.905	-0.222	0.841	1.842	0.01
	S06	24	0.254	0.877	-1.746	-0.405	0.540	0.889	1.810	-0.38

Comparisons in F&A Sections	**Separate-*Variance* *t* Test**	***p*-Value**
MAQ Means in S02 vs S06	*t* = 0.21	0.838
TAvg Means in S02 vs S06	*t* = -1.75	0.088

With respect to both the marketing-oriented courses and the finance and accounting-oriented courses, there is no evidence of a difference in mean MAQ performance in between sections with the same focus. Although there is some tendency toward better TAvg performance in the sections meeting later in the day (S06 and S16) compared to those meeting earlier in the day (S02 and S04), the difference in results is not significant and there is no reason to expect a

systematic difference since both sections within each discipline-focus were taught the same way. Therefore, it is reasonable to combine the two MKT sections together and the two F&A sections together for the main analysis.

Evaluating the Mathematics Assessment Quiz (MAQ) Score as a Potential Covariate

The MAQ, given in each class section by surprise early in the semester, provided a baseline measurement of student fundamental mathematical ability and was deemed a possible covariate. Table 4 summarizes the evaluation of the MAQ scores as a potential covariate. In the marketing-oriented course sections the MAQ scores were clearly significantly correlated with TAvg, the performance measure used in all analyses, while in the finance and accounting-oriented course sections a weaker positive association was indicated. Not shown here, both stem-and-leaf displays indicated a central clustering of MAQ scores with little-to-no skewness and the respective study groups (i.e., 52 and 62 students) are of sufficient size to discount the importance of the normality assumption in statistical inference. Moreover, when comparing the MAQ scores across the four chosen majors in each of the two study groups (i.e., F&A and MKT), there was no indication of a significant lack of homogeneity of variance and a one-way ANOVA *F* test showed no evidence of a significant difference in MAQ scores. Therefore, we concluded that the MAQ was a good covariate so that ANCOVA was the appropriate tool for ascertaining whether differences in overall performance across the chosen majors could be uncovered in each study group.

Table 4: Evaluation of MAQ as a Potential Covariate

	Finance & Accounting Sections	Marketing Sections
Assessing Correlation with TAvg		
Pearson	r = +0.228; p-value = 0.104	r = +0.387; p-value = 0.002
Spearman	ρ = +0.256; p-value = 0.067	ρ = +0.426; p-value = 0.001
Assessing Normality		
Anderson-Darling Test	AD = 0.978; p-value = 0.013	AD = 0.700; p-value = 0.064
Assessing Homoscedasticity		
Bartlett's Test	B = 5.66; p-value = 0.130	B = 4.52; p-value = 0.211
Levene's Test	L = 1.34; p-value = 0.272	L = 2.63; p-value = 0.058
Assessing Differences in Means		
ANOVA *F* Test	F = 0.10; p-value = 0.959	F = 0.34; p-value = 0.793

Since there was no evidence of a difference in entering student mathematical ability across the four categories of chosen major in these study groups, we may surmise that any difference in mean TAvg course performance among the four major categories using one-way ANCOVA in the separate group studies would likely be due to the influence of interest in the selected course orientation as a driver of increased motivation to succeed.

THE MAJOR ANALYSES AND IMPLICATIONS

The research hypothesis of interest is that there should be more learning by students who enter a class with specific subject interest because the course should be of more relevance and importance to them.

To test this hypothesis, two ANCOVA models will be developed along with their respective sets of adjusted means. Next, a description of the developed set of orthogonal contrasts, key to the analysis of the research hypothesis, will be provided along with a description of the developed

set of non-orthogonal *a priori* pairwise comparisons. Lastly, a description of the meta-analysis methods used for combining the results of the two separate studies will be presented.
If the findings from the two correlational studies support the hypothesis that introductory business statistics taught with a conceptualized and discipline-specific approach demonstrates more learning when compared to the more traditional, generalized approach, then the results would have several implications for improving business statistics instruction. First, discipline-specific course offerings would need to be developed to replace the current, more general course offerings. Second, textbook authors would need to develop shorter, discipline-specific texts that focus on the relevant topics, applications, and problems for each functional area of business.

Moreover, if the research hypothesis holds and teaching within specific course disciplines is good for teaching introductory business statistics, it would seem to follow that it will also be the appropriate way to teach introductory business analytics. Students should find it more relevant and interesting to explore, search, drill down, and use interactive databases when the subject matter is in their field of selected interest. Fortunately, the recent AACSB Standard 9 mandate (2017) to integrate analytics in the undergraduate curriculum provides much flexibility, enabling accredited business school programs to design courses and make curriculum changes while maintaining their particular education missions.

Scope and Limitations

As in much educational and social science research, randomized experiments for undertakings such as the one described here for F&A and MKT major groups cannot be developed because students self-select their majors and there is no randomizing process for the researcher to control. Therefore, correlational studies must be employed (Sheskin, 2011). In lieu of an experimental treatment variable, the chosen major is a classification variable (Keppel, 1982) and it is possible that the students within specific majors may differ systematically with respect to characteristics other than the classification variable major. Such potential confounding precludes cause-and-effect inferences permitted in true experimental studies. Nevertheless, and although the results of such correlational studies pertain specifically to the groups involved, the implications of the findings can be strongly suggested for similar educational contexts.

APPENDIX: TOPIC OUTLINES FOR DEDICATED COURSES FOR FINANCE & ACCOUNTING MAJORS AND FOR MARKETING MAJORS

Introductory Statistics for Finance & Accounting Majors

Topics

- Review of fundamental mathematics for finance and accounting majors.
- Data visualization through tables and charts with finance applications.
- Numerical descriptive measures in finance (including Sharpe and Treynor ratios).
- Introduction to index numbers with emphasis on the CPI-U and S&P500 Index.
- Probability and mathematical expectation with finance applications.
- Introduction to decision-making with applications in investing.
- Introduction to confidence interval estimation and hypothesis testing with finance applications.
- Simple linear regression (including CAPM with beta and alpha coefficients).
- Time series decomposition and forecasting.

Introductory Statistics for Marketing Majors

Topics

- Review of fundamental mathematics for marketing majors.
- Questionnaire design and sampling techniques.
- Data visualization through tables and charts with marketing applications in Pivot Table drilldowns.
- Introduction to probability with marketing applications in cross-classification tables.
- Numerical descriptive measures in marketing.
- Normal distribution and sampling distributions of $\bar{X}$ and P.
- Confidence interval estimation with marketing applications.
- Hypothesis testing (one-sample, two-samples, and multiple-samples) with marketing applications.
- Simple linear regression (descriptive and inferential) with marketing applications.

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A taxonomy of digitalization: an in depth understanding of the phenomenon

ABSTRACT

Digitalization is gaining importance in the business world yet the literature on digitalization lacks two major aspects. First, in providing a comprehensive vision on digital transformation of firms and second, in having empirical studies which could aid the advancement of the field. This study attempts to create a taxonomy of digitalization as an operations strategy based on three classification variables i.e. drivers, providers and capabilities of digitalization. The classification variables are populated through literature review and cluster analysis will be conducted to form strategic clusters of firms based on which set of drivers, providers and capabilities form a digital strategy.

Keywords: Digitalization, Taxonomy, Digital Transformation

INTRODUCTION

Configuration studies are an important tool for understanding the different phenomenon of management. These taxonomies are especially useful for exploration purposes where the aim is to gather a holistic understanding of the phenomenon. The purpose of this paper is to come up with a taxonomy of digitalization which is an emerging phenomenon and requires considerable attention in terms of research. For the purpose of theory development in this area it is necessary to have an in depth understanding of the different factors at play which are effecting the firms performance. Taxonomies serve as an appropriate mechanism which aid in exploration of the phenomenon, theory building and in identifying the different dimensions and their constituent factors which explain digitalization.

We treat digitalization as an operations strategy where firms make efforts to shift their operations to a digital state. Operations strategy is defined as “the building or positioning of resources in a way which enhance the competitiveness of a firm in the marketplace”(Southard and Swenseth, 2003). Digitalization as an operations strategy will guide firms as to what set of environmental drivers and practices will lead to certain capabilities of digitalization. The operations strategy has two important components namely “content” and “process”. Most of the manufacturing strategy studies focus on the content part which constitutes the choices and actions a company takes to achieve its goals. The literature on digitalization has not paid much attention to the topic of its realization in firms and neither has identified the different tasks which enable digitalization.

Digitalization itself is not a new phenomenon and the word “digitalization” has been extensively used in previous studies. However, the emergence of the fourth industrial revolution also called industry 4.0 has given it a new connotation yet the extant literature is not clear with respect to the definitions of these terms. This study creates a taxonomy for digitalization which is the broader phenomenon and is defined as “the integration of digital technologies to transform activities, processes, actors, and goods from analogue to digital to facilitate new forms of value creation” (Hagberg et al., 2016).

Classification Variables

The literature on digitalization is widespread and has been used in various ways. This study makes use of digitalization as an operations strategy and aims to identify the set of practices which enable the implantation of digitalization in firms and also what are the value additions due to this digitalization. We choose three classification variables based on previous studies which were populated with different constituent factors through a literature review of the relevant domain. These classification variables are the drivers, providers and capabilities of digitalization (Ketchen Jr and Shook, 1996). Drivers are the set of external and internal factors which force a firm to transit from their current traditional state to a digitalized one. These drivers include the volatility of demand, the uncertainty of the market place, the intensity of competition in the industry, technological dynamism, intense rivalry and many more (Gunasekaran et al., 2018, Buer et al., 2018, Ooi et al., 2018). The providers are the internal practices and resources which need to be developed and modified so as to support the goal of digitalization. These include organization factors, individual factors, technological factors, knowledge related factors, integration, collaboration, supply chain dynamics, data analytics and IT proficiency (Bokrantz et al., 2017, Battaïa et al., 2018). The capabilities are the outcomes of digitalization which enable the firm to sustain a competitive advantage such as mass customization, responsiveness, intelligent decision making, agility, flexibility, efficiency and servitization (Cenamor et al., 2017, Hermann et al., 2016, Arnold et al., 2016, Rüßmann et al., 2015).

Methodology

Digitalization is a new phenomenon and hence as a first step a literature review was conducted to explore the factors which would fall under the drivers, providers and capabilities. The classification variables were populated using inductive approach due to the exploratory nature of the study. A total of 33 journals with 4*, 4 and 3 ratings in the ABS list 2015 were selected for literature review. These journals belonged to the two categories of Operations & Technology Management and Information Management. Scholarly Peer reviewed articles published in the time frame 2010 – 2018 in English language were selected as a first steps. Articles were searched with the keywords Digitalization, industry 4.0, cyber physical systems and Industrial Internet. The selection of these keywords was based on their frequent usage in articles published in the nascent domain of digitalization. A total of 2409 articles appeared in these searches from which only those were selected which talked about digitalization in the connotation of the fourth industrial revolution. Articles which appeared due to the mere existence of the words “digital” and “digitalization” but not relevant to the specific domain and those which were duplicates were excluded in the first iteration. This resulted in remaining 121 articles which were skimmed for the identification of drivers, providers and capabilities. After the third iteration of a total of 32 usable articles were skimmed to extract content for the classification variables. The content was then clubbed into dimension based on their similarity. The content of the clusters will be operationalized using exiting literature.

Data will be collected from manufacturing and non-manufacturing firms, telecom, software houses and service sector. Cluster analysis will be conducted and strategic clusters of the firms will be made.

Appendix A

Operations & Technology Management	Information Management
Journal of Operations Management	*Information Systems Research*
Production & Operations Management	*MIS Quarterly*
International Journal of Production Research	*Journal of Management Information Systems*
Supply Chain Management: An International journal	*Journal of the Association of Information Systems*
Journal of Supply Chain Management	*Computers in Human Behaviour*
International Journal of Production Economics	*Decision Support Systems*
Computers in Industry	*European journal of Information Systems*
IEEE Transactions on Engineering Management	*Expert Systems with Applications*
International Journal of Operations & Production Management	*Government Information Quarterly*
Production Planning & Control	*Information & Management*
Journal of scheduling	*Information & Organization*
Manufacturing & Service Operations Management	*Information Society*
	Information Systems Frontier
	Information Systems Journal
	Information technology & People
	International Journal of Electronic Commerce
	International journal of Human Computer Studies
	Journal of Computer Mediated Communication
	Journal of Information Technology
	Journal of Strategic Information Systems
	Journal of the American Society for Information Science and Technology

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Innovate or merge?
The role of corporate social responsibility in the relationship between R&D and mergers and acquisitions

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ABSTRACT

In this research, we study how recent developments in corporate social responsibility (CSR) impacts the relationship between R&D investment and mergers and acquisitions (M&A). We find that CSR scores positively moderate the relationship. For firms with high CSR scores, higher R&D investment intensity is associated with a higher likelihood of M&A, but for firms with sufficiently low CSR scores, higher R&D intensity is associated with a lower likelihood of M&A. This finding suggests that CSR may create an insurance-like buffer that mitigates risks, and may improve knowledge sharing and absorption capabilities that ease the integration process during M&A.

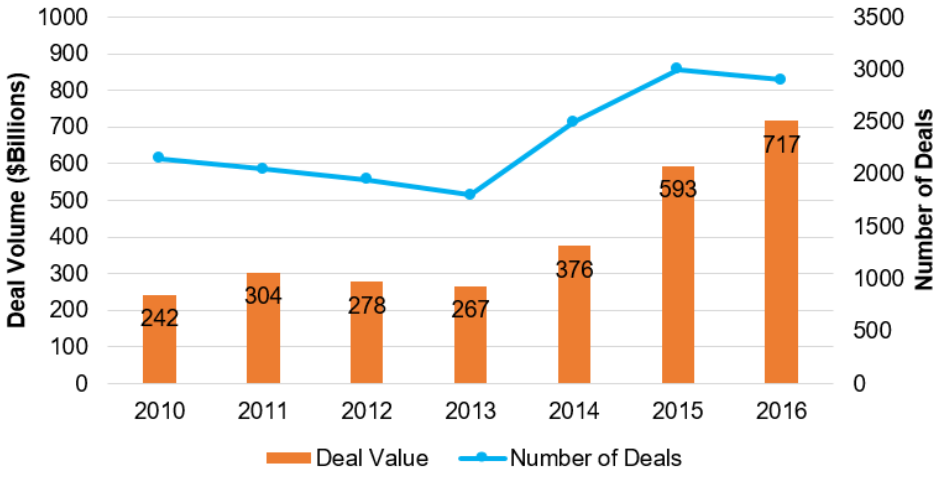
KEYWORDS: innovation, R&D investment, merger and acquisition, corporate social responsibility, emerging markets

1. INTRODUCTION

Innovation is critical to the firms' survival and long-term success in the markets. The mantra, "Innovate or Die", has been echoed across industries from traditional consumer packaged goods (CPG) to high-tech products (Caldbeck, 2016). Innovation can be obtained internally by investing in research and development (R&D), externally by merger and acquisition (M&A), or both. The past years have seen a significant increase in M&As driven by technological innovations (See Figure 1), and about 20% of M&A deals from 2015 to 2016 involved high-tech targets, whereas, in 2012, it was 14% (BCG M&A Report, 2017). A firm can replace its R&D investment by acquiring an innovative firm, or alternatively, leverage its R&D to enhance its market position by acquiring a firm for market access. A fundamental question, however, is whether M&A can be employed as a substitute to replace R&D or used as a complement to enhance its market access (Cassiman & Veugelers, 2006). The answer hinges on firms'

capabilities to manage risks in post M&A knowledge sharing and integration. Recent developments in corporate social responsibility (CSR) have shown CSR provides an insurance-like mechanism for firms to mitigate internal and external risks (Godfrey et al., 2009; Jacobs et al., 2016), and therefore may have significant implications to the relationship between R&D investment and M&A. This research contributes to the literature by focusing on the role of CSR in the relationship between R&D investment and M&A.

Figure 1. Tech M&A Value and Volume



The literature and evidence of “innovate or merge” is mixed. Some argue for a substitutable effect, where firms that underinvest in R&D are more likely to choose to “replace” internal R&D with M&A, indicating a negative relationship between R&D investment and M&A (Phillips & Zhdanov, 2012; Seru, 2014). For example, General Motors (GM) acquired Cruise Automation, a developer of autonomous vehicle technology, in 2016, which allowed GM to quickly access self-driving technology without its own R&D investment. Others, however, argue for a complementary effect, where R&D-intensive firms are more likely to engage in M&A because they can leverage their strong knowledge base to expand to new markets post M&A, indicating a positive relationship between R&D investment and M&A (Bena & Li, 2014; Entezarkheir & Moshiri, 2017, Cassiman & Veugelers, 2006). Tesla acquired SolarCity, a solar energy and panel provider, to leverage Tesla’s technology assets and create a vertically integrated energy company. Regardless of the types, innovation-driven M&As are risky. Fail to manage the risks associated with lack of integration of knowledge and capabilities, loss of autonomy, incompatibility of brand images, or cultural clash between the acquirer and the target company, may cause disruptions on existing organizational routines and structures after M&A (Ahuja & Katila, 2001; Puranam & Srikanth, 2007). “Nortel went on frequent buying sprees, often using its own stock to take over tiny companies with promising technologies. In 2000 alone, it bought 11 companies for a total of $19.7 billion” (CBC News, September 16, 2009). These aggressive innovation-driven M&A activities eventually wiped out shareholders’ wealth and led to the downfall of Nortel (FinancialPost 2014). Moreover, the risk exposure during M&A for firms with extensive investment in R&D may be higher than the risks for those that underinvest in R&D. This is because the potential negative impact of failures of M&A is likely higher for firms with established technological assets and reputation (Cassiman & Veugelers, 2006). Leveraging such high value assets and technical knowhow is challenging, and potential damages to reputation in the case of failure can be substantial and long lasting. While this

seems to suggest that the replacement effect of M&As applies to firms of low R&D intensity, it has been argued that high R&D intensity firms may also leverage better-developed technological infrastructure to ease risks involved in integrating new technologies and new organizations under M&A (Bauer & Matzler, 2014). Therefore, the literature is not settled with whether M&A is a replacement of R&D, and the answer seems to hinge largely on the firm's risk exposure and impact, and the absorptive capabilities to manage and mitigate the risks, in M&A integration (MacCormack & Mishra, 2015; Cohen & Levinthal, 1990; Hitt et al., 2009).

Effectively managing risks depends on a firm's ability to absorb internal and external knowledge, to promote learning, and to facilitate integration during the process (Hitt et al., 2009), which is what CSR programs are set out to accomplish. CSR programs are designed to achieve sustainable growth and value creation for both their stakeholders and society (Sodhi, 2015), by enhancing corporate governance that facilitates sharing of information and knowledge, and integration of organizations, and by mitigating internal and external risks. This design purpose positions CSR perfectly as a potential facilitator for M&A integration and a buffer for its risk exposures. The extant literature has focused on the role of firms' investments in R&D in their M&A decisions, but mostly overlooked the potential effect of CSR, which is the focus of this research.

The connection between CSR, R&D, and M&A can often be observed in real business cases. In 2012, Microsoft acquired Yammer, StorSimple, and MarketingPilot, to advance its market position in social networks and cloud-based storage and marketing (Price 2012). More recently, Qualcomm acquired NXP Semiconductors in a record $47 billion deal. The objective is to quickly develop and improve chips and sensors for drones, self-driving cars, mobile payment and other devices. Interestingly, both Microsoft and Qualcomm have been active leaders in CSR. Qualcomm's ten-year-old program Qualcomm Wireless Reach "brings advanced wireless technologies to underserved communities globally, improving lives with programs that strengthen economic and social development" (www.qualcomm.com/company/wireless-reach). In fact, many firms with high investments in R&D have embraced CSR at an early stage, and they are often involved in M&A rumors and deals (Hopkins, 2009).

Evidence and literature both indicate that these two roles of CSR as a facilitator and a buffer have their roots in various aspects of CSR programs. First, firms with effective CSR programs tend to be better at sharing and absorbing information and knowledge with stakeholders, which helps develop strong and long-term relationships with stakeholders (Luo & Du, 2012). The improved relationships with stakeholders promote mutual trust and lend an insurance-like benefit to firms under high uncertainty. In recent surveys conducted by PwC, for example, CEOs indicate their plans to increase their firms' engagement in CSR activities to restore stakeholder trust during a crisis (PwC 2013; 2014). Furthermore, by better aligning corporate governance and promoting social value and diversity, CSR fosters creativity, broadens absorptive capacity, and facilitates knowledge spillover across organizations, which can help R&D intensive firms hedge high risks in M&A (Hoisl, Gruber and Conti 2017; Porter & Kramer, 2006). CSR also creates goodwill among stakeholders, partners, and customers, which may reduce external risks in case of failure (Deng et al., 2013). Second, CSR can enhance internal adaptability and social inclusiveness, which facilitates the integration process post M&A. For instance, CSR contributes to "improved risk management, reputation, employee engagement or customer loyalty", as a part of a firm's M&A due diligence process (p.7, PwC Principle for Responsible Investment Report, 2012). In the M&A case of Tech Data Corp and Avnet, Tech Data set up internal improvement and communication tools for employee knowledge sharing with Avnet, which eased the integration process. This case was made possible by the firms' "common cultures, shared values, and commitment", which are core components of CSR (Thomson Reuters Corporate Responsibility Ratings). Hence, by promoting

social value and strengthening stakeholder relationships, easing the integration process and reducing barriers between organizations, CSR programs create much-needed support to mitigate the risks during and post M&A (Kramer, 2011; Porter & Kramer, 2006; Lins et al., 2017).

The existing literature on R&D and M&A offers mixed views on the relationship between R&D investment and M&A, without involving the important role of CSR. To further examine this complex relationship and the much-overlooked effect of CSR, this research addresses the following research questions: *Is M&A a substitute for a firm's internal R&D or is it a complement? And more importantly, how does CSR moderate the relationship between R&D investment and M&A?*

To answer these questions, we collect firm-level data from multiple data sources and construct econometric models to connect a firm's R&D intensity to its acquisition decision. To examine the role of CSR, we include CSR scores of acquiring firms and focus on CSR's moderating role in the relationship between R&D and M&A. We apply conditional logit models to analyze firms' R&D investment intensity, CSR scores, and M&A likelihood. Our main results show that R&D intensity can be positively or negatively associated with M&A, suggesting that M&A can be both complementary and substitutable to R&D investment. One key factor in separating the two effects is CSR. We find that CSR scores positively moderate the relationship between R&D and M&A. This is because CSR creates an insurance-like buffer that mitigates risks by improving knowledge sharing and absorbing capabilities that ease the integration process during M&A. For firms with low CSR scores, less R&D intensive firms employ M&A to "replace", or to substitute, R&D. For firms with sufficiently high CSR scores, R&D intensity is positively associated with M&A, which implies a complementary relationship between R&D and M&A. We further extend our research to M&A cases involving target firms in emerging markets, which are challenging for U.S. firms because of the economic, technological and social gaps between the two markets. While CSR programs encourage open communications and embrace different corporate structures and cultures, the lack of regulations and laws for intellectual property protection in emerging markets hinders the possibilities of leveraging innovative capabilities by U.S. firms. Our results support this argument and suggest that the moderating role of CSR is still positive but is weaker when target firms are in emerging markets. In addition to studying R&D intensity as a R&D input, we also examine a R&D output and the corresponding effect of CSR. We find that regardless of CSR, a more efficient firm in R&D is more likely to engage in M&A. This finding is different from our main results based on R&D intensity, an input for R&D, where M&A can be a "replacement" for R&D for low CSR firms but is consistent with our results for sufficiently high CSR.

We contribute to the emerging stream of research in the operations management literature that studies the effect of CSR on firm strategy. Previous research has focused on the impact of CSR on organizational risk (Servaes & Tamayo, 2013; Jacobs et al., 2016), supply chain risk (Jira & Toffel, 2013; Porteous et al., 2015; Giannakis & Papadopoulos, 2016; Jacobs & Subramanian, 2011; Letizia & Hendrikse, 2016), and operational and cost efficiency (Gui et al., 2015; Alev et al., 2015; Alev et al., 2016; Jacobs et al., 2016). Our contributions extend the existing literature by investigating the role of CSR in the relationship between R&D and M&A, and by focusing on CSR's facilitating effect of knowledge sharing and its mitigating effect of risks in M&A decisions. Lee & Tang (2017) call for research on socially responsible value chain innovations. As R&D investments facilitate value chain innovations and M&As create value chain wide changes, this research, with a focus on CSR, answers the call at a strategic level of firm decisions.

The rest of paper is organized as follows. We first review the literature drawn from operations management, finance, and strategic management that is related to M&A, innovation,

and CSR. We then discuss our data and variables. In the subsequent section, we present our main econometric models, followed by discussions of the main results. We also discuss some robustness tests and extensions, and we conclude with managerial implications and final remarks.

2. LITERATURE REVIEW

Existing literature on M&A has mostly focused on operating synergies and performance implications in post M&A, particularly the mechanisms through which firms can succeed in post-integration period, and its impact on pricing, inventory pooling, and cost efficiency (Ahuja & Katila, 2001; Cho & Wang, 2016; Hitt et al., 1991; King et al., 2008; Zhao, 2009). Less understood are the complex factors driving a firm's adoption of M&A. Among the typical drivers of M&A, such as increasing market share, diversifying businesses, and acquiring complementary resources, capability, and knowledge, innovation is one that is critical to a firm's long-term success. Previous studies have examined the association between a firm's innovation and M&A, with mixed findings as either replacement (Zhao, 2009; Phillips & Zhdanov, 2012) or complementarity (Bena & Li, 2014; Entezarkheir & Moshiri, 2017). It is hence unclear whether a firm's innovation will encourage or discourage a firm's decision-making with regard to M&A. The highly-limited M&A research in the operations literature has focused on the impacts on inventory pooling as a result from economies of scale, and subsequent cost savings and pricing effects (Cho & Wang, 2016; Cho, 2014), without involving innovation in M&A decisions.

Corporate social responsibility can play an important role in M&A, but a firm may have mixed feelings towards it. CSR reflects the extent to which a firm actively engages in environmental, social, and economic initiatives in response to a diverse set of stakeholder interests (McWilliams & Siegel, 2001). Many firms engage in CSR activities in the hope to build a reservoir of goodwill to attenuate negative reactions from stakeholders in different situations, one of which is M&A (Deng et al., 2013). However, firms that focus on CSR also try to attend to all stakeholders in strategic decisions and thus may be unwilling to merge or acquire other firms. This is because mergers and acquisitions are likely to unsettle key stakeholders in a firm, damaging a firm's CSR commitment and thus stakeholder support (Morgan, 2009). In spite of the growing importance of CSR, the question that how a firm's CSR performance influences its R&D and M&A strategies is still subject to debate.

In this study, we focus our attention on a firm's innovation and CSR as two important factors in the firm's M&A decision. Specifically, we examine how a firm's investment and efficiency in R&D, and the firm's CSR score, will impact the firm's adoption of M&A as a strategic option. We review the related literature in the following on M&A, R&D, and CSR.

2.1. The Role of R&D in M&A

Extensive research has been conducted to study the relationship between R&D investment, often used as a measure for innovation, and M&A decisions, with mixed findings.

First, research in finance and management literature shows that a firm's R&D investment is often negatively related to the firm's involvement in M&A. Firms consider M&A for several reasons: efficiency related gains, market power, disciplining, agency costs, and diversification (Zhao, 2009), among which "buying innovation" is an important one (Higgins & Rodriguez, 2006). With limited resources and tight financial budgets, M&A can be an efficient way of increasing innovation when firms lag behind in their internal R&D investment. This may happen either because of risks during the internal innovation process, a lack of resources and expertise, or a focus on core competence that does not include innovation (Phillips & Zhdanov, 2012).

Hence, less R&D intensive firms may find it optimal to acquire innovative firms, avoiding the risky and time-consuming process of internal innovation (Puranam & Srikanth, 2007). R&D-intensive firms, on the contrary, less likely depend on M&A to source innovation for two reasons. On one hand, the larger R&D investment creates the greater resource and capability, particularly related to innovation. Hence, M&A becomes less attractive to R&D intensive firms as the likelihood of resource redundancy will increase and the target firm's resource is less beneficial and potentially counterproductive when acquired. On the other hand, for a R&D intensive firm, M&A often involves high-valued, intangible assets and critical human capital, which may be more challenging to integrate after M&A. Risks of integration failure in M&A are high because of inherent complexity and uncertainty during M&A. Difficulties in the integration of knowledge and capabilities, loss of autonomy, incompatibility of brand images, or cultural clashes between the acquirer and the target company all contribute to the high risks (Ahuja & Katila, 2001; Puranam & Srikanth, 2007). In addition, the potential failure of integration may disrupt the acquiring firm's established R&D process by affecting its culture for innovation (Burgelman et al., 1996), lowering the acquiring firm's incentives for developing new products and process ideas (Ornaghi, 2009). Furthermore, the integration tasks in a merger, especially a mega merger, distract management from long term planning and execution of R&D, as their attention and efforts are redirected to more immediate challenges such as aligning people, systems, and cultures (Bansal & Mark, 2015). Thus, acquisitions may reduce the acquiring firm's commitment to internal innovation, which is key to such firm's continued success (Hitt et al., 1991).

The literature also shows the possibility that a firm's R&D intensity is positive related to the M&A choice. First, firms that focus on internal innovation tend to be more risk-taking, as their past successes may increase their tolerance of risks of failure (Miller & Friesen, 1982). They may constantly seek to acquire niche resources, technical capacity, and new market access, which also lead to a high likelihood of M&A activities (King et al., 2008). Through M&A, firms that focus on internal innovation can better leverage their R&D resources, learn from others, and dampen market competition (Entezarkheir & Moshiri, 2017). For instance, the development of a new drug in the pharmaceutical industry may take several years and large investments. The requirement for large investments may lead to mergers between large companies in this industry, such as GlaxoWellcome and SmithKlinee Beecham in 2001 and Hoechsr and Rhone Poulenc in 1998 among many others (Jost & van der Velden, 2008). Second, R&D intensive firms may be better equipped and more efficient in recognizing, exploiting, and adapting external innovation developed in other firms, making it easier to effectively integrate with the targets (Cohen & Levinthal, 1990). Thirdly, R&D-intensive firms may also accumulate assets and capabilities through extensive innovation activities, allowing them to more easily create synergies with other firms during M&A (Bena & Li, 2014).

2.2. The Role of CSR in the Relationship between R&D and M&A

Firms that consider CSR in M&A decisions tend to assess opportunities with a holistic approach, and thus may be conservative towards MA when different types of risks are involved. Firms with a CSR focus often evaluate the scope and cost of potential impacts of M&A, including cultural and social impacts, as well as environmental impacts such as remediating soil and water contamination (Deloitte 2009). A comprehensive review of M&A also likely brings attention to incompatibility in CSR between the two firms, discouraging M&A for those with seriously committed CSR programs and ethical standards. A KPMG survey found that a third of companies interviewed had been impacted by environmental, safety, and social issues post M&A from target firms, and 42 percent resulted in higher operating costs and 21 percent in

direct financial liabilities (KPMG 2004). In addition, the more important CSR is to a firm, the more likely the stakeholders of the firm can wield power and influence over the firm's strategic decisions, such as in the case of M&A (Gedajlovic & Shapiro, 2002). Firms with high CSR scores may be concerned that the disruptive nature of M&A activity would destroy the interests of various stakeholder groups, lowering their CSR standards and damaging the firms' CSR culture (Morgan, 2009). The integration process post M&A is difficult and distracts management from attending to stakeholder interests (Bansal & Mark, 2015). On the other hand, however, firms with active and engaging CSR initiatives are often more open-minded and more adaptive toward M&A. For example, firms with more experience in social programs can be less concerned with cultural barriers in the post M&A integration (Meckl & Theuerkorn, 2015).

More importantly, the role of CSR in M&A may extend to the relationship between R&D and M&A because of the interactions between CSR programs and R&D activities. First, a R&D-intensive firm with extensive knowledge sharing and absorbing resources and capabilities may more readily gain from synergies during M&A integration, to which CSR further contributes (Hitt et al., 2009). A R&D intensive firm with a highly committed CSR initiative may invest in, for instance, green product innovation or social service offerings, allowing firms to possess more differentiated assets and capabilities. CSR, therefore, strengthens the complementarities in the resources and capacities behind R&D and hence encourage M&A (Hull & Rothenberg, 2008). Second, a R&D-intensive firm may be less likely to engage in M&A, because of the complexity and risks involved during the integration process, which can lead to disruptions on organizational routines, corporate culture, and innovation outcomes. A firm's CSR programs protect the acquiring firm from such risks in post M&A integration by offering an insurance-like effect (Jacobs et al., 2016; Godfrey et al., 2009). The insurance-like effect indicates that by actively involved in CSR, the firm sends positive signals to stakeholders and accumulates moral capital that can be leveraged by the firm in difficult times (Godfrey et al., 2009). In other words, a firm's good reputation, as enhanced by CSR, can serve as an intangible asset and attenuate negative stakeholder responses (Kang et al., 2016). Many R&D intensive firms build their success upon their well-trained and highly desirable employees and high-value customers (Wu et al., 2016). Effective CSR programs enhance corporate governance and stakeholder relations, mitigating the risks and concerns of key stakeholders that are significantly affected by M&A (Bekier et al., 2001). CSR programs promote corporate and social value for openness, diversity, and collaboration, all compatible with R&D intensive firms, accelerating the integration process to take advantage of synergy.

While the roles of innovation and CSR in M&A decisions have been extensively discussed in finance and management, the effect of CSR in moderating the relationship between R&D and M&A has not been studied, particularly in the operations management literature. In addition, while R&D investment creates pro-innovation corporate environment and culture, the ability and efficiency to convert the investment to innovation and financial performance is more important and relevant to operations management. We study these largely untapped issues to contribute to the operations literature.

3. DATA AND RESEARCH SETUP

In this research, our goal is to study the relationship between R&D and MA, and the moderating effect of CSR in this relationship. In this section, we introduce our data samples, definition of variables, and research setting.

3.1. Dataset Overview

From Thomson Financial's SDC Database (SDC), we develop our sample based on all completed U.S. and Cross-Border M&A cases with announcement dates between January 1, 2005 and December 31, 2015. The SDC database has been commonly used to study M&A. We focus our analyses on the domestic M&A cases and extend to the cases in emerging markets as extensions. Following the prior literature (Bena & Li, 2014), we include acquisition cases in our sample based on the criteria below: *(a)* The acquirer has to be a U.S. firm with financial information available from Standard & Poor's COMPUSTAT dataset (Compustat). *(b)* The acquirer owned less than 50% of the target firm before the bid was announced and should have owned more than 90% of the target firm post-acquisition. The transaction size of a deal has to be greater than a million (in U.S. dollar), and the payment method has to be a cash offering. We exclude the payment method using security offering as such an M&A activity may have little impact on the acquirer's R&D expense. *(c)* Neither the acquirer nor the target firm is from the financial sector (SIC 6000–6999). Acquirers and targets in the financial sector are typically high leveraged firms, and this industry is highly regulated.

In our extended studies, we consider M&A cases that involved target firms from the emerging markets. We define a country as an emerging market country if the country is covered by one of the analysts at International Monetary Fund (IMF), BRICS+Next Eleven, FTSE Group (FTSE), Morgan Stanley Capital International (MSCI), Standard & Poor's (S&P), Emerging Markets Bond Index (EMBI), Dow Jones, Russell Investments Emerging Markets Fund (Russel), and Columbia University Emerging Market Global Players (EMGP) (See Appendix Table A.1). An M&A case is included in the sample for emerging markets if the target firm is from a country identified based on the above standards.

We collect the CSR data from the Thomson Reuters ASSET4 database (ASSET4), which has provided comprehensive CSR evaluations for firms in the Russell 1000 beginning in 2005. Information in ASSET4 has been collected since 2002 for evaluating firms' CSR performance on environmental, governance, and social dimensions. To assess a firm, ASSET4 considers more than 900 evaluation points, which are equally weighted to calculate 250 key performance indicators (KPIs). Each including firm receives an annual z-score based on KPIs for environmental performance, corporate governance, and social performance respectively. All the primary data used in the assessment are objective and publicly available.

In addition, we collect financial information for R&D expenditure and other firm-level control variables from Compustat. We extract quarterly data from Compustat, 91,475 domestic M&A cases and 82,917 emerging market M&A cases from SDC, and 13,851 year-level observations from ASSET4. We split domestic M&A and emerging market M&A and consolidate the three data sources using 9-digit CUSIP, 6-digit CUSIP, and ISIN as identifiers. The final merged domestic M&A sample (called the original domestic M&A sample) includes 9,449 observations, and the final merged emerging market M&A sample (called the original emerging market M&A sample) includes 5656 observations.

3.2. Definition of Variables

We define our key variables as follows. For M&A case *m* announced at time *t* (in fiscal year *y* and fiscal quarter *q*), we denote *ACQ* as a binary variable with 1(0) to indicate whether firm *i* is the actual acquirer in M&A case *m* or not. *RDI* represents a firm's R&D intensity, while *CSR* as corporate social responsibility performance, *M/B* as Market-to-book ratio, *ROA* as return on assets, *CFO* as cash flow, and *LEV* as the financial leverage.

First, the dependent variable *ACQ* = 1 for the unique actual acquirer with a unique target firm in a domestic M&A deal. Bidders or potential competitors (potential acquirers) are coded as zero. We exclude acquiring firms with cross-border M&A experience in this sample for the main

analysis and examine such cases with emerging market targets in our extended studies. Observations are grouped based on the M&A cases with the actual and potential acquirers. While the actual acquirer of each M&A case in the SDC database is observable, the same cannot be said about potential acquirers. We generate a "potential acquirer" pool comparable to the actual acquirers following a procedure developed in Bena & Li (2014). The details of the procedure will be discussed later with the estimation techniques.

The main independent variable for R&D investment is R&D intensity (*RDI)*. *RDI* is defined to measure a firm's input for innovation (Han, Dong and Dresner 2013). Consistent with previous research (Chen & Miller, 2007), we calculate *RDI* as the ratio of R&D expenditures to firm total assets (Compustat item RD/AT). We exclude observations with missing R&D information in Compustat.

We measure a firm's CSR performance using a score set from the ASSET4 ESG database that reflects the extent of the firm's involvement in CSR-enhancing practices (Cheng, Ioannou and Serafeim 2014). Operations literature also measures CSR combining a variety of areas including community, corporate governance, human rights, environment, etc. (Chatterji et al., 2009; Chen and Delmas 2011; Jacobs et al., 2016). We focus on corporate governance and social performance as our main CSR components. Firms experienced in social programs are more willing to engage in M&A, as they do not see cultural barriers and knowledge transfer as challenges in integrating with other firms (Morgan, 2009), and corporate governance influences significantly the reorganization after a merger (Wang & Xie, 2008). Specifically, in the social and corporate governance domains of ASSET4, firms are asked whether they have the appropriate "internal communication tools" to improve employee relations, the appropriate mechanism to protect intellectual properties, the internal information tools to develop balanced board structure, and the appropriate limitations to the shareholders right to approve significant company transitions such as M&As. To calculate the comprehensive CSR score for each firm, we take the average between social and corporate governance scores, which are normalized and curved to derive ratings between 0 and 100 for each company. The higher the value, the better the firm performs in CSR.

Following the existing literature (Blonigen & Taylor, 2000; Marquardt & Zur, 2014), we identify and develop our main control variables relevant to M&A decisions. First, we control for Market-to-Book ratio (*M/B)*, a measure of overvaluation, growth opportunities, and asset complementarity, as the ratio of market value of equity to the book value of equity (Compustat item PRCC* CSHO/ CEQ) (Andrade et al., 2001; Shleifer & Vishny, 2003). In addition, we control for Return on Assets (*ROA*) as net income scaled by total assets (Compustat item NI/AT). Furthermore, we control for Cash Flow (*CFO),* as cash and short-term investment scaled by total assets (Compustat item CHE/AT), and Leverage (*LEV),* as total debt scaled by total assets (Compustat item DLTT/AT), because they reflect a firm's resource and risk. Table 1 shows the data summary and definitions.

Table 1. Variable Definition and Summary Statistics	
Variable	Definition
Dependent Variable	
ACQ=0	Potential acquirers
ACQ=1	Actual acquirers
Independent Variables	
CSR	Average score of social and corporate governance performance
RDI	R&D expenditure scaled by total assets
Control Variables	
M/B	The ratio of market value of equity to the book value of equity
ROA	Net income scaled by total assets
CFO	Cash and short-term investment scaled by total assets
LEV	Total debt scaled by total assets
Matching Covariate	
SIZE	The log-transformed total assets

	Domestic M&A Sample				Emerging Market M&A Sample			
	Potential Acquirers (N= 7891)		Actual Acquirers (N= 1558)		Potential Acquirers (N= 5206)		Actual Acquirers (N= 450)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CSR	64.48	20.23	67.40	19.16	64.48	20.57	71.10	18.96
RDI	0.06	0.07	0.06	0.06	0.06	0.08	0.04	0.05
M/B	3.56	6.72	4.26	5.29	3.54	7.25	3.54	3.71
ROA	0.01	0.04	0.02	0.02	0.01	0.04	0.02	0.02
CFO	0.18	0.16	0.19	0.16	0.19	0.16	0.14	0.13
LEV	0.18	0.15	0.17	0.14	0.18	0.15	0.18	0.12
SIZE	9.06	1.46	8.99	1.36	8.99	1.47	9.67	1.37

4. METHODOLOGY

We develop two econometric models to test our research questions. We estimate these models to achieve two goals: *1)* to test for the direct relationship between R&D input and the likelihood of M&A, and *2)* to test for the potential moderator, CSR, of the association.

4.1. Conditional Logistic Regression

To estimate the likelihood of a firm to be involved in M&A as an acquirer, we need to understand the difference between the actual acquirer and its competitors, i.e. those who are potential acquirers, in an M&A case. Given the lack of information from competing bidders, we apply two standards to define the potential acquirer(s). We first identify industries based on prior literature, which suggests that an acquirer and its competitors are likely to operate in the same industry (Andrade et al., 2001). We use actual M&A deals as the unit of grouping. For M&A deal *m* announced at time *t*, we group each actual acquirer and its competitors by industry, defined by the 2-digit SIC code. This grouping process creates a pool of potential acquirers clustered by time-industry dyad (Maksimovic et al., 2013). There are no M&A activities for potential acquirers in the same period, or the year before, when they are grouped to an actual acquirer. In addition, potential acquirers with similar sizes to that of the actual acquirer are more likely to be actual

competitors in an M&A case (Gorton et al., 2009). To select the potential firms with similar sizes, we apply a propensity score matching approach. Propensity scores provide sampling weights (Hirano et al., 2003; Levine & Toffel, 2010) for assigning different weights to treatment and control observations based on observable covariates. We split all firms into two groups. We define firms with at least one M&A activity as the treatment group and firms without any M&A activity as the control group. Then, we use a Logit regression to calculate propensity scores (*pscore*), where the dependent variable is whether a firm has been an acquirer ever, and the covariate is the firm's log-transformed total assets. In each group, we control for the inverse probability weights (IPW) by assigning the weight for the actual acquirer as *1/pscore*, while the weights for the potential acquirers as 1/(1-*pscore*). Therefore, potential acquirers are given more weights if they are similar to actual acquirers in our analysis (Desyllas & Hughes, 2010; Hirano & Imbens, 2001). Figure 2 shows the kernel density estimation (DeFond et al,. 2016) in examining distributions of firm's total assets across the treated firms and the control firms and Table 2 shows the tests for the mean difference between the treatment group and the control group before and after matching. Both suggest that the propensity score distributions are reasonably similar after reselecting.

Figure 2. Kernel Density Estimation

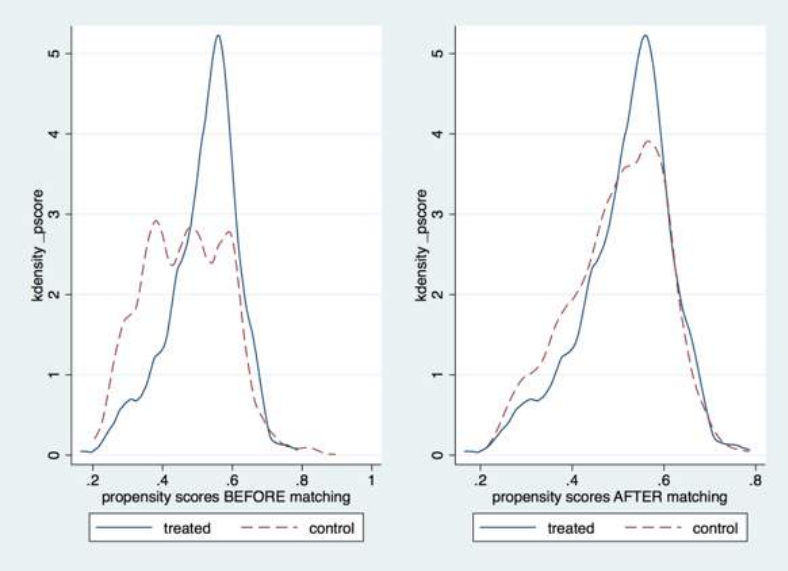


Table 2. Test for Matching Quality						
		Mean			t-test	
Variable		Treated	Control	%bias	t	p-value
SIZE	Unmatched	8.65	9.39	-52.50	-25.14	0.00
	Matched	8.64	8.64	0.00	-0.01	0.99

In stratification and grouping, we utilize the weighted conditional (or fixed-effects) logistic regression. A conditional logistic regression model is more appropriate than a classic logistic regression model in our analysis because the latter would result in biased predictions when grouped data is analyzed (Selvin, 2004). In each M&A case, the actual acquirer may compete with other potential acquirers, thus, the possibility of the acquirer-target combining is conditional on the differences between the actual acquirer and the potential acquirers. Because each M&A

case may involve a limited number of bidders, we randomly draw up to 5 firms from the pool of potential acquirers and group them with the actual acquirer. Each stratum has one observation for the actual acquirer and up to five observations for the potential acquirers matched with the actual target. We drop the acquirer with more than one M&A case in a quarter so that the same firm will not be observed multiple times in the same quarter. The conditional likelihood approach deals with the possibility to be the acquirer in an M&A case *m* in Equation (1):

$$P(Y_{m1}=1, Y_{m2}=0, \dots, Y_{mk}=0 | \mathbf{T_{m1}}, \mathbf{T_{m2}}, \dots, \mathbf{T_{mk}}, \textstyle\sum_{i=1}^{k} Y_{mi}=1) = \frac{\exp(\mathbf{T_{m1}B})}{\exp(\mathbf{T_{m2}B})+\exp(\mathbf{T_{m3}B})+\cdots+\exp(\mathbf{T_{mk}B})} \quad (1)$$

where *Y* is the outcome of whether firm *i* is an actual acquirer or a potential acquirer in M&A case *m* ($k \leq 6$, one actual acquirer with up to five potential acquirers), and **T** is a matrix of firm-specific information, such as CSR performance, R&D intensity, and other financial statuses. Because our observations are grouped by the unique M&A case, deal time, and acquirer industry, the conditional logit model also controls for industry fixed effects and deal fixed effects, such as the target firm's financial information, deal size, and the macro-economic environment around the deal time.

4.2. Endogeneity

We discuss the potential endogeneity in R&D intensity and CSR in the following section. On one hand, the M&A preparation may reversely affect R&D investment and CSR performance. These related decisions can be jointly determined by some unobserved factors that lead to an omitted variables problem. Resource commitment toward M&A preparation and planning diverts resources that would be allocated to R&D or CSR. On the other hand, M&A activities may reversely affect R&D and CSR. The acquirer may reduce the R&D investment immediately after acquiring an innovative firm (Cassiman & Veugelers, 2006). Choi et al. (2015) shows that, while acquiring a socially responsible target may create synergy that improves focal firm's CSR, it may also lower the focal firm's CSR performance due to the target's social irresponsibility.

4.1.1. Lagged Independent Variables

To address the simultaneity problem, we use lagged independent variables and control variables to predict the possibility of a firm to become an acquirer. Firms may make M&A decisions based on their current and previous financial and operational performance. However, whether they are able to complete M&A deals later is unpredictable due to different unobserved risks. Therefore, M&A completion may be exogenous to the financial and operational status of the firms in the preparation phase of M&A. Assuming that a firm starts to prepare an M&A case before making the announcement rather than during or after the announcement, we lag independent variables to a year before the deal and lag controls by a quarter before the deal to avoid the potential simultaneity. We control for the interaction between CSR and R&D intensity (*RDI*CSR*) to test for the moderating effect. We present the main regression Equation (2) below:

$$\mathrm{Prob}(ACQ_{i,m,t}) = \alpha + \beta_1 RDI_{i,m,t-1} + \beta_2 CSR_{i,m,t-1} + \beta_3 RDI_{i,m,t-1} * CSR_{i,m,t-1} + \mathbf{X}_{i,m,t-1} * \mathbf{B} + \delta_m + e_{i,m,t} \quad (2)$$

where the subscript *i* represents the firm, *m* the deal number, and *t* the deal announcement time. **X** is the matrix of control variables including *M/B*, *ROA*, *CFO*, and *LEV*. $\boldsymbol{\delta}$ first absorbs the deal fixed effects such as the target's financial performance and the time fixed effects. Because

the actual acquirer and the potential acquirers are in the same industry and have similar total assets, δ also captures the industry and firm size fixed effects. R&D intensity and *CSR* are lagged one year before the deal announcement date, and **X** are lagged one quarter before the deal announcement date.

4.1.2. Instrumental Variables

We address the potential endogeneity issues of CSR and R&D intensity by using instrumental variables (IVs) to show the robustness. The IV approach requires instruments that are highly correlated with the endogenous variable and uncorrelated with the error term. To predict the CSR performance, we adopt the political voting pattern in the state where the firm headquarters is located (*BLUE*). A Firm's CSR performance may be highly correlated to the external political environment because of its CEO's political engagement (Deng et al., 2013; Di Giuli & Kostovetsky, 2014; Chatterji & Toffel, 2016). For example, Di Giuli & Kostovetsky (2014) find that firms in Democratic-leaning states are more socially responsible than those in Republican-leaning states. To address the endogenous CSR performance, Deng et al. (2013) apply a dummy instrument, which is coded as 1 if firms are headquartered in a Democratic state (blue) and 0 if in a Republican state (red). Such a dummy IV defined at the quadrennial level may not have the variations for the yearly firm-specific CSR strategy. Instead, we collect each state's annual party affiliation from Pew Research Center (PRC). PRC randomly selects participants and asks their party identifications. We define our IV, *BLUE*, as the democratic advantage by using the share difference between democratic and republican. Therefore, we consider that *BLUE* should be largely exogenous with firm characteristics. To address the endogenous *RDI* in our research, we use the lagged 3-year moving average R&D intensity (*M_RDI*). Lagged values of the data are less likely to be influenced by current shocks. Thus, *M_RDI* is formatted exogenously.

5. ANALYSIS AND RESULTS

5.1. Analysis—Bootstrapping

The pool of potential acquirers includes the potential competitors that are in the same industry and have a similar size as the actual acquirer but did not have any M&A activity in the same period. Due to the data limitation of ASSET4, many firms that do not report their CSR performance are missing in the pool of potential acquirers. Therefore, the pool of potential acquirers represents a subsample of the potential acquirer population. Given the observed data, we estimate bootstrap-based conditional logit regressions. Bootstrapping is a type of resampling where large numbers of smaller samples are repeatedly drawn, with replacement, from a single original sample so that the sample data can be the inference about a population (Cameron et al., 2008; Simar & Wilson, 1998). In our case, we treat the pool of actual acquirers with the pool of potential acquirers as the original sample. Each bootstrap sample consists of the actual acquirers and up to five potential acquirers randomly drawn with replacement from the pool. A bootstrap sample is a smaller sample that is "bootstrapped" from the original sample. The actual acquirer group and control acquirer group do not remain constant across bootstrap because each observation in the original sample can be drawn multiple times to a bootstrapped sample. We also drop strata with a control group size smaller than or equal to five since the variation across the bootstrap can be relatively small. A different regression is fitted for each bootstrap sample as a result. We bootstrap 1000 times to get 1000 subsamples. After an independent regression for each bootstrapped subsample, we collect a matrix composed of 1000 coefficient

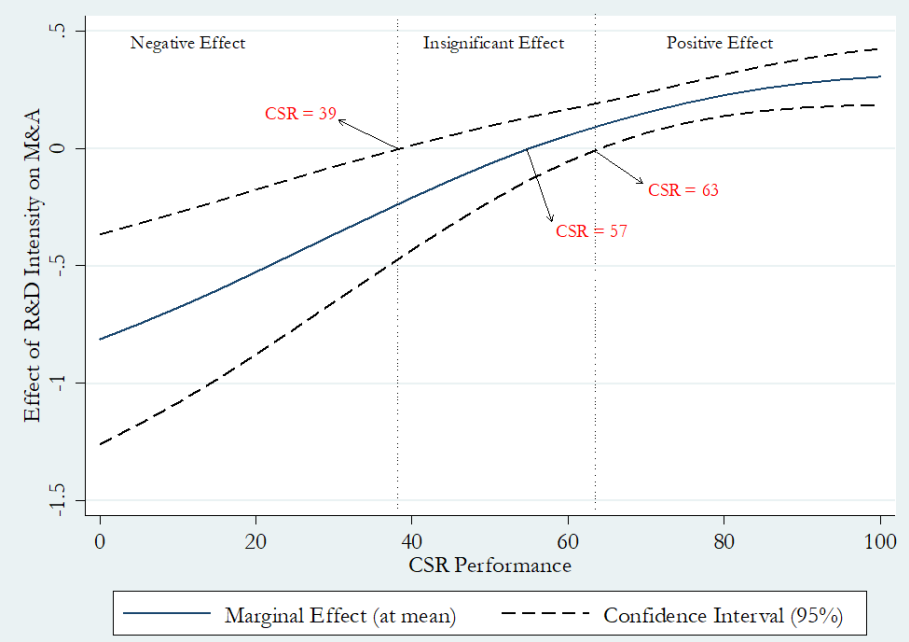
vectors to obtain an empirical distribution that is close to the true population distribution. Ideally, if we have an accurate subsample of the actual competitors, we only need to run a simple model to collect the coefficient of each variable. Unfortunately, we cannot match the exact competitors to the actual acquirer because of missing peer information in the SDC database. Instead, after bootstrapping, we calculate the median and standard deviation of each coefficient in Equation (4) from the coefficient matrix. The estimated standard deviations are the bootstrapped standard errors, while each *z* value is calculated by using the median divided by the bootstrapped standard error (Bena & Li, 2014; Efron & Tibshirani, 1994).

5.2. Main Result—R&D Intensity

We present the model estimates in Table 4 based on the domestic M&A sample as our main results. We later extend these results to target firms in emerging markets.

In Model (1) of Table 4, we first show the direct effect of R&D intensity on the possibility to acquire. As we discussed early, literature is mixed—some argue for a substitutable effect, that a less R&D intensive firm may obtain innovation through acquisition (Seru 2014; Phillips & Zhdanov, 2012), others find it to be the opposite, a complementary effect, that a R&D intensive firm can leverage its strengths in innovation in M&A (Bena & Li, 2014, Cassiman & Veugelers, 2006). We find that *RDI* has a positive and significant (0.40, $p < 0.05$) association with *ACQ*. In Model (2), however, after we control for the interaction between CSR and R&D intensity to explore the moderating effect, we find that the linear term of *RDI* becomes negative and significant (-2.06, $p<0.01$). More importantly, our primary interest, the interaction term *CSR* RDI,* is positive and significant, 0.04 ($p<0.01$). The combination of the negative linear term and the positive interaction term connects the two conflicting streams of literature with CSR, indicating that M&A can be both a substitute and a complement to R&D, depending on CSR. Specifically, when CSR performance is low, firms with low R&D intensity tend to replace R&D with M&A, whereas firms with high R&D are less likely to be an acquirer. A better CSR performance positively moderates the relationship between R&D and M&A, such that with sufficiently high CSR performance, firms with high R&D intensity become more likely engaged in M&A. Figure 3 shows the interaction between R&D intensity and CSR in a Johnson-Neyman plot (Shang et al,. 2017), which indicates that the marginal effect of CSR on R&D-M&A relationship is significantly negative if the CSR score is below around 39. As the score moves from 39 to around 62, the marginal effect is insignificant. When it goes beyond 62, the marginal effect becomes positive and significant.

Figure 3. Johnson-Neyman Plot: The Marginal Effect of CSR on R&D and M&A Relationship



The linear term of CSR performance has a positive and significant effect on the likelihood of M&A in two models. In addition to moderating the innovation-related risks, the positive coefficients of CSR indicate that a better CSR performance encourages and facilitates firms to acquire new resources because the barriers of post-merger integration are lowered. Other findings not directly related to R&D and CSR are consistent with prior work on M&As (Maksimovic & Phillips, 2001; Moeller et al., 2004). We show that firms with lower M/B ratios, less cash flow, better ROA, and higher leverage are more likely to engage in M&As as acquirers.

In Model (3) and Model (4), we show the two-stage IV estimations. We include three IVs presented in Section 4.2.2 to predict the endogenous *CSR* and *RDI* in the first stages. Then, we plug the predicted CSR performance (*CSRhat*) as well as R&D intensity (*RDIhat*) into the second stages. Given that all F-statistic values in the first stage are greater than 10, indicating our IVs are valid in predicting the endogenous variables, the two-stage model results are qualitatively consistent with our main results based on the weighted conditional logit model. The Wald tests of exogeneity also indicate the correlation between the error terms in the structural equation and those in the reduced-form equation for the endogenous variable (Wooldridge, 2010). We observe that the *p*-values of the Wald tests of exogeneity are significant in the two models and the null hypothesis of no endogeneity is rejected.

Table 4. Weighted Conditional Logit Model Results				
Domestic M&A (*ACQ*) Actual Acquirers=1 Potential Acquirers=0	Conditional Logit Model		Instrumental Variables	
	Model (1)	Model (2)	Model (3)	Model (4)
Explanatory Variable				
CSR	0.015***	0.013***		
	(0.00)	(0.00)		
CSRhat			0.07***	0.01***
			(0.02)	(0.00)
RDI	0.4**	-2.06***		
	(0.18)	(0.52)		
RDIhat			1.73***	-6.01***
			(0.48)	(0.95)
Moderating Effect				
*CSR*RDI*		0.04***		
		(0.01)		
*(CSR*RDI)hat*				0.09***
				(0.01)
Control Variables				
M/B	0.015***	0.015***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)
ROA	3.28***	3.12***	1.88	5.99***
	(0.41)	(0.40)	(1.17)	(0.62)
CFO	-0.31***	-0.29***	0.40	-1.25***
	(0.07)	(0.07)	(0.38)	(0.09)
LEV	-0.14*	-0.15**	-0.79***	-1.31***
	(0.08)	(0.08)	(0.17)	(0.12)
Bootstrap Sample	6508	6508	4237	4237
Original Sample	9449	9449	9449	9449
Log Likelihood	-4251	-4247.5	-3023.50	-2962.50
Wald Chi2	134	138	174	295
Pseudo-R2	0.03	0.03	0.03	0.05
Deal FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
PSM Covariate	*SIZE*	*SIZE*	*SIZE*	*SIZE*
Sample Weight	IPW	IPW	IPW	IPW
# Potential Acquirers	Up to 5	Up to 5	Up to 5	Up to 5
Wald test of exogeneity	-	-	0.00	0.00
Bootstrap std err. are in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Log Likelihood and Bootstrap Sample Size are calculated as the medians of 1000 regressions				

5.3. Robustness Checks

In this section, we present and discuss a number of robustness checks. The detailed results are included in Appendix Table A.2.

Innovation-related M&A

We argue, and our main findings suggest that a firm's CSR performance may mitigate the innovation-related risks in M&A. Our sample contains M&As of a variety of different purposes. To provide a more focused view of this role of CSR, we zoom in on the innovation-related M&A cases by creating a subsample with such cases only. We define, following SDC categorization, innovation-related acquisitions as deals if one of the deal purposes is to develop new products or to acquire patents, new technologies, or intellectual properties. When reconstructing the dependent variable, *ACQ*, we code the actual acquirers of innovation-related M&As as 1. The grouped potential acquirers are coded as 0. This subsample includes 524 innovation-related cases. We show that the positive moderating effect of CSR remains significant for innovation-related acquisitions.

Sample Construction and Weighting Standard

First, we adjust the number of potential acquirers to check whether the main results are sensitive to potential acquirers. When grouping the actual acquirers with the control acquirers, we randomly draw up to five control acquirers by industry and firm size. As robustness checks, we control for the closest one potential acquirer and, then, control for ten closest control acquirers of the actual acquirer. The results remain the same. In addition, we control for the total asset and market-to-book ratio as the covariates in propensity score estimation to test for weighting approach, and the results are highly consistent with the main results.

Alternative Model Configuration

We also test if our findings are robust when using a different sampling approach. Instead of using M&A deals to group each stratum, we use the SIC-quarter dyad as the grouping standard. We add firms engaged in more than one M&A deal within a quarter and reform the dependent variable as the aggregate number of deals completed in a quarter. Therefore, our new dependent variable (*MA_COUNT*) follows a Poisson distribution. We estimate a Poisson regression with industry and time fixed effects to test the relationships between R&D intensity, CSR, and M&A activities. These results explain how R&D intensity affects M&A frequency, and how CSR moderate this relation. The results are consistent with those from our main model.

6. EMERGING MARKET M&A AND RESEARCH QUOTIENT

6.1. Cross-border acquisitions of emerging-market multinationals

As emerging markets have seen significant improvements in technology in the recent decades, targeting firms in the emerging markets for M&A is no longer motivated solely by cheap resources and labor. The growing scale of economic activities in emerging markets provides opportunities for firms to leverage technological advantages and develop new markets (Parker, Ramdas & Savva, 2016; Han et al., 2013). The existing literature shows a different role of R&D in emerging market M&A decisions. On one hand, firms in the emerging markets are often

behind in technology and less innovative than firms in the U.S. (Lall, 2003), and therefore, acquiring innovative firms to compensate or replace internal R&D is less likely. US firms that target emerging markets are more likely to extend new markets and sell their new products that are technologically advanced and innovative (Hitt et al., 2000). On the other hand, Meyer et al. (2009) indicate that firms target emerging markets for M&A opportunities based on demand of local resources rather than innovative technologies. Because firms in the emerging markets are significantly behind in technologies and innovation, it is difficult for R&D-intensive firms in the U.S. to take advantage of the resources from emerging markets for technological benefits. The cultural and economic differences may also make it ineffective for R&D-intensive firms to develop synergy after acquiring firms in the emerging markets.

In terms of the role of CSR performance in emerging market M&A decisions, there are two different opinions in the existing literature. On one hand, poor corporate governance practices in emerging markets have been well documented in the literature (Aybar & Ficici, 2009). If the difference between the acquirer and the target is too much, it is difficult to develop synergy after merger. On the other hand, when the focal firm has strong corporate governance (relative to the target), the governance of the target firm can be improved so that part of the post-merger synergy value can be obtained (Martynova & Renneboog, 2008). We consider that CSR may perform a different moderating role when the target firm is in the emerging markets.

In this section, we examine the role of R&D intensity and CSR in emerging market M&As. We group the actual acquirers and potential acquirers based on the emerging market M&A cases. All actual acquirers and potential acquirers are domestic firms. All targets are firms in the emerging markets. We replicate the weighted conditional logistic model with the bootstrapping procedure in the previous section. The actual acquirers only have the emerging market activities in the studied period and have no other M&A activities in the previous year. We present the model estimates in Table 5. In Model (5), we find that the combined effect of R&D intensity becomes negative (-0.56, $p<0.10$), indicating that R&D intensive firms are less likely to target the emerging markets. The coefficients of CSR remain positive (0.018, $p<0.01$) and consistent with the domestic M&A model. This finding shows a positive effect of CSR on both domestic M&A and cross-border M&A. We also test the moderating effect of CSR in Model (6). The positive moderating effect (0.10, $p<0.01$) shows that firms with higher R&D intensity and better CSR performance are more likely to acquire targets in emerging markets than those with high R&D intensity but lower CSR performance. While this positive moderating effect of CSR is consistent with that for domestic targets, it is weaker because the combined direct and moderating effect of R&D intensity is negative, as in Model (5). Compared with the positive combined effect for domestic targets, this negative effect shows that substantial technological gaps and cultural and economic differences between U.S. acquirers and emerging market targets may intensify the challenges in knowledge sharing and post M&A integration, which weakens the positive effect of CSR.

Table 5. Emerging Market M&A		
Emerging Market M&A (*ACQ*) Actual Acquirers=1 Potential Acquirers=0	Conditional Logit Model	
	Model (5)	Model (6)
Explanatory Variable		
CSR	0.016***	0.013***
	(0.00)	(0.00)
RDI	-2.26***	-6.38***
	(0.45)	(1.23)
Moderating Effects		
*CSR*RDI*		0.059***
		(0.02)
Control Variables		
M/B	0.0061*	0.0065*
	(0.00)	(0.00)
ROA	3.195***	3.12***
	(0.90)	(0.89)
CFO	-1.15***	-1.11***
	(0.17)	(0.17)
LEV	-0.9***	-0.92***
	(0.16)	(0.16)
Bootstrap Sample	2268	2268
Original Sample	5656	5656
Wald Chi2	61.2	59.3
Pseudo-R2	0.038	0.039
Log Likelihood	-1993	-1991
Deal FE	Yes	Yes
Industry FE	Yes	Yes
PSM	*SIZE*	*SIZE*
Sample Weight	IPW	IPW
# of Potential Acquirers	Up to 5	Up to 5
Bootstrap std err. are in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Wald Chi2, Log Likelihood and Bootstrap Sample Size are calculated as the medians of 1000 regressions		

6.2. Research Quotient

R&D intensity measures the portion of internal R&D investment in total asset, which can be seen as a measure of R&D input. However, heavy investment in R&D does not necessarily produce the desired outcome, that is, innovation and firm financial performance (Chandrasekaran et al., 2015). Rather, a highly R&D intensive firm with a low level of innovation outcome tends to lack necessary knowledge sharing and absorptive capacities to fully convert the investment to the outcome. In this case, merging with a different company will further burden the acquiring firm's inefficient or inadequate learning capacities, leading to higher risks and lower innovation and financial performances. On the other hand, a firm with a higher efficiency

in converting R&D investment to innovation and financial outcomes should have a more adaptive and capable internal mechanism to facilitate knowledge sharing and absorbing post M&A (Cohen & Levinthal, 1990). Moreover, efficient R&D improves operations and aligns with the output of CSR (Jacobs et al., 2016). In this regard, R&D input of a firm, i.e. R&D investment, may function differently from the firm's ability to create R&D output, i.e. R&D efficiency, in the firm's decision with respect to M&A. The existing literature, therefore, is mixed on the association between R&D and M&A, and the potentially different mechanisms, between R&D investment and R&D efficiency. In this section, we adopt a measure of R&D output, i.e., research quotient (*RQ*), to test if *RQ* is related to R&D differently from R&D intensity (Knott, 2008; Cooper et al., 2015).

RQ is available in the *WRDS RQ™ database* from 2005 to 2010. To match this variable with our timeframe, we re-estimate *RQ* following Cooper et al. (2015), but without considering advertising expenditure because of the missing value issue. Based on the assumption that R&D is one of the factors to maximize the output (Knott 2008), we estimate, *RQ*, as the output elasticity of R&D, by applying the Cobb-Douglas production function with natural logarithm transformation(Cooper et al., 2015).Then, in Equation (3), we derive *RQ* by using a multilevel model that allows for the heterogeneity among firms in the output elasticity for R&D expenditure:

$$lnY_{it} = (\beta_0 + \beta_{0i}) + (\beta_1 + \beta_{1i})lnK_{it} + (\beta_2 + \beta_{2i})lnL_{it} + (\beta_3 + \beta_{3i})lnR_{i,t-1} + (\beta_4 + \beta_{4i})lnS_{i,t-1} + \varepsilon_{it} \quad (3)$$

where *i* represents the focal firm and *t* represents the fiscal year. β and β_i capture the general effect and the firm-specific error of each exponent. *Y* is annual revenue, and *A* represents a firm fixed effect; *K* is capital, *L* is labor, and *R* is lagged R&D expenditure. *S* is lagged R&D spillovers (Eeckhout & Jovanovic, 2002), which is computed as the sum of the differences in R&D expenditure between focal firm *i* and rival firm *j* with more knowledge (R&D) than the focal firm in the same 4-digit SIC industry. We construct *RQ* for each firm-year using rolling 7-year windows from 1997 to 2015, following the *WRDS RQ™* process. For example, *RQ* for each firm in 2015 is estimated based on data from the 2009 to 2015 window. We obtain the best linear unbiased predictions (BLUPs) after multilevel analysis to estimate the industry-level random effects. Then, *RQ* for each firm-year, capturing by $\beta_3 + \beta_{3i}$, represents the revenue increase when investing 1% more on R&D. In addition, *RQ* is controlled at the end of the fiscal year prior to the merger announcement because literature shows that the successful R&D input at a previous stage will increase the commitment to the allocation of future R&D resources (Nelson & Winter, 1982). The correlation between our estimated *RQ* and the *RQ* from *WRDS RQ™ database* is 0.85.

In Table 6, we show the effect of the R&D output, *RQ*, and the moderating effect of *CSR*. *RQ* captures firm's ability to convert R&D to profit. We find the direct effect of *RQ* is positive and significant (2.75, $p<0.01$) in Model (7). In Model (8), the positive moderating effect of CSR (0.023, $p<0.05$) shows the robustness and consistency. However, the linear term of *RQ* remains positively and marginally significant (1.27, $p<0.1$), which means firms with higher *RQ* still seek the opportunity to acquire new resource even CSR performance is at a low level.

Table 6. Research Quotient		
Domestic M&A (*ACQ*) Actual Acquirers=1 Potential Acquirers=0	Conditional Logit Model	
	Model (7)	Model (8)
Explanatory Variable		
CSR	0.015***	0.011***
	(0.00)	(0.00)
RQ	5.17***	2.2***
	(0.26)	(0.55)
Moderating Effect		
*CSR*RQ*		0.052***
		(0.01)
Control Variables		
M/B	0.015***	0.015***
	(0.00)	(0.00)
ROA	2.86***	2.96***
	(0.40)	(0.41)
CFO	-0.48***	-0.47***
	(0.07)	(0.07)
LEV	-0.22***	-0.21***
	(0.08)	(0.08)
Bootstrap Sample	6476	6476
Original Sample	9449	9449
Wald Chi2	168	178
Pseudo-R2	0.04	0.041
Log Likelihood	-4189	-4187
Deal FE	Yes	Yes
Industry FE	Yes	Yes
PSM	*SIZE*	*SIZE*
Sample Weight	IPW	IPW
# of Potential Acquirers	Up to 5	Up to 5
Bootstrap std err. are in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Wald Chi2, Log Likelihood and Bootstrap Sample Size are calculated as the medians of 1000 regressions		

7. DISCUSSION AND CONCLUSION

Using a combination of datasets over the period 2005-2015, we examine the R&D and M&A relationship with a focus on the moderating role of CSR. We find M&A can be employed as both a substitute and a complement to R&D investment, depending on CSR performance. In particular, when a firm's CSR score is low, the relationship between R&D intensity and M&A likelihood is negative, indicating the substitutable effect, which is supported by the existing literature shown as a "replacement" role of M&A. When the CSR score is sufficiently high, however, the R&D and M&A relationship becomes positive, suggesting a complementary effect of M&A. Our findings contribute to the literature by highlighting the moderating role of CSR that

reconciles the opposite effects of R&D on M&A.

Replacing internal investment in R&D with M&A is risky, mainly because of the uncertainties involved in the integration process and in absorbing the new knowledge and technology. Resorting to M&A to grow market for innovative firms can be riskier, not only because of uncertainties and challenges in integrating new organizations and leveraging technological knowledge, but because of the high costs of failure for the established acquirers. This is where CSR engagements play a key role—CSR functions as an insurance-like mechanism that reduces internal risks in integration by enhancing absorptive capabilities to sharing knowledge and information, and accommodating different corporate cultures and structures, and reduces external risks by protecting corporate and brand reputation in case of failure. As such, this buffering effect of CSR is more critical and value-added for innovative firms that have invested substantially in R&D and established reputation. Literature has well documented the R&D and M&A relationship, with conflicting findings, but has not investigated these effects from the perspective of CSR and its moderating role in the relationship. This research is a first empirical attempt in this regard and firmly establishes the significant role of CSR.

Furthermore, by including data from M&A target firms in emerging markets and using an alternative measure for R&D efficiency, this research strengthens our major finding with regard to CSR in the R&D and M&A relationship. It also expands and enriches the literature of R&D and M&A by incorporating different cultures and economic conditions in emerging market, and by allowing a more in-depth understanding of the R&D effect, i.e., investment vs. efficiency. Acquiring a target firm from emerging markets involves higher risks, because of differences in corporate culture, economic and regulatory environment, and governance. While the firm's higher social values, and open and absorptive corporate environment still strengthen the R&D and M&A relationship with emerging market targets, the barriers in communication and knowledge sharing further challenge the integration process. Further, R&D is a process—while R&D investment creates infrastructure and provides resources that enable and facilitate the process, the outcomes of the process also depend on many other factors (Cooper et al., 2015). Therefore, a firm with low R&D investment may find acquiring another firm with established technologies an efficient replacement strategy, but a firm with low efficiencies of converting R&D efforts into meaningful outcomes will less likely be able to take advantage of the acquired technologies via M&A. This research is a first attempt to connect R&D efficiency, as a comparison to R&D investment, to M&A, with the moderating effect of CSR.

These findings have important managerial implications. First, establishing effective internal process and programs, as well as external reputation, CSR is critical for managers in making M&A decisions. An effective role of CSR encourages knowledge sharing and coordinates integration risks post M&A, and as a result, enhances R&D under M&A. Managers challenged by investing in R&D or replacing it by M&A should strengthen CSR programs and improve corporate governance and social image. Further, the moderating role of CSR remains positive even for emerging market targets, but it is weaker compared with U.S. targets. Acquiring an emerging market firm is still risky for R&D intensive firms, even after taking into account of the positive CSR effect. Moreover, when a firm's R&D is highly efficient, it can leverage the high efficiency to expand its market, and CSR can help increase the likelihood of the firm choosing M&A as a strategy. Therefore, managers considering M&A as a R&D option should focus on increasing R&D efficiency as an output, rather than investment as an input, and better coordinate R&D and CSR activities.

This research is limited by data availability from target firms, in particular for the CSR related information. Future research can increase data sources and improve CSR data availability. Particularly, the current analysis can be extended to study CSR synergy between

acquiring firms and target firms, if more and higher quality CSR data for the target firms is available. Further, because CSR can better facilitate post M&A integration, a post M&A analysis could explore whether or not a firm with established CSR programs could recover faster from M&A shock.

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APPENDIX

Table A.1 Emerging Markets by Each Group of Analysts

Country	IMF	BRICS+ Next Eleven	FTSE	MSCI	S&P	EMBI	Dow Jones	Russell	EMGP	Our Sample
Argentina	Yes					Yes			Yes	Yes
Bangladesh	Yes	Yes			Yes	Yes				Yes
Brazil	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bulgaria	Yes									Yes
Chile	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
China	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colombia	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Czech Republic			Yes	Yes	Yes	Yes	Yes	Yes		Yes
Egypt		Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
Greece			Yes	Yes	Yes		Yes	Yes		Yes
Hungary	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
India	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Indonesia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Iran		Yes								Yes
Israel						Yes			Yes	Yes
Malaysia	Yes		Yes	Yes	Yes	Yes	Yes	Yes		Yes
Mauritius									Yes	Yes
Mexico	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nigeria		Yes				Yes				Yes
Oman						Yes				Yes
Pakistan	Yes	Yes	Yes	Yes		Yes				Yes
Peru	Yes		Yes	Yes	Yes	Yes	Yes	Yes		Yes
Philippines	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Poland	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Qatar				Yes		Yes	Yes			Yes
Romania	Yes					Yes				Yes
Russia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Slovenia									Yes	Yes
South Africa	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
South Korea		Yes		Yes					Yes	Yes
Taiwan			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Thailand	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Turkey	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ukraine	Yes					Yes				Yes
United Arab Emirates			Yes	Yes		Yes	Yes	Yes	Yes	Yes
Venezuela	Yes					Yes				Yes
Vietnam		Yes				Yes				Yes

Table A.2. Innovation-related M&A (Panel A)		
Domestic M&A (ACQ)	Conditional Logit Model	
Actual Acquirers=1	Innovation-related M&A	
Potential Acquirers=0	Model (A1)	Model (A2)
Explanatory Variable		
CSR	0.023***	0.017***
	(0.00)	(0.00)
RDI	1.35***	-4.9***
	(0.41)	(1.34)
Moderating Effect		
*CSR*RDI*		0.1***
		(0.02)
Control Variables		
M/B	0.018***	0.02***
	(0.00)	(0.00)
ROA	3.69***	3.29***
	(0.90)	(0.87)
CFO	0.0305	0.035
	(0.14)	(0.14)
LEV	0.495***	0.47***
	(0.17)	(0.17)
Bootstrap Sample	2340	2340
Original Sample	5269	5269
Wald Chi2	93	97.3
Pseudo-R2	0.058	0.061
Log Likelihood	-1566	-1561
Deal FE	Yes	Yes
Industry FE	Yes	Yes
PSM	*SIZE*	*SIZE*
Sample Weight	IPW	IPW
# Potential Acquirers	Up to 5	Up to 5
Bootstrap std err. are in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Wald Chi2, Log Likelihood and Bootstrap Sample Size are calculated as the medians of 1000 regressions		

This table reports coefficient estimates from conditional logit models in Equation (2) with the adjustment of the dependent variable. Model (A1) and Model (A2) test if our model is sensitive to the purposes of M&A. The dependent variable is equal to one for the actual acquirers who merge for acquiring new technologies or patents and zero for the potential acquirers. We control for total assets as the covariate of propensity score matching. Then, we randomly draw up to 5 potential acquirers from the pool of potential acquirers to match with the actual acquirers. We present the median and standard deviation (as the bootstrapped standard error) of the empirical distribution of coefficient estimates from conditional logit regressions of 1000 bootstrapped samples.

Table A.2 Robustness Check (Panel B)				
Domestic M&A (ACQ) Actual Acquirers=1 Potential Acquirers=0	Conditional Logit Model			
	Adjustment for the # of potential acquirers			
	Model (B1)	Model (B2)	Model (B3)	Model (B4)
Explanatory Variable				
CSR	0.019***	0.015***	0.015***	0.013***
	(0.00)	(0.00)	(0.00)	(0.00)
RDI	0.32	-2.72*	0.38**	-2.04***
	(0.56)	(1.64)	(0.15)	(0.44)
Moderating Effect				
*CSR*RDI*		0.052*		0.039***
		(0.03)		(0.01)
Control Variables				
M/B	0.017***	0.018***	0.014***	0.015***
	(0.01)	(0.01)	(0.00)	(0.00)
ROA	4.27***	4.08***	3.165***	3.02***
	(1.23)	(1.21)	(0.26)	(0.26)
CFO	-0.56***	-0.56***	-0.26***	-0.24***
	(0.18)	(0.18)	(0.07)	(0.07)
LEV	-0.044	-0.053	-0.16**	-0.17**
	(0.20)	(0.20)	(0.07)	(0.07)
Bootstrap Sample	2850	2850	7949	7949
Original Sample	9449	9449	9449	9449
Wald Chi2	110	112	139	143
Pseudo-R2	0.06	0.061	0.027	0.028
Log Likelihood	-1986	-1983	-4627.5	-4625
Deal FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
PSM	*SIZE*	*SIZE*	*SIZE*	*SIZE*
Sample Weight	IPW	IPW	IPW	IPW
# Potential Acquirers	1	1	Up to 10	Up to 10
Bootstrap std err. are in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Wald Chi2, Log Likelihood and Bootstrap Sample Size are calculated as the medians of 1000 regressions				

This table reports coefficient estimates from conditional logit models in Equation (2) with the adjustment of the number of potential acquirers. The dependent variable is equal to one for the actual acquirer, and zero for the potential acquirers. From Model (B1) to Model (B4), we test if our model is sensitive to the number of potential acquirers. We control for total assets as the covariate of propensity score matching. In Model (B1) and Model (B2), we only draw the closest potential acquirer from the pool of potential acquirers to match with the actual acquirers. In Model (B3) and Model (B4), we randomly draw up to 10 potential acquirers from the pool of potential acquirers to match with the actual acquirers. We present the median and standard deviation (as the bootstrapped standard error) of the empirical distribution of coefficient estimates from conditional logit regressions of 1000 bootstrapped samples.

Table A.2 Robustness Check (Panel C)		
Domestic M&A (ACQ) Actual Acquirers=1 Potential Acquirers=0	Conditional Logit Model	
	Adjustment for the propensity score matching	
	Model (C1)	Model (C2)
Explanatory Variable		
CSR	0.016***	0.014***
	(0.00)	(0.00)
RDI	0.59***	-1.49***
	(0.19)	(0.54)
Moderating Effect		
*CSR*RDI*		0.034***
		(0.01)
Control Variables		
M/B	-	-
	-	-
ROA	3.85***	3.73***
	(0.45)	(0.45)
CFO	-0.28***	-0.26***
	(0.07)	(0.08)
LEV	-0.0625	-0.068
	(0.08)	(0.08)
Bootstrap Sample	6497	6497
Original Sample	9449	9449
Wald Chi2	129	131
Pseudo-R2	0.03	0.03
Log Likelihood	-4257	-4254
Deal FE	Yes	Yes
Industry FE	Yes	Yes
PSM	*SIZE & M/B*	*SIZE & M/B*
Sample Weight	IPW	IPW
# Potential Acquirers	Up to 5	Up to 5
Bootstrap std err. are in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Wald Chi2, Log Likelihood and Bootstrap Sample Size are calculated as the medians of 1000 regressions		

This table reports coefficient estimates from conditional logit models in Equation (2) with the adjustment of the covariates of propensity score matching. The dependent variable is equal to one for the actual acquirer, and zero for the potential acquirers. Model (C1) and Model (C2) test if our model is sensitive to the covariates of propensity score matching. We control for total assets and the market-to-book ratio as the covariates of propensity score matching. Therefore, potential acquirers and actual acquirers, within the same industry, are grouped based on the similarity of firm size and the similarity of market-to-book ratio. Then, we randomly draw up to 5 potential acquirers from the pool of potential acquirers to match with the actual acquirers. We present the median and standard deviation (as the bootstrapped standard error) of the empirical distribution of coefficient estimates from conditional logit regressions of 1000 bootstrapped samples.

Table A.2 Robustness Check (Panel D)		
MA_COUNT	Conditional Poisson Model	
	Model (D1)	Model (D2)
Explanatory Variable		
CSR	0.016***	0.014***
	(0.00059)	(0.00071)
RDI	0.61***	-1.83***
	(0.19)	(0.57)
Moderating Effect		
*CSR*RDI*		0.038***
		(0.0082)
Control Variables		
M/B	0.014***	0.014***
	(0.0014)	(0.0014)
ROA	2.58***	2.43***
	(0.40)	(0.41)
CFO	0.0021	0.018
	(0.079)	(0.080)
LEV	-0.13	-0.14
	(0.099)	(0.100)
Original Sample	9,767	9,767
Wald Chi2	129	131
Log Likelihood	-10346	-10341
Time FE	Yes	Yes
Industry FE	Yes	Yes
PSM	*SIZE*	*SIZE*
Sample Weight	IPW	IPW
Robust (at industry-time level) std err. are in parentheses. *** p<0.01, ** p<0.05, * p<0.1		

This table reports coefficient estimates from the Poisson model with industry and time fixed effects. Firms engaged in more than one M&A deal within a quarter are included in this sample. The dependent variable is the aggregated number of deals done in a quarter. Model (D1) and Model (D2) test if our model is sensitive to a different model. We control for total assets as the covariate of propensity score matching. Therefore, acquirers and non-acquirers, within the same industry and time, are grouped based on the similarity of firm size.

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Innovation Patterns in Sustainable Practice Implementation: A Supply Chain Perspective

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ABSTRACT

A review of literature suggests that further empirical research, supported by an applicable and appropriate theoretical base, is critical to further understanding the relationship between types of innovation implementation of sustainable supply chain management (SSCM) practices in different industries. In this study, we adopt a multi-level innovation perspective to explore the relationships between innovation creation and the development of SSCM practices through theoretical lenses of organizational learning, ambidexterity, and absorptive capacity. Our multiple case design contributes to supply chain management and innovation literature and practice by identifying the different innovation types that emerge when SSCM practices are being implemented.

KEYWORDS: Sustainability, Innovation, Supply Chain Management, Case Research

INTRODUCTION

Sustainability as a business phenomenon has occupied the attention of academicians, practitioners, and consumers for more than three decades (Linton, Klassen, & Jarayaman, 2007; Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2016). The World Commission on Environment and Development (WCED) defines sustainability as “satisfying today’s needs without compromising the needs of future generations” (WCED, 1987, p. 43). Sustainability in organizations refers to the optimization of its three dimensions: environmental, economic and social (Elkington, 1997; Kaynak & Montiel, 2009; Svensson et al., 2016). Since the early 1990s, interest in sustainability has been expanding and now, as a result, includes supply chain management (SCM). Both practitioners and academicians have attempted to explain the importance of sustainable supply chain management (SSCM) in organizations (Handfield, Sroufe, & Walton, 2005; Linton et al., 2007; Srivastava, 2007; Carter & Rogers, 2008; Min & Galle, 1997). Surveys show that more than half of the executives queried believe that sustainability is extremely important for new product development, firms’ reputation, new practices, and as an overall strategy in their organization (Bonini & Gorner, 2011). However, a

significant number of organizations still do not know how to implement sustainability (The pain of sustainability, 2012). Some of the main challenges that companies face implementing sustainable practices are the costs associated with sustainability implementation, accurate risk assessment issues, fear of tradeoffs, and changes in corporate priorities (Epstein, 2008).
A review of the literature makes clear that sustainability can be effectively implemented by adopting new approaches to product development, adopting new processes, modifying an organization's structure (Hausten, Luther, & Schuster., 2014), and engaging in stakeholder management (Kaynak et al., working paper), but effective implementation also requires consideration of the internal and external factors that can affect firms' supply chains. Competition in the market and the need to improve sustainability forces companies to focus on innovation as well as on their research and development efforts. As the Rio Declaration of 1992 states in Principle 9, a focus on developing and adapting new technologies is a must for seeking the new practices and new implementations that will enable sustainable development in organizations (Rennings, 2000). Implementing new sustainable practices requires that organizations create new eco-innovations in their supply chains, and several studies address supply chain practices that can assist firms in achieving their sustainability goals (e.g., Adams et al., 2015; Wu, 2013). A frequently cited article in the Harvard Business Review (Nidumolu, Prahalad, & Rangaswami, 2009) as well as other studies (Seebode, Jenrennaud, & Bassent, 2012; Tohidi & Jabbari, 2012), for example, state that the ability to create innovative products, processes, and ways of operating is crucial if an organization implements sustainable practices.

Although there have been studies that investigate innovation in the context of sustainability, their scope is limited. Most address innovation from a single perspective (a micro or macro level). A study by Dangelico and Pujari (2010), for example, focuses on product innovation, whereas Schaltegger, Lüdeke-Freund, and Hansen (2012) emphasize business model innovation, and Elzen, Geels, and Green (2004) investigate system innovation. A single-level perspective limits the research to a narrow scope; thus, it often obscures the big picture of innovation, its creation, and its effects on firm performance.

Despite a vast amount of literature on the creation of innovation and its types, research on levels of innovation that show the magnitude of innovation coverage is lacking. Until now, only a few studies have attempted to examine various levels of innovation in a single study (Boons, Montalvo, Quist, & Wagner, 2013). Meyer and Goes (1988) investigated innovation from a multi-level contextual perspective. In this study, we will adopt a multi-level innovation perspective to explore implementation of SSCM practices because they are important to the creation of innovation and its types (Roy, Sivakuvar, & Williamson, 2004; Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2015). Implementing sustainability in supply chain management transforms the business arena into a competitive landscape and compels firms to alter the way they think about products, technologies, processes, and business models (Nidumolu et al., 2009), and these alterations require a series of innovations on multiple levels.

A review of literature suggests that further empirical research, supported by an applicable and appropriate theoretical base, is critical to further understanding the relationship between types of innovation implementation of sustainable SCM practices in different industries Organizational learning, ambidexterity, and absorptive capacity theories are appropriate theoretical lenses through which the research for this study can be viewed. Organization learning theory explains the processes by which organizations develop, innovate, and implement (Hedberg, 1981; Dibella, Nevis, & Gould, 1996).. In this study, absorptive capacity will help explain the relationship among SSCM practices and innovation patterns in firms' adapted sustainability practices in their supply chains. Ambidexterity directly affects how organizations approach the creation of new knowledge and innovation. In this research context, ambidextrous organizations use different strategies and approaches in the innovation process that seek new SSCM practices. Taking into consideration the theories cited above, this study proposes to find answers to the following question: What specific innovations do companies generate to implement SSCM practices effectively in specific industries?

We have utilized a multiple case design to achieve the purpose of this study. In addition to interviews, company reports and other available secondary data sources have been examined to triangulate the findings. This research contributes to supply chain management and innovation literature and practice by identifying the different innovation types that emerge when SSCM practices are being implemented in various industries.

LITERATURE REVIEW

Sustainable Supply Chain Management

Resource scarcity and operational inefficiencies in SCM have made sustainable supply chain management (SSCM) essential for organizations. Sustainability has been defined and become the focus of several research projects in various disciplines for three decades; however, in-depth research on SSCM has not yet been developed. SSCM is defined as an approach to supply chain management that creates, protects, and grows long-term environmental, economic, and social values for all levels in the chain (The Sustainable Supply Chain, 2010). Several studies have investigated the three-dimensional approach — environmental, social and economic — to sustainability in SCM (e.g., Seuring & Müller, 2008; Ahi & Searcy, 2013; Beske, Land, & Seuring, 2014).

Scholars have conducted numerous studies of SCM practices; however, only a few of these studies have focused on SSCM practices. SSCM practices encompass the internal and external practices of a firm that are implemented to make its supply chain more sustainable in terms of all three dimensions of sustainability (Kaynak & Montiel, 2009; Morali & Searcy, 2013; Paulraj, Chen, & Blome, 2015).

Sustainable supply chain practices (SSCP) are defined as activities or actions taken to improve supply chain-related functions or processes by increasing sustainability efforts in its social, environmental, and economic aspects (Golicic & Smith, 2013). Each aspect of sustainability impacts different processes and functions. The environmental aspect of SSC practices has been the major focus of SSCM research. Increasingly scarce resources, pollution, and waste have drawn attention to the environmental aspects of SSCM research and application (Zhu & Sarkis, 2004). The term green supply chain practices (GSCP) is commonly used in the research literature to refer to a number of activities performed by an organization to minimize its impact on the natural environment (Vachon & Klassen, 2006; Sarkis, Gonzalez-Torre, & Adenso-Diaz, 2010). Zhu, Sarkis and Lai (2008) also assert that green supply chain practices are an adoption of environmentally friendly supply chain management practices that include such things as cooperation with customers, eco-design, waste reduction, recycling, and the reuse and substitution of materials (Carter & Narasimhan, 1998), reverse logistics (Eltayeb & Zailani, 2009), supplier management inventory (Liu et al., 2012), supply selection and evaluation (Ben-Brik, Mellahi, & Rettab, 2013), and investment recovery (Perotti, Zorzini, Cagno, & Micheli, 2012). The current environmental and green practices that have been examined in the literature are listed in Table 1.

Recognition of the importance of sustainability's social aspects is growing significantly. Organizations that focus on social aspects of SSCP provide guidelines on corporate social responsibility initiatives, thereby creating a sustainable organization culture among employees and applying fair labor practices at all levels of their supply chains (e.g., Lopez, Garcia, & Rodriquez, 2007; Kaynak & Montiel, 2009). Increasing labor and workers' rights issues, community involvement efforts, and fair trade and sourcing have become focal points for firms whose operations are implementing sustainability (Erkul et al., 2015). As Table 2 shows, researchers have identified some of the social sustainability practices organizations can follow to comply with sustainability standards throughout the supply chain such as those relating to supplier ISO 26000, external codes of conduct, and employee health and safety (Castka & Balzarova, 2008; Spence & Bourlakis, 2009; Erkul et al., 2015).

The research on the economic aspect of SSCP emphasizes the reduction or elimination of environmental impact and increasing the economic value of an organization by reducing the cost of inputs such as eco-sourcing and waste management practices (e.g., Melnyk et al., 2003; Kaynak & Montiel, 2009, Golicic & Smith, 2013; Erkul et al., 2015). Improved sustainability efforts will enable firms to improve their brand reputation which will lead to higher market value (Shrivastava, 1995). Table 3 lists studies that examined the economic aspects of sustainability at the time firms were implementing sustainable practices.

Innovation and Multi-Level Perspective

Innovation has been a prominent phenomenon in the history of organizational research. For decades and for various reasons, practitioners and scholars have been studying the importance

of innovation in organizations (Biemans, 1992; Storey & Salaman, 2005; Trott, 2008; Simon, 2009). These investigations have produced an immense body of literature on innovation and definitions of the term, but so far no consensus has been reached on a definition of innovation (Rowe & Boise, 1974; Dewar & Dutton, 1986; Utterback, 1994; Utterback & Afuah, 1998; Garcia & Calantone, 2002). For this study, we will adopt the definition from the frequently cited study by Damanpour and Evan (1984) that defines innovation as "the implementation of an internally generated or a borrowed idea — whether pertaining to a product, device, system, process, policy, program, or service — that was new to the organization at the time of adoption" (Kaynak, 1997, p. 25). The holistic viewpoint considers innovation as changes in process, product, or organization aimed at adapting to an organization's external environment or to change its own external environment (Damanpour, 1996). For these reasons, innovation and its derivatives are used to explain the phenomena that include new products and services, processes, technology, structure, systems, and new programs in an organization.

Organizations' innovativeness is a key aspect of innovation development (Hult et al., 2004; Wang & Ahmed, 2004; Lee & Tsai, 2005), and several studies have already investigated organizations' innovativeness and types of innovation in various fields and settings. Wolfe (2007) asserts that across diverse disciplines, there are three major research streams regarding

TABLE 1

Environmental/Green Supply Chain Practices Investigated in Major Studies

Green SSCM Practices/Study	Handfield & Walton, 1997	Klassen & Johnson, 2004	Zhu & Sarkis, 2004	Srivastava, 2007	Nikbakshsh, 2009	Zhu & Sarkis, 2011
Environmental Certification	X	X				
Pollution Prevention		X		X	X	
Life Cycle Assessment	X	X		X	X	
Eco-Design	X		X	X	X	X
Reserve Logistics	X			X	X	
Internal Environment Management (E.G Waste Management)	X		X	X	X	X
Green Purchasing	X				X	X
Customer Involvement I in Environmental Requirements						X
Investment Recovery			X			X
External GSCM			X			
Upstream Practices	X		X			X

TABLE 2

Social Practices Investigated in Major Sustainable Supply Chain Management Studies

Social SSCM Practices/Study	Carroll, 1991	Carter & Jennings, 2002	Maloni & Brown, 2006	Castka & Balzarova, 2008	Hutchins & Sutherland, 2008	Spence & Bourlakis, 2009
Socially Responsible Purchasing		X				X
Code of Conduct	X				X	X
Health and Safety				X		
Community Initiatives					X	
Labor Rights			X			X
Fair Trade			X			
Animal Welfare			X			
Supplier Selection (Standards, e.g. IS0 26000)		X		X		X

Table 3
SSCM Practices and Economic Aspect of Sustainability in Major Studies
Innovation and Multi-Level Perspective

Studies/Practices	Production	Upstream/Supplier Facing	Downstream/Customer Facing	Product/Process Design
Carter, Kale & Grimm (2000)		X		
Kassinis & Soteriou (2003)	X			
Zhu & Sarkis (2004)		X	X	
Zhu & Sarkis (2005)				X
Gonzalez-Benito &Gonzalez-Benito (2005)			X	
Rao & Holt (2005)		X		
Zhu, Sarkis & Lai (2007)		X		
Vachon & Klassen, (2008)	X	X	X	
Yang et al. (2011)	X			
Govidan et al. (2014)	X	X	X	X

innovation typology: product vs. process (Gopalakrishnan & Damanpour, 1997), radical vs. incremental (Ettlie, Bridges, & O' Keefe, 1984; Normann, 1971), and technical vs. administrative (Evan, 1966).

Innovation has also been examined at many levels: micro, meso, and macro (Goffin & Pfeiffer, 1999). For this study, we propose a multi-level perspective of innovation characterized by structural and dynamic dimensions. The structural dimension pertains to the hierarchy of levels nested within one another where the most internal level is that of innovation representation at the micro-level of innovation. In other words, the micro level innovation is a single product, process, or technology level that is nested within the meso and macro levels of innovation, both of which are a broader phenomenon. Organizational learning theory has significant implications for the development of new knowledge and absorptive capacity over time, which may lead to much broader innovations and innovative performance of organizations (Cohen & Levinthal, 1989). Innovativeness as a shared system of meaning can be formed at each of these levels. The dynamic dimension pertains to the interrelationships among the different levels of innovation and the way they impact each other. The micro level innovations are much more specific and their effects on the environment are significantly limited as compared to meso and macro level innovations. As companies move to meso and macro level innovations, the effects of innovations on the environment become greater, respectively. The multi-level perspective claims the ability to analyze the innovation process from a broader perspective, the transition of simple incremental innovations to a new system of production or process, perhaps even a new socio-technical system that changes how a society operates (Smith et al., 2010). This broader perspective requires different innovation types at each level to cope with internal and external environmental factors.

The essential characteristic of the multi-level innovation perspective is that firms' organizational learning capacity and innovation creation process will vary in response to their environment, competition, and strategy. Thus, there will be a strong mutual relationship between a firm's choice of an innovation strategy and, particularly, the industry in which the firm operates.

Micro level innovation refers to an innovation that introduces a new or significantly improved service, process, or product at a level where it is effective only in its specific function. The scope of micro innovation is limited to a single product or process level, and most of the time it is a modification of existing technology, product, or service. Therefore, micro innovations are only marginal departures from existing practices and largely reinforce the existing potential of firms (Henderson & Clark, 1990; Ettlie, Bridges, & O'Keefe, 1984; Meyer et al., 1990). The difference between micro level innovation and the other two levels, meso and macro, is clear and distinct.

Over the past two decades, literature on innovation has emphasized organizational-level innovations, and this emphasis includes supply chains. *Meso level innovations* are defined as sets of activities linked by some product or process groups that create significant improvements or changes in organizations such as using or sharing new technologies or production systems

with suppliers (Malerba, 2004). Knowledge and technology varies across organizations or industries in terms of their specificity, tacitness, complexity, and interdependence (Breschi et al., 2000). The main characteristic of meso level innovation is that innovation patterns tend to display commonalities across elements of an organization such as different departments within the company that use the same innovative technology or buyers-suppliers who use the same innovative process in their supply chains. At the meso level of innovation, micro innovations are amplified by elements of an organization and its supply chain. In the last three decades, we have seen some dramatic examples of innovation creation at the meso level in big corporations and their supply chains like Proctor & Gamble's (P&G)'s Continuous Replenishment System which operates in conjunction with its suppliers. This system changed the company's whole supply chain strategy and its supply chain operations.

Macro level innovations can be defined as breakthrough changes that lead to newer and/or improved systems and structures. A list of examples of macro level innovations that have changed the structure of industry and even society might include such innovations as printing, the computer, and micro loans. Macro level innovations have a broader context than product and or process innovations; they require fundamental structural changes (Frantzeskaki & De Haan, 2009). The invention of the steam engine seems to be a product innovation; however, it also created a fundamental transition from carriage to automobiles and eventually to planes (Geels, 2002). Moreover, this far-reaching transition changed society and how it operates. Macro level innovations affect broader organizational and societal contexts; in other words, these innovations not only include product and process innovations but also changes in the external environment such as industry, government and policies, culture, consumer behaviors and habits, and management styles of firms (Kemp & Rotmans, 2005; Geels, 2006).

Innovation and Sustainable Supply Chain Management Practices

Our literature review indicates that firms implementing sustainability in their supply chains may map their innovation creation process at three levels: (1) whether it focuses on single and limited innovations, (2) the firm's view of innovation has broadened to include its supply chain and other business functions, and (3) the extent to which innovation extends beyond the supply chain to become closer to society and industry.

Based on organizational learning (OL) theory, sustainability, and OL support each other (Senge, 1999), and OL is essential for sustainability innovation (Sinkula, Baker, & Noordewier, 1997). Moreover, OL encourages a holistic approach to innovation and sustainability at every level. The literature shows that the higher the level of learning orientation, the greater the degree of firm innovativeness (Calantone et al., 2002; Weerawardena et al., 2006). The OL theory helps firms transform existing knowledge into new insights about products, processes, and services (Nonnaka, 1994), and it can explain the transformations that occur between different levels of innovation (Jimenez & Valle, 2011). Knowledge sharing within organization and with a supply

chain through interaction creates an appropriate environment for firm innovativeness (Jerez-Gomez Céspedes-Lorente & Valle-Cabrera., 2005).

In the multi-level innovation approach, organizations at the micro level of innovation add new sustainable products or processes to their existing product line and processes. In this stage, organizations aim to improve their sustainability efforts and reduce their sustainability impact by reducing waste and focusing on lean practices. Firms focusing on improving their environmental sustainability, for example, concentrate on pollution prevention, environmental certification, life cycle assessment, eco-design product and process design, reserve logistics activities, waste management, green purchasing, and upstream practices (e.g., Zhu & Sarkis, 2004; Klassen & Johnson, 2004; Zhu & Sarkis, 2011; Nikbakshsh, 2009; Srivastava, 2007; Walton & Handfield, 1998). At this level, innovations are typically incremental, address one issue at a time and tend to be focused inward with regards to both development and outcome. Companies typically rely on internal resources to innovate, and the resulting innovations are most likely company-centric: their intent is primarily to reduce costs or maximize profits.

Organizations at the meso level observe significant improvements in innovations, and they introduce new products or processes that may also improve other supply chain units such as downstream and upstream elements. This level can be exemplified as a new business model innovation in sustainability. Organizations at the macro level are already introducing significant innovations that change other agents in the industry and society that are parts of a broader interconnected ecosystem. As they move from the micro to the macro level, firms have a significant impact on sustainability in the system. Tesla cars, for example, will never be completely sustainable as long as its electrical vehicles are charged by fossil-powered energy sources. However, focusing on innovation and continuous learning, Tesla is expanding its product line to include solar energy panels and high capacity batteries, both of which perfectly represent the transition from micro to meso level innovation.

Every organization has different learning capabilities and absorptive capacities and, for this reason, organizations can, based on their resources and capabilities, move through different innovation levels. The leaps from the micro to the meso level and the meso to the macro level require radical shifts in an organization's mindset, shifts that vary with each company. Not all organizations start at a single level. Some launch innovations directly at the meso level by using business model innovation to implement sustainability in their supply chains. Lifestraw, a personal water filter company, is an excellent example of an organization that starts from meso level innovation. Its business model focuses not only on product and process innovation but also on meso level innovations that include unique distribution, societal, and financial innovation. Lifestraw targets markets that do not have access to clean water; thus, carbon-offset systems become a financial option. So, while this framework shows innovation and SSCM practices implementation as a sequential process, some ambidextrous organization can straddle more than one level. The ambidextrous organization is one that has a specific business unit or department experimenting with a more advanced stage of innovation while the rest of the

organization maintains a conventional approach. The ambidextrous approach to sustainability provides organizations flexibility and better chances for survival in the market (Van Looy, Martens, & Debackere 2005).

At the macro level of innovation, organizations perceive their sustainability initiatives as being part of industry and society, not distinct from them. At this level, innovations are designed and created to be collective and part of the system, and they are more break-through than incremental. System innovation is a great macro level innovation that includes not only a firm's supply chain partners but also includes competitor and other environmental actors. Because the concept is so broad, only very few new sustainable practices qualify for this level.

Rather than focusing only on innovations of limited scope, organizations can benefit from a broader new technology or process in their supply chains. Organizations may see opportunities to have all entities in their supply chains comply with sustainability standards, or serve new markets with sustainable products, or become new entrants with business models based on creating sustainability in their holistic operations.

Regarding the discussion above, the role of innovation in SSCP varies with the level of innovation, and firms need to introduce many different innovations and practices in quick succession. This could mean developing more than one version at once to comply with and achieve sustainability goals in the marketplace and learn where to focus their energies next. In short, companies need to be highly adaptable, so their SSCM practices need to be highly adaptable too. Firms tend to have diverse patterns while implementing SSCP.

RESEARCH METHODOLOGY

To achieve the objective of this the study, an exploratory qualitative research approach was adopted. The advantage to this approach is that researchers are able to obtain participants' stories and their insights into the phenomenon under study. It is because we want these stories and insights about firms' sustainability efforts that we employed the case study approach. One other advantage to this approach is that the case study methodology helps researchers explore a confined system of a case or multiple case by utilizing in-depth data collection from information sources rich in context (Creswell, 1998). Moreover, this methodology enables researchers to not only question the concepts and phenomenon itself but also provide a rich, in-depth context (Yin, 2003; Stake, 2013). The multi-case study method utilizes analysis within cases and between cases, and it produces a literature referred to as "creative reframing" (Eisenhardt, 1989). Researchers are interested in case studies because of both their commonality and uniqueness. To date, only limited empirical work has been done that draws on qualitative data to explore the relationship between innovation and SSCM. The multi-case study approach was utilized for this research because it provides robust methodological support that can generate new theories and detailed information (Eisenhardt, 1989; Ellram, 1996) that can help researchers explain the symbiotic relationship between sustainability and innovation. This

comparative, multi-case study is designed to explore how organizations in different industries develop and implement sustainable practices in their supply chains through the innovation creation process.

Case Selection

We used established criteria from the literature to select the companies for this study. The companies were chosen from multiple industries to identify innovation and SSCM patterns, and only companies that have implemented sustainability in their supply chains were recruited to participate. Multiple industry perspectives may reveal different patterns due to both the nature of the specific industry and the similarities among industries. External sustainability indices and rankings will be used to ensure that the selected companies have developed some form of sustainability practices. We consulted the following sources to select participant companies: (1) The Dow Jones Sustainability Index (DJSI). This index monitors the sustainability initiatives and performance of more than 500 top sustainability companies around the world; (2) The MSCI/KLD Index/Ranking. The MSCI/KLD is a global index that rates 6000 companies (11,000 with subsidiaries) based on their sustainability efforts and performance; (3) Global Reporting Initiative (GRI). The (GRI) is a comprehensive, global database that includes sustainability reports by companies and organizations about the economic, environmental, and social impact caused by their everyday activities.

In this study, 30 companies from eight different industries were contacted and 13 of them from seven industries agreed to participate. Two companies from each industry were selected to analyze the industry effect on the phenomena. At the end of case selection one participating company was eliminated from analysis due to a non-existing pair in the same industry. All companies are publicly traded global companies. U.S. and global companies that are based in the U.S. will be selected on the basis of research interest and ease of accessibility. Interview respondents were selected based on their involvement in innovation, sustainability implementation and adoption in their supply chain management.

Data Collection

The unit of analysis for this study is the individual organization, and data for each participant company is gathered from multiple sources: (1) semi-structured interviews, (2) internal company documents, and (3) publicly available online data (e.g., annual financial and sustainability reports). Semi-structured interviews enable the researchers to gather detailed information about the relationship between innovation and SSCM, the subject of our research, and provide answers to our research questions (Patton, 2005). Rigorous guidelines and steps will be followed in case selection, data collection and the data analysis process (See Figure 1). Combining multiple data sources enabled an in-depth investigation of sustainability (Yin, 2008) that includes current practices of SSCM and relevant innovation in the organizations being

studied. (Due to space limitation we could not include a copy of the interview protocol in the paper.)

After the selection of case participants, each interviewee was contacted by email and/or telephone (see Table 4 for the overview of the companies that participated in our study). From each company, two titles were identified to be part of the research. All the participants were knowledgeable about the research topic and have experience on the topic in their company. Titles of respondents vary in most cases. Regional and global supply chain directors/managers, lead sustainability officers, sustainability directors, lead R&D researchers/engineers and purchasing managers are the titles of the participants. In this stage, researchers obtained information about interviewees' willingness to participate in the study and scheduled an interview with interviewees. In this first communication, participants were informed about the study and interview process.

FIGURE 1
Research Methodology Framework

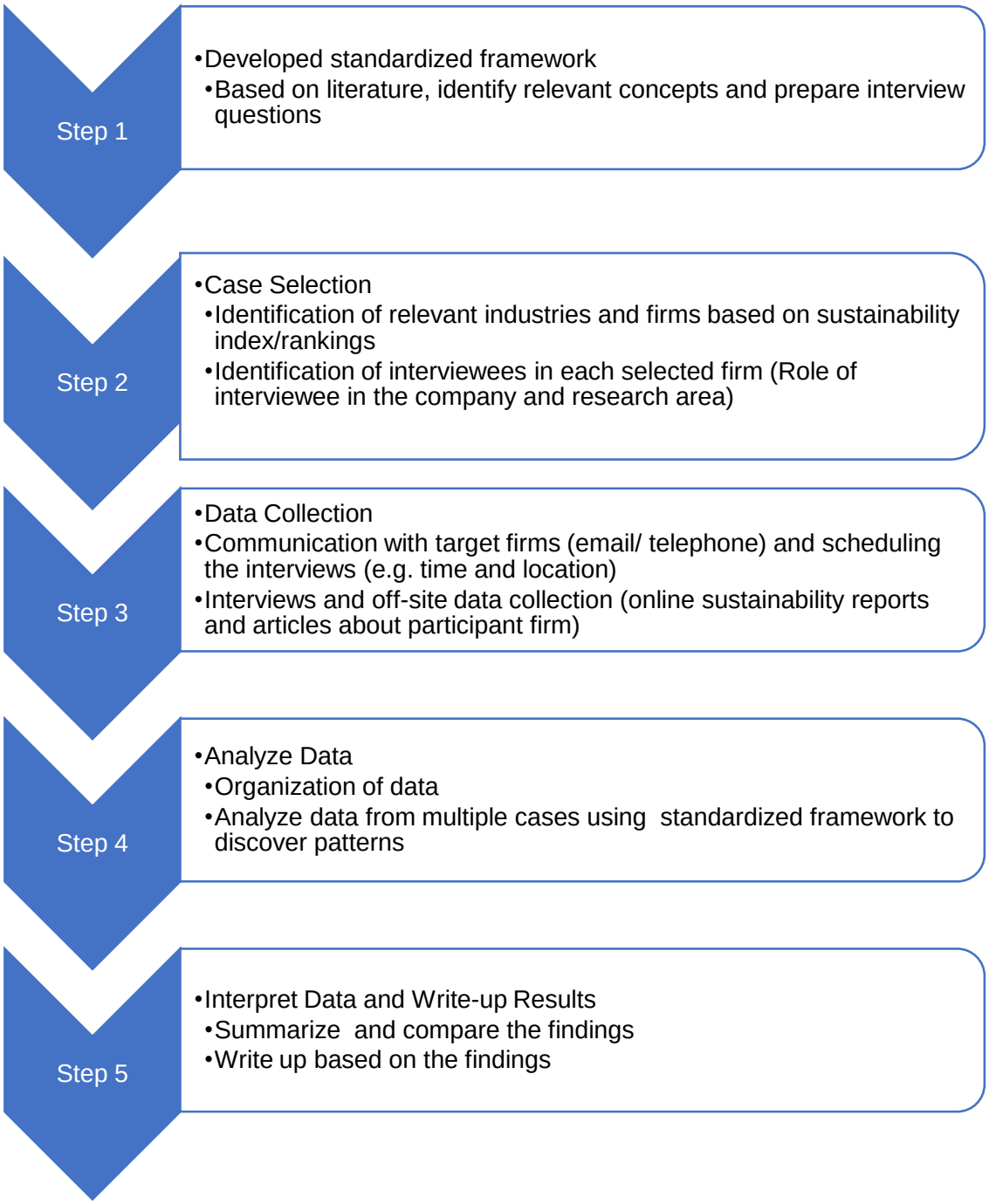

TABLE 4
Overview of the Firms Participated in the Study

Industry	**Pharmaceutical**		**Medical Device/Equipment**		**Food/Confectionary**		**Advanced Energy Storage and Solutions**		**Heating/Energy Solutions**		**Small Electronics**	
Cases/ Firms	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Research Setting	U.S. Head-quarter	U.S. Headquarter & Research Center	U.S. Head-quarter	U.S. Head-quarter	U.S. Head-quarter	U.S. Head-quarter	U.S. Head-quarter	U.S. Head-quarter	U.S. Head-quarter	U.S. Head-quarter	U.S. Head-quarter	U.S. Head-quarter
Size (No. of Employee)	Over 7,500 Employees in U.S. and Canada Only	Over 59,700 Employees Worldwide	Over 54,000 Employees Worldwide	Over 48,000 Employees Worldwide	Over 15,000 Employ-ees World-wide	Over 70,000 Employ-ees World-wide	Over 8,000 Employees Worldwide	Over 9,000 Employees Worldwide	Over 12,000 Employees Worldwide	Over 29,000 Employees Worldwide	Over 30,000 Employees Worldwide	Over 300,000 Employees Worldwide
Age of Company	Over 100 Years	Over 15 Years	Over 150 Years	Over 80 Years	Over 110 Years	Over 100 Years	Over 70 Years	Over 100 Years	Over 100 Years	Over 100 Years	Over 90 Years	Over 100 Years
Global Operations	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global
Primary Customers	Consumers, Organiza-tions and Governments	Consumers, Organiza-tions and Governments	Consumers, Organiza-tions and Governments	Consumers, Organiza-tions and Governments	Consumers	Consumers	Consumers, Organiza-tions and Governments	Consumers, Organiza-tions and Governments	Consumers, Organiza-tions and Governments	Consumers, Organiza-tions and Governments	Consumers, Organiza-tions and Governments	Consumers, Organiza-tions and Governments
R&D Expenditure	Over 2 Billion U.S. Dollars in 2016	Near 6 Billion U.S. Dollars in 2016	Near $ 300 Million	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed
Revenue	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	Not Disclosed	12 Billion Dollars	11 Billion Dollars	12 Billion Dollars	73 Billion Dollars

DATA ANALYSIS

Reliability and Validity

Scholars have criticized the validity of qualitative studies and their methodology, but researchers can utilize numerous validation methods to increase a study's reliability and rigor (Creswell & Miller, 2000). In this study, a triangulation method was used to establish credibility and validation. Data were triangulated by using several forms of data collected such as literature review, media interviews, and other documents. In addition, transcripts were rated by two researchers and patterns were identified based on their agreements. One of the most severe limitations of case research is that findings cannot be generalized due to the small number of cases. On the other hand, case methodology provides deep insights of unexplored phenomena that cannot be achieved by other methodologies.

Within Case Analysis

Pharmaceutical Industry

In this study, we selected two pharmaceutical companies to analyze the phenomena (see Table 4 for the overview of the companies that participated in our study). Industry has a unique nature, R&D development budgets are very high, and regulations imposed by both government and industry are strict. The cases studied in this research are major players in the industry. Both companies are market leaders in sustainability and members of the Pharmaceutical Supply Chain Initiative (PSCI) organization, which aims to support pharmaceutical suppliers in their efforts to operate with consistent quality while remaining compliant with industry standards of sustainability and consistent with industry expectations regarding labor, health and safety, environment, ethics, and management systems.

Firm A leads the Over the Counter (OTC) market in US and captures the majority of medicines. The division operates as headquarters and a research center for their products. North America office controls majority of the functions such as product development, manufacturing and supply chain activities. The office also controls the operations and manufacturing facilities in Mexico.

Economical sustainability is the main driver for Company B's implementation of sustainability practices in its supply chain. Lean practices, internal supply chain practices, and waste management practices are the main economical practices that have been implemented in its supply chain. The firm eventually realized that lean practices, resource, and waste management practices improved its environmental sustainability. Interviewees added that most of the innovation and practices are relevant to single product and process levels, though some, such as lean practices, have a broader scope. The firm established lean practices and worked with its supply chain players so that it affects a broader range and magnitude of sustainability practices. The social aspects of sustainability and social practices were not well developed until recent years, but Company B now has new social initiatives that capture the social aspects of sustainability.

Medical Device Industry
As in the pharmaceutical industry, innovation and improvement are crucial in the medical device industry if it is to survive and be successful. Innovation creation and R&D activities help the firm increase its efficiency and improve product and process performances. On the other hand, the medical field has very strict regulations which may slow down innovation creation.

The companies C and D emphasize the process innovation that will enable it to reach their sustainability goal. Water consumption, efficient material management, and waste management are some of the major improvements that enable companies to create operational advantage. Additional improvements in production processes and sustainable sourcing with green manufacturing facilities have improved production's sustainability performance.

The quality of life of both employees and the community is important in this industry. Firm C, for example, has continuous improvement programs that promote employee health and safety as well as community wellness. These programs are the major social sustainability efforts undertaken with the aim of increasing Company C's sustainability initiatives.

Confectionary
In this industry, companies E and F implement several sustainability practices to reduce their environmental impact such as reducing carbon emission waste, water consumption, and packaging material. Supplier development is another practice they implement to promote both environmental and social sustainability. Innovation in processes and their supply chain, the company believes, is the key to reaching sustainability goals. The companies in the industry mainly focus on process and social innovation to increase sustainability initiative.

Advanced Energy Storage and Solutions
The companies in the advanced energy storage and solutions industry suffer from a poor sustainability image due to the materials they use in their products. But the industry also has the highest recycling rate compared to other industries. Advertisements, recycling educations, and buyer-integrated recycling programs make the industry one of the top performers in recycling.

The companies implement continuous improvements, and they pursue new technological advancements in battery technology. These innovations range from enhancements of existing products with higher reliability and efficiency rates, to innovative service solutions, and to transformative technologies that will change the power solutions of the future. For example, Company H's innovation strategy is based on delivering better products that reduce costs, extend product life cycles, and reduce environmental impact. By recycling batteries, the firm decreases its costs significantly and it tries to impose the same sustainable practices on its suppliers, so that they too can achieve a lower environmental footprint while still making money. Waste management and lean manufacturing are the other practices that the company actively implements to promote sustainability.

Heating and Energy Solutions
Heating and energy solutions industry is an industry that has a direct effect on sustainability issues. The industry is evolving around new energy sources, so efficiency is becoming a key factor in the heating and energy solutions industry.

Company I, for example, engages in all three aspects of sustainability. The major activities that the company implements for environmental and economic sustainability are material management, recycling, eco-product, waste management, process design, and lean practices. The company also focuses on elevating the quality of life of its employees and society by implementing health and safety practices and educational programs.

Small Electronics
The small electronics and personal electronics industry is growing drastically due to new technological developments. Increasing efficiency due to automation and lower labor costing developing countries support the rising trend of small electronics. The industry is known for fast-paced product introduction and technological developments. The downside of new product introduction is growing in sustainability concerns. Increased energy consumption due to high use of electronics, electronic waste, limited recycling programs, and some health and well-being effects of small electronics challenges the sustainability of the industry. Both companies 'emphases are on their environmental and manufacturing processes. To achieve these environmental goals, firms K and L implement new practices and technologies that enable them to reuse and recycle materials and reduce waste from their operations. The scope of recycling and waste management is generally limited (micro level) and is usually implemented in both companies in this study.

Between Case Analysis

Each case described above has gone through a unique process of innovation and sustainability in its operations. This evolutionary process and the relationship between innovation and SSCM practices and the levels of innovation are captured in this study. We now discuss how each of these areas of comparison plays out in these cases.

The results of the cross-case analysis showed that the innovation creation process varies based on companies' resources and product types; however, some innovation patterns are similar. The companies emphasize innovation because of market conditions and economic factors, and they pursue innovation and sustainable practices with the aim of cutting their long-term operational costs. Environmental and economic practices such as waste management and quality management are the most common practices across industries and the cases studied. Only a few of the cases actually innovated to implement social sustainability practices to impact society and improve the quality of life in their communities.

Some industries are highly regulated, so product development in such industries as pharmaceuticals and medical devices can take years. Those industries tend to focus on

product/process innovation at the micro level, quality and lean management practices at the meso level, and social practices at the macro level, such as social initiatives in developing countries.

DISCUSSION

This research investigated innovation creation and the implementation of sustainable supply chain management practices to answer the research question: “What specific innovations do companies generate to implement SSCM practices effectively in specific industries.” While companies create innovations to implement sustainability in their supply chains, there are some specific innovations that outshine the others in SSCM practices implementation in different industry condition. All the cases studied have participated in various activities that developed new, innovative sustainable processes as well as products. The interviews allowed us to understand the innovative activities in different industries and firm settings. Implementing sustainability practices has also led companies to the development of diverse innovation mixtures from a multi-level perspective. Companies have focused on micro innovations to improve their current processes and products, and they have focused on meso innovations mainly to increase supply chain sustainability and efficiency. Results showed that macro level of innovations are rare, almost non-existent in current market conditions, and they are currently limited to social aspects of sustainability such as society welfare practices in the markets of developing countries.

As noted earlier, a multi-case research approach was utilized to investigate our research question with a relevant theoretical framework. The results indicate that organizational learning, absorptive capacity, and an ambidextrous orientation of the firms have significant effects on innovation and SSCM practice implementation and management. Firms vary to some degree in management approaches and exploration-exploitation ratio; however, all sustainability-oriented firms follow an ambidextrous strategy. Firms with high revenues and R&D budgets tend to manage implementation simultaneously and effectively, and they aim to pursue the original innovations that guarantee technological advances in the future. Given finite resources, firms need to balance exploration and exploitation during the process of innovation and implementing SSCM practices. Otherwise, they fail to develop both new sustainable products and processes for market launching and original technologies for sustainability implementation and its outcomes while continuing their current operations. However, some industries such as pharmaceuticals and medical device/ technologies, have been significantly affected on implementation processes due to higher regulations and industry requirements.

Cross-case analysis helps researchers identify uncommon innovation patterns, practices, and development processes. The advanced power storage and energy solutions industry is unique in its nature. Products and sourcing are standard, mature, and unsustainable. The main product can be one of the most toxic products that every consumer uses every day such as batteries. Furthermore, interviewees unconventionally expressed their concerns about their products’ future because current technology has reached 95 percent capacity. But market demand is

growing due to increasing use of electronics, hybrid cars, and new energy solution options. All these factors encourage battery producers to be more innovative in their internal and external processes and adopt such practices as product life cycle analysis, recycling/waste management, and lean practices within the company and throughout the supply chain; innovations yield higher efficiency and lower costs.

> *Proposition 1: In industries with mature products, where market demand for new products is high, companies are more likely to create internal and external process innovations that lead to economic sustainability.*

In some industries, products must align with sustainability demands of the market. In this study, two companies in the heating/energy solution industry are distinctive from others. These two companies must be sustainable due to characteristics of the products they manufacture. Customers of this industry seek the energy efficiency that will reduce costs and be greener. Because they produce sustainable products, the companies are aware that social sustainability practices are needed to achieve complete sustainability and increase customer satisfaction, and these factors are the ones that ultimately motivate firms to emphasize sustainability in all three aspects.

> *Proposition 2: In industries with sustainability-oriented products, companies tend to emphasize all three dimensions of sustainability along their supply chains.*

Cross-case analysis reveals that companies in innovative industries have different innovation creation patterns and prioritize their innovation choices based on the characteristics of the products and industry. In this study, for example, small electronic companies chose to implement innovations that emphasize eco-product design, product life cycle analysis, and process efficiency by employing lean and quality management practices. In other words, the industry is dynamic, so firms must come up with new products frequently. Therefore, these firms channel their sustainability efforts into the product and process level.

> *Proposition 3: In industries with innovative products emphasize micro and meso level innovations rather than macro innovations. These companies are more likely implement product and internal/external process practices than social practices.*

Overall, this research revealed that the pattern of innovation creation and the implementation of SSCM practices in the studied organizations differed based on the industry in which they are operating. Future studies can be conducted to see if these results hold for other organizations in different industries.

Little research has been performed using a survey methodology to study sustainability in supply chain management. After developing appropriate measurements, the use of survey methodology could provide greater insight and generalizability into how innovations are created

and sustainable practices are implemented in companies and their supply chains which by expanding this research could be used to verify results of this study.

In addition, further research is needed to assess recent changes in sustainability as well as industry and market conditions. Involvement in sustainability has increased substantially since early 2000, and more stakeholders are demanding that organizations be sustainable in their operations, especially in their supply chains. As a result, companies are driven to sustainability by business needs versus just “being good.” Since most firms have been implementing sustainability for over a decade, applications of sustainability may be less challenging in some cases. Future research is needed to study sustainability within supply chains to determine if they keep innovating and continuously improving, as they stated in the interviews.

LIMITATIONS AND CONCLUSION

As with all empirical studies, this one has several limitations that must be considered when interpreting the above findings. To begin with, we address several issues with the research methodology used. In the studies that use a multi-case qualitative approach, the results of the study are based on researchers’ interpretation of the data. As a result, researcher bias can inevitably be present. To mitigate this bias, two researchers transcribed and analyzed the data.

The study was also limited by the number of companies selected for analysis. These companies are large, global organizations considered leaders in sustainability. They are involved in industries that are innovative and amenable to sustainability, and they have a history of being sustainable and addressing environmental, economic, and social issues. Different results may have been found if the following types of companies had been used: smaller-sized companies, companies in sustainability-averse industries such as oil or mining industries, companies with weaker sustainability standings, and companies in less regulated and developing countries.

The research data were also limited based on the relatively limited number of interviewees for each case. The participants were all related to sustainability and supply chains in upper-level management. The results may have been different if a larger number of participants was included in the study or if participants from different functions of operations had been included. Finally, the study only utilized a case methodology to explore phenomena, and this limitation may create some shortcomings in generalizing the results in different company settings.

Implementation of sustainability in supply chains is a complex process. It is affected by several factors such as industry, customer demand, suppliers, government and industry regulation, and financial markets. It also requires full collaboration within organizations and initial investment. This research provided insights into the relationships between innovation and SSCM practices and their complex implementation patterns in various industries. The findings of this research contribute to ongoing sustainability research that examines the influence of innovation creation that ultimately may affect firms’ sustainability outcomes.

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DECISION SCIENCES INSTITUTE
Institutional Uncertainty and Supply Chain Quality Management:
A Conceptual Framework

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ABSTRACT

This paper considers the impact of institutional uncertainty on supply chain quality management (SCQM). The influence of institutional environments on SCQM practices is important to understand as lengthening supply chains cross international borders and are subject to increasingly complex institutional jurisdictions. Generally, SCQM facilitates stability of resource flows in institutional contexts. As uncertainty increases, SCQM practices are proposed to shift from abiding postures to those that evade and alter unstable institutional settings. An implication is that effective inter-organizational quality management requires capability for coping with political and legal instabilities that influence quality-related aspects of resource exchange between supply chain members.

KEYWORDS: Quality management and systems, Relationship management, Innovation Process, Contracts, Outsourcing, Supply chain management, Conceptual modeling

INTRODUCTION

Supply chain quality management (SCQM) is a systematic approach to performance management involving the coordination and integration of business processes among upstream sellers and downstream buyers to create value and achieve customer satisfaction (Foster, 2008; Robinson & Malhotra, 2005). SCQM is essential to integrating supply chains as it spans organizational boundaries to govern quality-related attributes of transactions between supply chain members (Flynn & Flynn, 2005; Ford, 2015; Terziovski & Hermel, 2011).

Although modern supply chains operate in a variety of environments, research concerning external contexts that shape SCQM practices has only recently captured scholarly attention (Foster, 2011). For example, Ford (2015) proposed that the intensity and nature of SCQM was contingent on the degree of uncertainty present in supply chain environments. Generally, the more uncertain the environment, the greater the SCQM intensity required to stabilize the quality of resource exchange between supply chain partners. Empirical investigations into antecedents of supply chain integration (e.g., Wong & Boon-itt, 2010) offer confirming evidence in this regard.

Research that investigates SCQM as a function of the external environment can be enriched by extending the uncertainty construct into the institutional realm. Institutional uncertainty should play a significant role in shaping inter-organizational quality management

activities. In the context of supply chain management, institutional uncertainty fosters unpredictability and doubt about the political and legal systems in which supply chain managers operate. Political and legal systems are essential components of supply chain environments because institutions therein set "the rules of the game" for everyday market exchange and its governance (Baumol, 1990; Williamson, 2000).

Although they generally change slower than everyday market contexts, institutional environments provide evolving backdrops for SCQM practices that are important to understand, particularrly as lengthening supply chains cross international borders and are subject to increasingly complex institutional jurisdictions (Foster, 2011). Uncertainties about institutional environments such as those brought about by regime change and regulatory revision should prompt managers to adjust their SCQM practices to better stabilize resource flows (Ford, 2015). The nature of those adjustments constitutes the primary focus of this paper.

This study extends research into the external context of SCQM by considering the impact of institutional uncertainty on SCQM practices. The paper proceeds as follows. First, Williamson's (2000) hierarchical model of economic institutions is employed to link previous work that conceptualizes SCQM as a means for stabilizing resources flows in uncertain environments to the institutional context. Then, drawing from concepts developed by Henrekson and Sanandaji (2011) in the domain of institutional entrepreneurship, propositions are developed that frame SCQM as a progression of postures meant to abide by, evade, or alter governing institutions as uncertainty increases. Finally, these propositions are summarized and discussed along with their theoretical and practical implications. A primary contribution of this work is the idea, largely novel to the quality literature, that effective inter-organizational quality management requires capability for responding to, and in some cases altering, political and legal systems that influence quality-related aspects of resource exchange between supply chain members.

GENERAL RELATIONSHIP

Because they are rarely self-sufficient, organizations must interact with their environments to acquire resources for survival and growth (Lawrence & Lorsch, 1967; Pfeffer & Salancik, 1978). Conditions of interdependence arise as organizations rely on each other for production and trade of important resources in supply chains (Handfield, 1995). Maintaining orderly resource flows from supply chain partners thus becomes a primary organizational objective (Katz & Kahn, 1978). Unfortunately, operating environments are prone to uncertainty that challenges the stability motive (Emery & Trist, 1963; Pfeffer & Salancik, 1978; Weber & Meyer, 2014). As uncertainty increases, interdependent organizations are likely to establish negotiated environments where exchanges are governed by various mechanisms aimed at stabilizing resource flows (Cyert & March, 1963; Williamson, 1991; Oliver, 1991; Paulraj & Chen, 2007; Wong et al., 2011).

Central to the governance of exchange among supply chain members is managing the *quality* of resource flows (Flynn et al, 2010). Poor quality upsets resource exchange (Ford, 2015). For example, low quality shipments might be rejected outright or create subsequent problems in the supply chain that hinder trade. To stabilize the quality of resource flows, managers develop sets of practices—supply chain quality management (SCQM) practices—that govern quality-related dimensions of supply chain exchange.

Like their intra-organizational counterparts (Flynn et al., 1995), SCQM practices can be categorized as core or infrastructure based (Ford, 2015). Core SCQM practices are formal activities that enhance uniformity and reduce quality-related upsets in resource flows between supply chain partners. Examples of core SCQM practices include quality incentive contracting

and audits of supplier facilities. Infrastructure SCQM practices are informal activities that strengthen relationships between supply chain partners. Interorganizational problem-solving teams and joint customer/supplier planning groups exemplify infrastructure SCQM practices. Table 1 displays representative SCQM practices associated with the various categories of the Baldrige Criteria for Performance Excellence (CPE).

Table 1: Traditional Supply Chain Quality Management Practices
Adapted from Ford (2015)

Baldrige CPE Category	Representative Practice	Quality Practice Orientation
Leadership	• Senior leader participation in inter-organization quality initiatives • Development of cross organization visions and values • Senior leader information sharing between organizations	Infrastructure
Strategic Planning	• Joint customer:supplier long range planning • Strategic initiatives that involve collaboration with supply chain partners	Infrastructure
Customer Focus	• Engagement with customers in market listening and learning processes • Customer relationship and complaint management • Co-development of product and service specifications	Core/Infrastructure
Information & Analysis	• Extensive customer and supplier databases • Cross organization data sharing • Supplier process capability assessment	Core
Workforce Focus	• Inter-organizational problem-solving teams • Customer-supplier training programs • Incentive systems that reward inter-organization collaboration	Infrastructure
Process Management	• Supplier quality assurance system registration • Supplier selection and evaluation processes • Joint product and process design	Core

- Co-managed work systems and processes

Because risk of quality problems increases as environments become less stable (Sitkin et al.,1994), SCQM efforts are likely to intensify in uncertain contexts so that quality of resource flows can be stabilized (Ford, 2015). Moreover, SCQM practices should assume different orientations depending on whether volume or technological uncertainty is present in the environment (Ford, 2015). Volume uncertainty impairs ability to accurately forecast quantity requirements in supply chain relationships (Geyskens et al., 2006). When volume uncertainty is present, managers are likely to orient SCQM toward core practices, such as quality contracting and audits (e.g., Gray & Handley, 2011; Sroufe & Curkovic, 2008), in order to reduce the likelihood of interorganizational quality problems (Zhu et al., 2007). Technological uncertainty stems from unpredictable standards or specifications, or from general conditions of rapid innovation or technological ferment that reduce ability to forecast technical requirements in supply chain relationships (Benner & Tushman, 2003; Geyskens et al., 2006). When technological uncertainty is present, SCQM orientations shift toward practices that build relational infrastructure and interorganizational capacity for cooperation (e.g., Dyer & Singh, 1998; Geyskens et al., 2006; Handley & Gray, 2013; Heide, 1994; Kanter, 1994) to increase the likelihood that quality of resource flows will be maintained in turbulent supply chain settings.

While volume and technological uncertainty have been long been seen as important dimensions of external environments (e.g., Walker & Weber, 1984), uncertainty stemming from institutional forces is likely to shape supply chain contexts as well (Williamson, 2008). Williamson's (2000) hierarchical model of economic institutions (Figure 1) is useful for conceptualizing institutional dimensions in supply chain environments. The bottom level of the hierarchy, L4, represents markets, or "the game." This is the level of everyday resource allocation in supply chains. Economic actors play the game by making decisions about prices, quantities, incentives, quality, and other factors that drive market exchange. The dynamic nature of markets keeps this level in a constant state of flux.

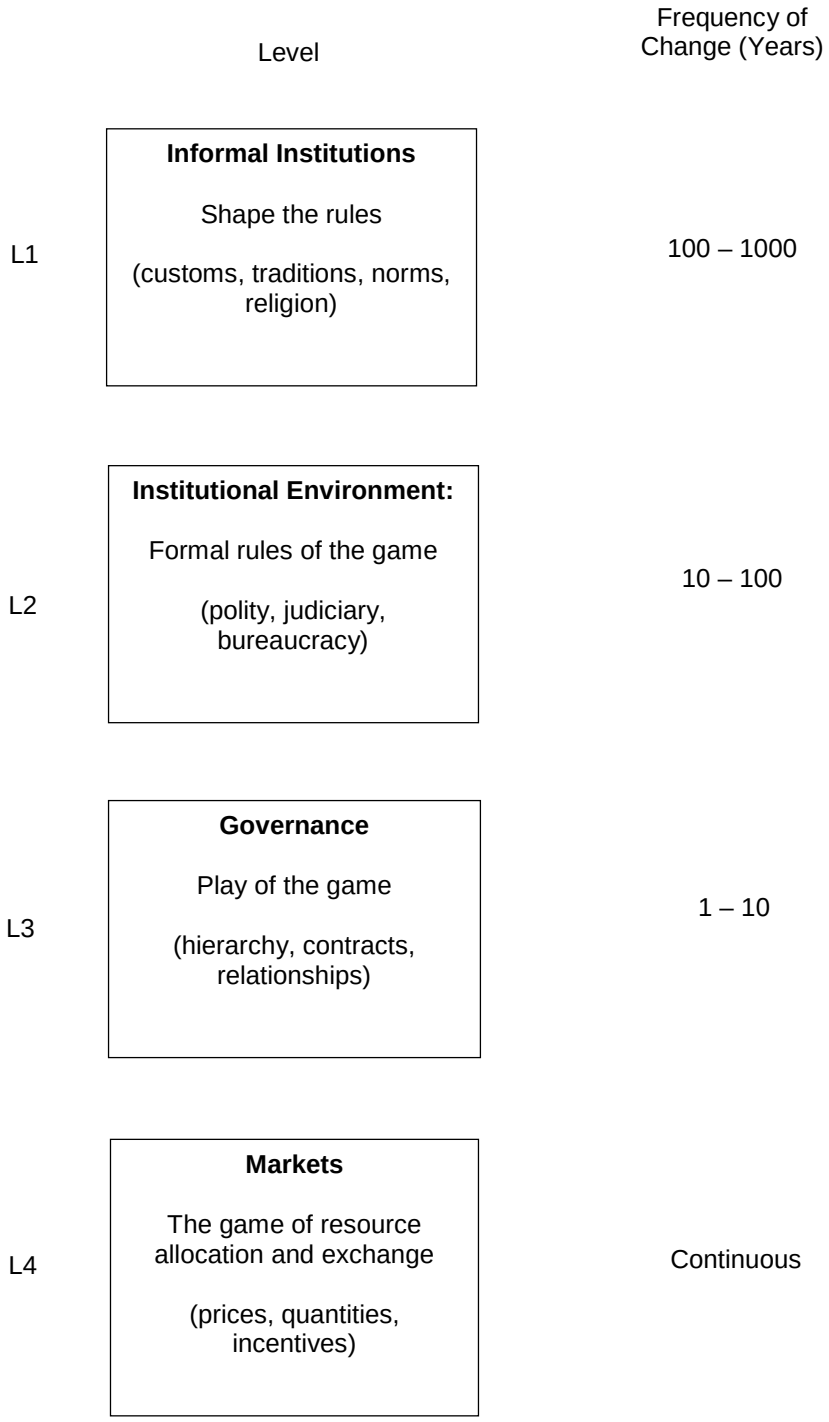
One level higher in the hierarchy, L3, involves mechanisms that buyers and sellers employ to govern resource exchange. These mechanisms direct "the play of the game" and include contracts and organizational hierarchy that assist in stabilizing resource exchange. Because they serve to maintain stable resource flows between supply chain partners, SCQM practices such as those noted in Table 1 can be seen as methods of exchange governance associated with L3. The L3 environment is less dynamic than L4, with important changes occurring perhaps over one- to ten-year time spans (Williamson, 2000).

Presiding overhead is the institutional environment, L2. The institutional environment establishes the formal "rules of the game" for the lower levels of the hierarchy and, when necessary, enforces those rules as well (Baumol, 1990). Because the rules important to market exchange generally concern property rights and contract law, L2 traditionally involves political and legal systems as well as acts of administrative bureaucracy. The institutional environment changes slower than lower levels (Dimaggio & Powell, 1983; Williamson, 2008). The institutional environment is influenced from above by an L1 level involving informal customs, norms, and traditions that evolve very slowly and are generally not subject to economizing behavior by market actors.

Uncertainty increases at the institutional level when doubts surface about the rules of the game or their enforcement. This uncertainty may stem from various sources. For example, voluminous laws and regulations may be difficult for supply chain managers to understand. Newly elected regimes may foster reservations among practitioners about how rules will be interpreted and enforced. Varied legal opinions rendered by courts may create confusion about

how laws will be applied toward particular exchange relationships between supply chain members. Slow moving bureaucracies could reduce confidence in the content and timing of new regulations as well as the disposition of contests over existing regulations.

Figure 1: Hierarchy of Economic Institutions
Adapted from Williamson (2000)



It is uncertainty associated with the institutional level (L2) that is the primary focus of this paper. How uncertainty at the L2 level shapes SCQM is discussed below.

SCQM RESPONSES TO INSTITUTIONAL UNCERTAINTY

Because institutional uncertainty can be conceptualized as originating at a level that presides over everyday environments facing supply chain managers (Williamson, 2008), it is reasonable to question whether it constitutes a unique problem for inter-organizational quality management. Perhaps institutional uncertainty is merely an antecedent of the volume and technological uncertainties that supply chain managers routinely cope with. For instance, doubts about a newly elected regime's regulatory stance at the institutional (L2 in Figure 1) level might create volume uncertainty in a supply chain to be dealt with actions at the governance (L3) or market (L4) levels. If institutional uncertainty merely trickles down to shape everyday uncertainties experienced by supply chain managers, then there may be little that is interesting about the situation from a theoretical standpoint.

However, institutional uncertainty *does* present unique challenges to supply chain managers. One issue involves coping with time lags between institutionally caused disturbances in the environment and everyday supply chain effects. For instance, it may take several years before the regulatory preferences of an incoming political regime manifest in routine volume or technological uncertainties. Uncomfortable with waiting out the process and its potentially undesirable consequences, supply chain managers might consider preempting the lagged effects with near term actions that respond to institutional forces directly and provide clarity sooner rather than later.

A larger issue involves the effect of institutional uncertainty on SCQM practices themselves. Rather than indirectly influencing everyday supply chain uncertainties, instability at the institutional level could motivate managerial responses that differ from the stable of practices in Table 1 designed to cope with volume or technological uncertainty.

Insight into the shape of such practices can be drawn from research in institutional entrepreneurship. When facing institutional uncertainty, managers can respond entrepreneurially in three general ways (Henrekson & Sanandaji, 2011): they can *abide* by the existing institutional order, they can *evade* its influence, or they can *alter* the institutional environment in some way. SCQM practices that address institutional uncertainty can be viewed in a categorically similar fashion as a function of the general level of perceived institutional uncertainty present.

Low Institutional Uncertainty

When institutional uncertainty is low, managers possess little doubt about the compatibility of their SCQM practices with existing institutions. Institutional rules that influence SCQM practices, such as government-enforced product quality and safety standards, are generally understood and uncontested. Because the institutional environment (L2 in Figure 1) is viewed as relatively benign, managers are likely to abide by the existing institutional order. Maintaining the status quo under such circumstances supports the stability motive and preserves resource flows (Oliver, 1991).

With the higher level (L2) institutional environment perceived as stable and non-threatening, supply chain managers are likely to focus attention on instabilities emanating from lower levels of the hierarchy (L3 and L4). Volume and technological uncertainties prone to impact everyday resource exchange are easier to recognize, and managers can draw from their stable of traditional activities appearing to Table 1 to orient SCQM toward addressing them. High levels of volume uncertainty will prompt core SCQM orientations that emphasize formality while high levels of technological uncertainty will engender infrastructure SCQM orientations that favor informal relationship building (Ford, 2015).

When institutional uncertainty is perceived as low, the cost of bearing that uncertainty by assuming an abiding posture in SCQM is presumed to be low as well. Managers will favor the status quo and draw from their familiar set of SCQM practices to maintain resource stability in the event of volume and technological uncertainty.

Proposition 1: At low levels of institutional uncertainty, organizations will prefer abiding postures composed of traditional core and infrastructure SCQM practices.

Rising Institutional Uncertainty

As institutional uncertainty rises, doubts increase about the legal and regulatory backdrop that establishes the rules for everyday supply chain exchange. Abiding SCQM postures that worked well in stable institutional environments become problematic for supply chain quality managers because maintaining status quo measures when institutional environments are in flux can be risky. Rules thought to govern routine supply chain exchange may no longer apply, rendering the stock of traditional SCQM activities appearing in Table 1 ineffective. Moreover, because abiding postures reinforce the prevailing institutional order (Henrekson & Sanandaji, 2011), supply chain managers might fear that they will fortify undesirable institutions in-the-making if they maintain status quo SCQM measures.

Because institutional uncertainty increases the cost of keeping what has worked in the past (Bylund & McCaffrey, 2017), supply chain managers will search for alternative arrangements that will stabilize resource flows and their quality despite institutional turbulence. Due to the cost of change, however, managers will generally be reluctant to change practices too radically. Therefore, when they begin to sense that institutional uncertainty is rising, managers are likely start with incremental changes that still constitute an abiding posture. Early attention will be paid to the existing stable of SCQM practices (Table 1) and how its application can be modified to better facilitate quality of resource exchange. In particular, managers are likely to reduce their reliance on core SCQM orientations. By definition, rising institutional uncertainty decreases confidence in rules and regulations that shape governance of technical quality practices. For example, doubts about how contracts might be enforced by a new legal regime could reduce the perceived utility of quality contracting and quality auditing. It follows, then, that core SCQM orientations aimed at governing formal aspects of quality transactions will appear less attractive.

Instead, managers will increasingly favor infrastructure SCQM orientations as institutional uncertainty grows. Infrastructure SCQM practices such as interorganizational steering committees and problem-solving teams, and customer/supplier quality training programs, involve informal exchanges that are generally not legally enforceable. As such, infrastructure SCQM practices generally fall outside the purview of institutional control. Moreover, infrastructure SCQM practices focus on relationship-building between supply chain members. These relationships build governance mechanisms grounded in trust, joint action,

and procedural fairness that establish strong alliances over time (Chen & Paulraj, 2004; Dyer, 1997; Poppo & Zenger, 2002). Because they do not depend on particular rules or regulations, infrastructure SCQM practices can endure large institutional shifts while encouraging mutually beneficial collaboration between supply chain members on quality matters. By shifting toward infrastructure SCQM orientations, managers can develop relational governance mechanisms that stabilize resource flows in turbulent institutional settings.

Proposition 2: As institutional uncertainty increases, abiding will occur in the form of greater orientation toward infrastructure SCQM practices.

While helpful, greater use of infrastructure SCQM orientations is unlikely to be completely satisfactory as institutional uncertainty continues to rise. Inter-organizational relationship building can improve agility in unstable settings, but it underutilizes specialized assets that have been developed for formal governance of the quality of resource exchange (Handley & Gray, 2013). Quality contracting and auditing capabilities, for example, may depreciate from lack of use as managers reduce core SCQM orientations. As such, supply chain managers will seek ways to more fully employ SCQM assets by evading the influence of institutions perceived to be in a state of flux.

Evading postures are attractive because they manifest in activities that occur at the familiar, everyday levels of supply chain exchange, L3 and L4. Change at these levels is viewed by managers as relatively inexpensive as it usually requires extending existing practices to new domains that evade the reach of undesirable institutional forces. Examples of evasion at the L4 level in the context of SCQM include developing relationships with customers and suppliers deemed to be less affected by institutional turmoil in particular markets (e.g., “offshoring”), and intensifying market listening posts to extract more quality-related information in noisy institutional settings.

Evading at the L3 level involves modifying governance structures that stabilize quality of resource exchange despite institutional uncertainties that cast doubt about overarching rules of the game. For instance, supply chain managers might be uncertain about the level or direction of government-imposed quality standards perceived to be in a state of flux, or, under the auspices of a new political regime, managers might distrust the legal system’s ongoing capacity to justly enforce contracts.

Successful evasion often requires more collaboration among trading partners. A trade group, for example, might sponsor a committee of industry representatives to develop quality-related standards for industry use. Self-sanctioning contracts and voluntary quality audits based on trust and social control might replace legally enforceable contracts. It should be noted that greater reliance on collaboration during evasion suggests that the increased emphasis on infrastructure SCQM orientations proposed by Proposition 2 above may be a necessary antecedent of achieving evading postures

Proposition 3: As institutional uncertainty increases, SCQM practices will shift away from abiding postures and toward evading postures.

Abiding and evading SCQM postures are preferable because they permit managers to operate on familiar levels (L3 and L4), thereby keeping cost of change low. As institutional uncertainty grows, abiding and evading postures may not sufficiently stabilize the quality of resource exchange. For example, revision of an influential quality assurance standard with mandatory requirements linked to supply chain resource exchange might be perceived as too risky to leave in the hands of government bureaucrats alone. Under such circumstances,

managers might seek to alter their institutions in order to directly shape the formal rules of the game.

Altering is generally the most expensive posture for coping with institutional uncertainty because it requires managers to operate on L2—a level more familiar to politicians and bureaucrats than to most supply chain managers. As such, it could be viewed as a "last resort" approach generally pursued when other measures are deemed ineffective in suitably stabilizing the quality of resource flows in unstable institutional settings.

To keep altering costs low, managers will first prefer indirectly influencing the direction of institutional policy. For example, supply chain members might work through a trade group to convey their preferences with respect to quality regulation to government officials. The trade group channel is particularly attractive because it keeps managers in their familiar operating environment while agents lobby on their behalf. Moreover, the cost of retaining lobbying agents can be split among several supply chain partners. Campaign contributions, when done within legal limits, constitute an additional way for supply chain members to legitimately influence policy.

In some cases, however, the indirect approach may be insufficient. Agents may be incapable of accurately conveying the preferences of their supply chain principals, particularly if those preferences are highly technical in nature. Uncertainty in the institutional environment may also be such that managers doubt that their preferences, even if perfectly conveyed, would be adequately reflected in formative policies. Under such circumstances, altering postures will demand direct involvement of supply chain managers in institutional processes. Direct involvement is likely to begin in part-time or temporary capacities to keep costs low. For example, joint committees composed of industry participants and government bureaucrats might convene to draft the new quality assurance standard discussed above. Supply chain participants might also volunteer particular managers to serve in unelected positions of authority to oversee the development of governing rules and their subsequent enforcement.

Proposition 4: As institutional uncertainty increases, SCQM practices will shift away from abiding postures and toward altering postures.

Extreme Institutional Uncertainty

If institutional uncertainty rises to extreme levels where most rules of the game and their subsequent enforcement are in doubt, then trade between supply chain partners may decrease as the instability of resource exchange drives many operators to take transactions off the market through vertical integration (Williamson, 1991). Bringing transactions in-house permits better control over quality and reduces the need for both formal and relational governance mechanisms because disputes are subject to resolution by internal forbearance rather than by external court order (Williamson, 2008). Vertical integration can be seen as a form of evading where taking transactions off the market reduces the need for inter-organizational quality management and is replaced with intra-organizational quality management.

Proposition 5: If institutional uncertainty reaches extreme levels, then some evading in the form of vertical integration will occur that effectively reduces intensity of SCQM.

However, vertical integration may not completely insulate even diversified organizations from intrusion by institutional forces. Because few organizations become completely self-sufficient, it is likely that even vertically integrated firms must still manage quality-related exchanges with external partners. While shortening the supply chain might reduce the effects to

some degree, it does not fully shield organizations from institutional vagaries. Supply chain partners might also find the potential gains from specialization and trade too compelling to vacate. Higher transaction costs associated with unstable institutional environments may not offset the potential benefits perceived from keeping the supply chain long with high division of labor.

Consequently, when institutional uncertainty is extreme, evading and altering postures are likely to persist. The nature of those postures should become extreme as well. Supply chains will stretch around the globe to evade uncomfortable institutional regimes. If global expansion does not offer adequate relief from hostile institutional environments, then those environments could be evaded by taking markets underground. Black markets will form with voluntary quality standards and self-sanctioning enforcement. Altering postures will also become extreme. Supply chain members might also seek to install representatives in direct positions of political power in order to shape quality-related rules of the game in their best interests. Joint government-industry verticals might form, complete with quality-related rules and enforcement set by industry officials that have acquired legal authority to do so.

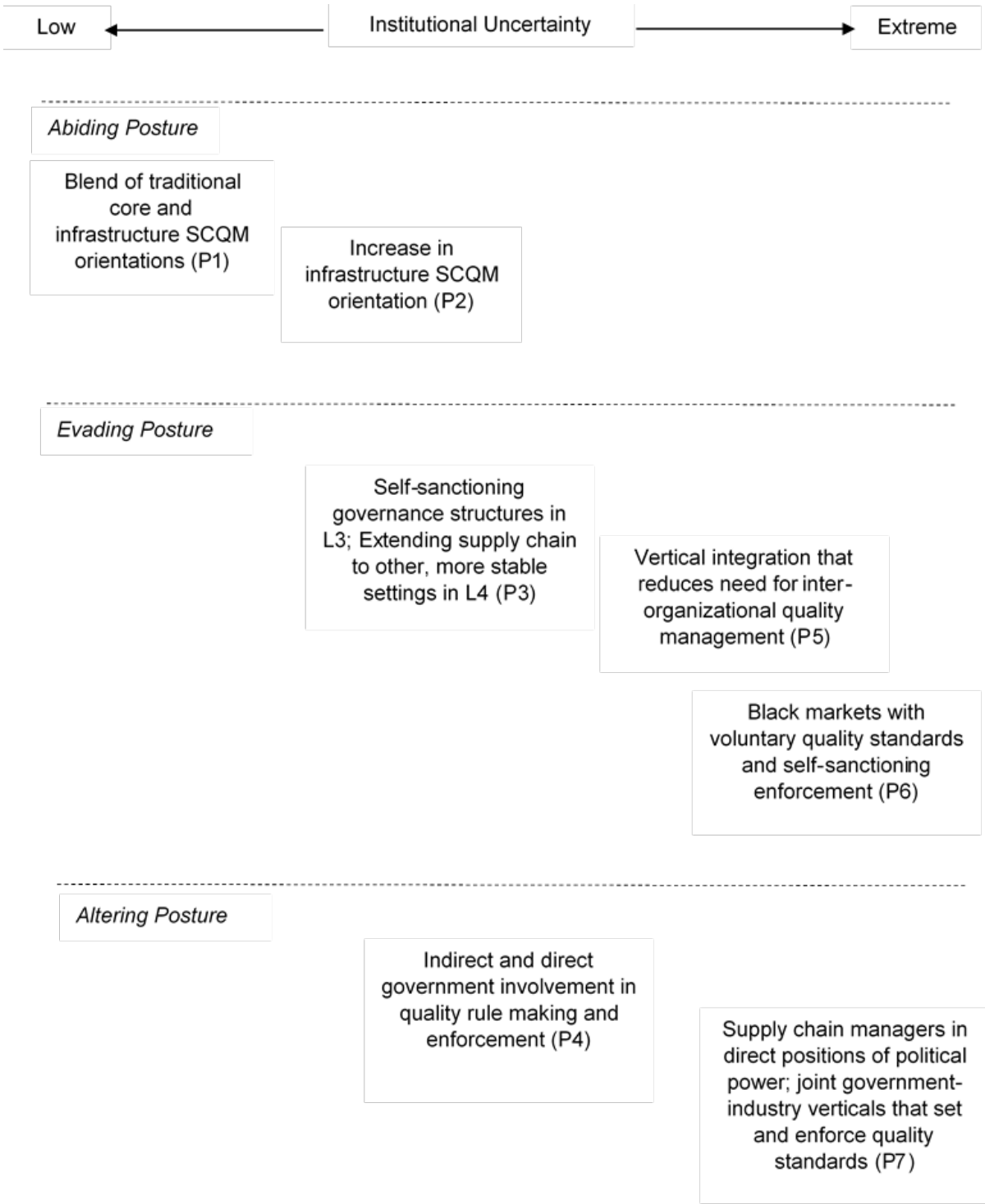
Proposition 6: If institutional uncertainty reaches extreme levels, then extreme evading SCQM postures will form to cope with the uncertainty.

Proposition 7: If institutional uncertainty reaches extreme levels, then extreme altering SCQM postures will form to cope with the uncertainty.

DISCUSSION

The framework proposed by this study appears in Figure 2. A general purpose of SCQM can be seen as stabilizing the quality of resource flows between supply chain partners in uncertain institutional environments). When institutional uncertainty is low, then managers are content to abide by the existing "rules of the game" by drawing from their traditional stable of core and infrastructure SCQM practices to manage resource stability (Proposition 1). As institutional uncertainty begins to increase, managers will initially re-orient SCQM toward more relationship-building with supply chain partners to facilitate inter-organizational adaptability in unstable settings (Proposition 2). In order to better utilize specific assets related to SCQM, organizations will be prone to evade mounting institutional uncertainty by, for instance, seeking trading partners in operating environments less subject to the institutional instabilities present in particular markets (Proposition 3). If an evading posture does not sufficiently stabilize resource flows, then organizations will pursue the costlier approach of altering its institutional environment by indirect or direct political involvement that permits supply chain members to influence the rules of the game (Proposition 4). When institutional uncertainty is extremely high, then some vertical integration is likely to occur to evade institutional processes that could jeopardize resource stability (Proposition 5). However, residual exposure to institutional vagaries as well as gains perceived from specialization and trade might prompt extreme forms of evading and altering, such as the formation of black markets with voluntary quality control, and joint government-industry verticals that permit industries to directly regulate quality standards, to cope with extreme institutional uncertainty (Propositions 6 and 7).

Figure 2: Supply Chain Quality Management as a Function of Institutional Uncertainty



This study extends inquiry about the influence of external environments on inter-organizational quality management into the institutional domain. Institutional environments are increasingly important to understand as supply chains lengthen across the globe and must operate under complex political and legal jurisdictions. A primary implication of this study is that SCQM practices must include capability for evading and altering unstable institutional settings—perhaps in extreme manners.

In the quality management literature, this implication is a novel one. Institutional environments are often portrayed as being beyond the interests and control of supply chain managers. While working with core and infrastructure SCQM practices such as those noted in Table 1 are commonly seen as within the scope of quality managers, evading and altering political processes are not. Hopefully, this paper will encourage dialogue and work in this direction.

Although the framework developed here offers a conceptual foundation, it must be tested and validated. Empirical work might pick up where others have left off in studies of how quality management practices differ across various supply chains and industries (e.g., Choi & Rungtusanatham, 1999). Variables might be introduced that capture country-related differences in perceived institutional uncertainty and in the abiding, evading, and altering postures of SCQM articulated here. In the context of entrepreneurship, Bylund & McCaffrey (2017) suggested that institutional uncertainty involves the extent to which managers trust the willingness of political institutions to provide ideological and political support for entrepreneurial action. Higgs (1997) added that the security of property rights rests not so much on the letter of the law but on perceptions about the character of governments that create and enforce those laws. Future investigations could incorporate similar ideas into construct development for empirical testing should prove useful.

From a practical standpoint, previous work (e.g., Ford, 2015) has alerted managers to the prospect of external contingencies in interorganizational quality management. Stabilizing the quality of resource flows may require different SCQM orientations in turbulent environments compared to stable environments. This study extends this implication to the institutional context. As institutional uncertainty grows, managers may need to stretch beyond their traditional stable of technical and relational SCQM practices for skills that allow them to evade and, in some cases, alter political and legal systems that influence their ability to manage the quality of resource exchange between supply chain members.

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DECISION SCIENCES INSTITUTE

Integrated Location and Inventory Decision Problem in a Three-tier Supply Chain Network

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ABSTRACT

In this paper, we consider a 3-tier supply chain network. There is one manufacturer, several warehouses and several retailers. Retailers' demand is constant and they do not allow shortage of inventory. We find the location of the manufacturer, number of warehouses and their locations, warehouse allocations to the retailers, and the inventory policies for the retailers and the warehouses. The purpose is to minimize average total cost in the long run. The cost function comprises of location, transportation and inventory holding costs. A math formulation and heuristics is developed.

KEYWORDS: Joint location and inventory problem, 3-tier supply chain, Cost minimization, Heuristic solution, Supply Chain Network

INTRODUCTION

Supply chain is evolving into a critical functional domain for organizations. One of the critical aspects of a good supply chain is its design. Supply chain design or supply chain network design determines that the number of facilities that a company is operating, the size of these facilities and their locations are optimal. A well designed supply chain network provides the companies significant opportunity for cost saving.

Our problem falls under the broad category of supply chain network design. The motivation comes from a manufacturer in the dairy sector that has two categories of customer centers, one with high demand and the other with low demand. Since UHT milk has shelf life of less than three months care is needed in its handling and efficient operation of milk supply chain is critical for success of companies in this sector. This manufacturer has a plant in a city with highest demand which is obvious. Furthermore the company has distribution centers in this city as well as other cities with different demands. For cities with low demand, the manufacturer has predetermined distributors. The distributors place order once or twice every week depending on the demand. They are supposed to inform the manufacturer of their requirements one day in advance. The company ensures a complete and timely order to the distributors. The distributors are only allowed to order in full-truckloads. As the demand for its product grows, the manufacturer is interested in reevaluating its supply chain network design to make it efficient and responsive.

A large set of companies are getting interested in reengineering their supply chain networks owing to the fluctuations in the oil price and rising transportation costs (Dong et al., 2009). This need has resulted in researchers studying the network design problem and coming up with models and solutions that both add to the literature and provide real life solutions for the companies. This paper is a continuation of this effort where we examine a 3-tier supply chain network with one manufacturer located in a high demand market, intermediate distribution centers or warehouses and multiple demand centers. These demand centers are cities in our case. We cluster the cities based on transportation and reordering costs. The distribution centers may be located at all the cities.

Alternatively, the firm can have a centralized distribution center for all the demand centers. We are interested in determining the number and location of distribution centers to serve a given set of existing cities. The objective is to reduce overall setup, transportation and inventory related costs over an infinite planning period.

We are furthermore interested in determining the inventory replenishment decisions from these warehouses to their respective markets. The problem hence falls into the domain of integrated facility location and inventory decisions.

We develop a mixed integer program for solving the deterministic demand problem. The goal is to determine the number and location of warehouses and optimal inventory policy for the given distribution network such that total cost of ordering, warehouse operations, transportation and inventory holding is minimized. The problem is both interesting and unique as it addresses an important practical problem in a multi-echelon distribution network with variable transportation cost and multiple warehouses that has not yet been addressed in literature.

LITERATURE REVIEW

The Network Design Problem

Given a set of existing customers, the network design problem is concerned with finding the number of facilities, their locations and allocation of facilities to the customers that would minimize the total cost of running the supply chain network. Initial work focused on determining models and efficient solution methods for finding answer to the network design problem under different settings of the two-echelon system. For example Baumol (1958) describes a heuristic for a non-linear warehouse location model. Later these studies were expanded to include the three-echelon case. An example is a recent study by Amiri (2004) in which they examine a three-echelon network to determine the number, location and capacities of plants and warehouses to open in order to meet all customer demand at minimum cost.

The extensive research conducted in the network design arena can be broadly into two categories i.e. uncapacitated facility location problem (UFLP) and capacitated facility location problem (CFLP). The above mentioned models have several common characteristics namely, a single-period planning horizon, deterministic parameters (i.e., demands and costs), a single product, one type of facility, and location–allocation decisions.

Extensions to this work include the multi-period and multi-product facility location problems. Furthermore, problems have started incorporating the stochastic nature of such problems. Although location decisions are made at the strategic level, a number of issues are strongly related to them. One such issue concerns inventory control policies.

The standard approach to the network design problem seeks to find locations of facilities and their allocation to customer sites without considering the inventory policy decision. Once the task of determining the number, location and allocation of facilities is complete the decision regarding inventory policy is made i.e. inventory policy decisions consider the location of facilities as given. However, consideration of inventory decisions while determining the location of facilities can have an impact on the solution to the network design problem. Croxton and Zinn (2005) consider inventory costs in the network design problem and show that including inventory in network design problems often significantly affects optimal design of the network.

Thus we have a new stream of research that focuses on the network design problem while simultaneously considering inventory policy decision. The problem is known as integrated location-inventory problem. The research in this area falls into two categories. One stream of research addresses the problem by including inventory costs without explicitly incorporating inventory related variables, for example Croxton and Zinn (2005). Another stream proposes a solution to the integrated location-inventory problem by explicitly considering both location and inventory related variables (Teo and Shu, 2004; Romeijn et al, 2007). Since our problem falls into the domain of latter research stream we go on to discuss this further.

Erlebacher and Meller (2000) developed an analytical model to decide on the number of distribution centers, their location and customer allocations that minimize fixed costs of operating the distribution centers, inventory holding costs at the distribution centers and transportation costs between plant and distribution centers and distribution centers and customers. They develop heuristic procedures to solve the problem since it is NP-hard.

More recently Uster et al. (2008) develop the integrated warehouse-inventory model in a three-echelon setting. They show that the model can be decomposed into two sub-models that resemble the single warehouse multi retailer (SWMR) problem and Weber problem respectively. They develop heuristic solutions to their problem.

We extend the work of Uster et al. (2008) by considering multi-warehouse problem in a three-echelon distribution network. We propose to study a supply chain network consisting of a single manufacturer at a given location, intermediate warehouses whose number and locations have to be determined and two markets one with high and the other with low demand. We intend to develop a MIP model for this network that would provide heuristics to solve for the number and location of warehouses as well as the inventory lot size.

THEORETICAL DEVELOPMENT/MODEL

Our problem includes fixed locations of manufacturing facility and demand centers. We have given transportation cost, inventory holding cost, warehouse operating cost and ordering cost. These costs are dependant on both number and location of warehouses and inventory lot sizes. These are the decision variables in our problem. These variables are consistent with those presented in Uster et al. (2007) except that we additionally need to determine the number of warehouses and their locations. The number of warehouses has been used as a decision variable in previous studies, for instance, Teo and Shu (2004).

The problem is to determine the location of a single manufacturing plant, number and location of distribution centers that are going to serve a known set of cities where there is constant deterministic demand for the product being made by the plant, allocation of cities to distribution centers and inventory ordering policy for the distribution centers and the cities. We consider a set of n≥2 cities. The known locations of the cities are denoted by $f_j = (aj,bj)$, $j \in N = \{1,2,\ldots\ldots..,$

n}, respectively. Each city has one bin. The unknown location of distribution center i is denoted by $X_i = (x_i, y_i)$, $i \in M = \{1,2,....., m\}$.

In determining the number, location and allocation of distribution centers as well as inventory policy for the distribution centers and cities we consider the following costs:

1. fixed operating costs of the distribution centers
2. order setup costs at distribution centers and bins
3. transportation costs from plant to distribution center and from distribution centers to the cities
4. inventory holding costs at the distribution center and at the bins in different cities

Following assumptions are used while developing the model:

1. The plant and distribution centers have unlimited capacity
2. A city cannot be served by multiple distribution centers
3. The vehicle transporting goods from plant to distribution center has unlimited capacity
4. Trucks used to transport goods from distribution center to cities have limited capacity
5. Cost of truck is proportional to the amount of truck space utilized
6. All trucks have same capacity
7. Demand at the cities is deterministic and constant
8. Transportation costs, fixed ordering costs and inventory holding costs are linear

We now develop the notations for the problem and then proceed with problem formulation.

Notations related to the network

N = set of cities with one bin in each city, N = {1,…., n}
M = set of distribution centers, M = {1,…., m}
X_0 = location of plant
f_j = location of cities, f_j = (aj,bj), $j \in N = \{1,2,....., n\}$
w_{ij} = constant deterministic demand rate at city j served by distribution center i

Input Parameters

f_i = fixed cost of operating the distribution center i
c_d = fixed truck capacity at distribution centers
c_p = fixed rail capacity at plant
s_{ij} = fixed setup and ordering cost from distribution center i to facility j
t_{ij} = per-mile transportation cost between the distribution center i and facility j
h_j' = unit inventory holding cost rate at city i
h_i' = unit inventory holding cost rate at distribution center i
h_{ij} = echelon holding cost rate at city j if it is supplied by distribution center at i

Tb = fixed base period (set a priori)
X0 = vector of unknown plant location, X0 = (x0, y0)
Xi = vector of unknown location of distribution center i, Xi = (xi, yi)
zij = {1 if DC i is open and serves city at j
0 otherwise

Using the above assumptions and notations we develop the objective function representing the system wide total annual cost. The function is expressed as follows:

$$\text{Min } Z = \sum_{i=1}^{m} f_i z_{ij} + \Big[\sum_{i=1}^{m} \sum_{j=1}^{n} (t_{ij} w_{ij} d(X_i, f_j)/c_d) + \sum_{i=1}^{m} \sum_{j=1}^{n} (t_{oi} d(X_0, X_i)/T_i)$$

$$+ \sum_{i=1}^{m} \sum_{j=1}^{n} s_{oi}/T_i + \sum_{i=1}^{m} \sum_{j=1}^{n} s_{ij}/T_j + \sum_{i=1}^{m} \sum_{j=1}^{n} 1/2\, h_i w_{ij} \max\{T_i, T_j\} + \sum_{i=1}^{m} \sum_{j=1}^{n} \tfrac{1}{2} h_{ij} w_{ij} T_j \Big] z_{ij}$$

subject to

$$\sum_{i=1}^{m} z_{ij} = 1$$

$$\sum_{j=1}^{n} w_{ij} * T_j <= (\sum_{j=1}^{n} w_{ij}) * T_i'$$

The first term represents the fixed operating cost that would incur if a distribution center at i is opened to serve customer set j. The second term is the annual transportation cost from distribution center to cities at j. The third term is the annual transportation cost from plant to the open distribution centers. The fourth and fifth terms are the fixed setup and ordering costs at the opened distribution centers and the cities respectively. The sixth and seventh terms represent the holding costs at the distribution centers and the cities.

The first constraint guarantees that only one distribution center serves a given city. The second constraint ensures that the quantity leaving the distribution centers is less than equal to the quantity leaving the plant.

Clustering

Clustering is a method of grouping together similar data. In clustering, data points that have close resemblance to each other are placed in one cluster. Points in one cluster are similar to each other while differ from data in other clusters. A more formal definition of clustering is presented in Witten and Frank (2001). “These [obtained] clusters should reflect some mechanism at work in the domain from which instances or data points are drawn, a mechanism that causes some instances to bear a stronger resemblance to one another than they do to the remaining instances."

Clustering problems are such that finding their solution is equivalent to seeking a global solution to the non-linear optimization problem which is NP-hard (Fung, 2001). Hence heuristic procedures are developed for the formation of clusters. The large range of cluster heuristics available may be broadly classified into two groups, namely parametric and non-parametric clustering methods. For the sake of brevity we will explain a few heuristic that have some resemblance to the clustering algorithm presented in this paper. For a detailed overview of clustering algorithms we refer the reader to Fung (2001).

Gillet and Miller (1974) made a sweep algorithm for cluster development. The algorithm consists of a forward sweep and a backward sweep. In the forward sweep locations are partitioned beginning with the location that has the smallest angle from a given location. The backward sweep is similar except that it forms clusters considering a reverse set of locations.

Jung and Mathur (2007) refined the algorithm by Gillet and Miller (1974) to form clusters for their vehicle routing problem. They index the retailers in increasing order of angular position from the warehouse and continue to put the retailers according to this order, in a cluster as long as the sum of demands of the retailers in the cluster do not exceed a specified parameter $D_{max.}$

We develop our cluster heuristic for the multiple warehouse multiple retailer problem in a similar fashion except that we consider weighted distances of locations from plant and distribution centers in deciding clusters.

Single Warehouse Multiple Retailer Problem

The one warehouse multiple retailer problem has been studied extensively since the breakthrough work of Roundy (1985). The problem considers deterministic and constant demand at the retailers over an infinite horizon. Shortages are not allowed. Retailers place orders at the warehouses which in turn place orders with the manufacturer. The inventory holding cost rates are facility dependant and are greater at the retailers as compared to those at the warehouse.

Roundy (1985) showed that the solution to the one warehouse multiple retailer problem can be approximated to within 98% accuracy. We use the algorithm developed in Roundy (1985) to find the reorder intervals in our network.

Lower Bound to the Multiple Warehouse Problem

One of the components of the objective function of our problem is the transportation cost. It is a major cost driving the decision concerning number of warehouses. The transportation cost as formulated in our problem has two components as depicted below.

$$\sum_{i=1}^{m}\sum_{j=1}^{n}(t_{oi}d(X_{0,}\,X_i)/T_i) + \sum_{i=1}^{m}\sum_{j=1}^{n}(t_{ij}w_{ij}d(X_{i,}\,f_j)/c_d) \qquad (1)$$

For ease of use, we call the first component T(1) and the second component T(2).

The first component is the inbound transportation cost i.e. cost of transporting goods from the plant to the distribution centers. The second component is the outbound transportation cost which is the cost of transporting goods from the distribution centers to different cities. The vehicle transporting goods from the plant to the distribution centers has unlimited capacity while the vehicles delivering products from distribution center to various cities have limited capacity c_d.

It is obvious to see that if we increase the number of warehouses the transportation cost from the plant to the distribution center increases. Since inbound transportation cost is a product of per unit transportation cost t_{oi} and $d(X_{0,}\,X_i)$ the distance between plant at X_0 and distribution center at X_i and the distance traveled from plant to distribution center increases as the number of distribution center increases, hence the inbound transportation cost rises as we increase the number of distribution centers irrespective of the reorder interval $T_{i.}$ On the other hand increasing the number of warehouses decreases the outbound transportation cost. It is clear from the second component of our transportation cost that as we increase the number of distribution centers (DCs) the distance traveled from DCs to the cities decreases. As an extreme case consider we have a DC in each city. If this happens then $f_j = X_i$ and the distance $d(X_{i,}\,f_j)$

between DC and the city to which the DC supplies is zero. Hence in this scenario the second component of our transportation cost becomes zero.

Thus we see that as the number of distribution centers m → ∞ , T(1) → ∞ and T(2) → zero. The total transportation cost is hence a convex function with a minimum value.

Now we go on to show that the minimum value to the transportation cost function in our problem occurs when the number of warehouses satisfy the following criteria.

$$d(X_i, f_j) < d(X_0, X_i)/T_i \quad (2)$$

The total transportation cost of establishing a distribution center in a city i = (1…m) is given by:

$$\sum_{j=1}^{n} (t_{oi} d(X_0, X_i)/T_i) + \sum_{j=1}^{n} (t_{ij} w_{ij} d(X_i, f_j)/c_d) \quad (3)$$

Given a fixed time interval T_i the above expression reduces to:

$$\sum_{j=1}^{n} t_{oi} d(X_0, X_i) + \sum_{j=1}^{n} (t_{ij} w_{ij} d(X_i, f_j)/c_d) \quad (4)$$

where w_{ij}/c_d give the number of vehicles traveling from the distribution centers to their respective cities in the interval T_i.

Though $t_{ij} < t_{oi}$, $t_{ij} * w_{ij}/ c_d$ is an increasing function of number of trips. For an average level of demand for any medium sized organization it is easy to see that the parameter $t_{ij} * w_{ij}/ c_d$ would have a value much greater than t_{oi}. We thus have

Since $t_{ij} * w_{ij}/ c_d >> t_{oi}$, the total transportation cost will be minimized only when distribution centers are established such that

$$d(X_i, f_j) < d(X_0, X_i) \quad (5)$$

Cluster Heuristic for the MWMR Problem

We develop a cluster heuristic to solve the multiple warehouse multiple retailer problem. The clusters are developed using an approach similar to that used in Jung and Mathur (2007). We first locate the plant using the famous center of gravity approach. The center of gravity method finds a weighted average location for the new facility that needs to transport and receive shipments from a set of pre-existing facilities.

Once we have determined location of the plant, we find the number and location of distribution centers. In order to establish the distribution centers we calculate Euclidean distances from plant to the existing locations. Next we sort the locations and index them based on increasing sequence of distances from the plant. These locations belong to a set of cities L = (1…..n). The distribution center is established at a location with the lowest index value to minimize transportation cost from the plant to the distribution center.

After establishing the first distribution center we form cluster in the following fashion. For a given set of locations as long as the distance of the locations from the distribution center DC1 is less than its distance from the plant they are placed in a cluster C1 = (1….n_1). L is updated by L <- L\ C1 such that L1 = (n_1+1….n_2). For the remaining locations a distribution center DC2 is established as before. Second cluster C2 is formed such that distance of the new set of locations L1 = (n_1+1….n_2) from DC2 is less than their distance from the plant and L is updated by L <- L\ C2.

Clusters are formed until L != {Ø}.

Given the established distribution centers, reorder intervals are calculated using the approach in Roundy (1985). This forms input to the cluster heuristic. Transportation costs are reevaluated on the reorder interval. We get new values for $d(X_0, X_i)/T_i$ and the number and location of the distribution centers is calculated again. If this results in incremental improvement in solution to the cost function we accept the solution. The procedure is repeated until the improvement is less than a pre-specified percentage value.

The step-wise procedure is for Cluster Algorithm is as follows:

Step 1: Locate the plant using center of gravity.

Step 2: Calculate distances from plant to cities and sort cities in ascending order of distance from plant. Assign cities to L = {1….n} where n is the number of cities in the set.

Step 3: Locate DC1 at a city (location) such that $d(X_0, X_i^*) < d(X_0, X_i)$ (for all cities in L). Update DC by DC U {DC1}.

Step 4: Form cluster C1 such that $d(X_i, f_j) < d(X_0, X_i)$ (for all j). Update set of clusters C by C U {C1}. Update L by L <- L\ C.

Step 5: Repeat steps 3 and 4 until L != {Ø}.

Step 6: Update distance from plant $d(X_0, X_i)$ by $d(X_0, X_i)/T_i$ where T_i is calculated using the approach in Roundy (1985). Go to step 2.

Step 7: Repeat steps 2 to 7 until incremental improvement in cost is below a specified percentage p%.

RESULTS

The program was implemented in C++ and run on a personal computer. Several runs of the program showed reduction in cost when multiple warehouse multiple retailer problem is considered as compared to single warehouse multiple problem. A detailed analysis of the results will be presented in a newer version of the paper.

CONCLUSION & FUTURE RESEARCH

Later on a system dynamics model for the three-tier distribution network considered in this paper may be developed. The integrated location and inventory analysis may then be performed from a system dynamics perspective and the results compared to those determined using this study.

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Integrated Product Design and Development: A Lean Manufacturing Approach

(Full Paper Submission)

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ABSTRACT

The focus of this article is to demonstrate the relationships between lean manufacturing (LM) principles and integrated product design and development (IPDD). Comparison and analysis of several critical factors show high degree of resemblances between the two methods. A number of hypotheses regarding similarities between factors of the two methods were developed and tested. Survey data strongly supports the hypotheses regarding similarities between the LM and IPDD methods. Statistical results also indicate compared with conventional companies, by utilizing IPDD, lean manufacturing organizations are able to design and develop products with better quality, less development time, higher frequency, and lower development and manufacturing costs.

KEY WORDS: Integrated Product Desing and Development, Lean Manufacturing

INTRODUCTION

Innovation and speedy new product development is crucial for companies to gain competitive advantage in a global market. Creating new product ideas that are consistent with organizational strategy and moving these ideas through the stages of design, development, and introduction quickly has been the hallmark of successful world class organizations (Jacobs and Chase, 2011; Ferioli et al. 2010; Roulet et al. 2010; Towner, 1994). Introducing new products to the market early has several strategic and operational advantages. It often means premium prices, building name recognition, controlling a large market share, and enjoying the bottom line profits. Better competitive position in the market makes it also difficult for competition to enter the market (Cooper and Kleinschmidt, 1994; Lofstrand, 2010; Zahra and Ellor, 1993).

Despite its well-known strategic role, for large number of manufacturing organizations innovation, design, and successful management of new product development (NPD) has often been a major challenge. Long development time, prohibitive development and manufacturing costs, and questionable quality have been the common result for many of these organizations. The primary factor contributing to such unsuccessful result is perhaps the use conventional sequential method of NPD by these organizations (Blackburn, 1991; Morgan and Liker, 2006). However, manufacturing literature for the past two decades clearly shows that through their lean manufacturing practices, some world class organizations such as Toyota have dominated competition not only in the area of manufacturing but also in the area of innovation, design, development, and quick commercialization of new technologies ((Marisa et al. 2008; Heinzen and Hoflinger 2017; Clark and Fujimoto, 1991; Ulrich and Eppinger, 2004; Michael, 2008; Unger and Eppinger 2009). Instead of traditional sequential approach to NPD, a successful strategy employed by these world class organizations is IPDD. The focus of this article is to understand such contrast

between the two type of organizations. The question of interest in this article is: Are there relationships between success in LM practices and success in IPDD?

LITERATURE REVIEW

Lean manufacturing has been a great force in the world of manufacturing since mid 1980's. Some of the main benefits of a LM such as lower inventory, quicker delivery, and lower cost have been well documented (Cook and Rogowski, 1996; Hobbs, 1994; Payne, 1993; Temponi and Pandya, 1995; Deshpande and Golhar, 1995; Billesbach, 1991; Handfield, 1993; Lawrence and Hottenstein, 1995; Golhar, Stamm, and Smith, 1990; Moras and Dieck, 1992). In the simplest form, LM requires maximizing value added production activities by removing unnecessary wastes. Identification and elimination of waste and respectful treatment of employee are the two fundamental principles of a LM system (Hobbs, 1994; Payne, 1993; Wantuck, 1983; Womack and Jones, 2003). Elimination of waste is achieved by adopting practices such as continuous quality improvement, setup time reduction, utilizing flexible resources, group technology layout, and pull production system (Gargeya, and Thompson, 1994; Sohal, Ramsay, and Samson, 1993; Suzaki, 1987)). Respectful treatment of people often means employee empowerment; it includes elements such as team work, fair compensation, employee training and new positive attitude toward suppliers (Sohal, Ramsay, and Samson, 1993; Wantuck, 1983). Unfortunately, since its beginning in mid 1980's, often a narrow view of LM has been accepted and utilized by western manufacturers. Application of LM to reduce inventory and increase deliveries is only a small fraction of the full potential benefits of a LM system (Blackburn, 1991; Kristav, 2016; Gilbert, 1994; Towner, 1994). To take advantage of the full benefits of LM, one needs to have a much broader view of LM principles (Blackburn, 1991). Looking at LM as a process of eliminating waste and respectful treatment of employee, its principles can be applied to other areas including service areas such as healthcare, education, government, and NPD (Womack and Jones (2003). Application of lean principles to NPD has great opportunity to shorten product development time, improve design quality, and reduce product development and manufacturing costs (Anand and Kodali, 2008). The company that originated famous LM system, TPS, also developed Toyota Product Development System (TPDS). TPDS employs LM principles and tools such as value stream mapping, Kanban, 5S system, and continuous improvement to eliminate waste from product development activities and bring quality products to market faster than their leading competition (Morgan and Liker, 2006; Ward, 2007). The focus of this article is on special case of TPDS called integrated method of new product development (IPDD).

The remainder of the article is organized in the following manner: First, an overview of the differences between conventional sequential and recent IPDD is presented. Second, the article compares and analyzes similarities between LM and IPDD for a number of critical factors followed by a set of test of hypotheses on similarities between the factors. Third, the article tests NPD performances for conventional sequential method and IPDD method. Research methodology, results, and conclusion are the final sections of the article.

TRADITIONAL VS. INTEGRATED PRODUCT DESIGN AND DEVELOPMENT

NPD process is a sequence of inter-connected activities in which information regarding customer needs is translated into final product design. In a traditional NPD nethod, also known as sequential or "over-the-wall" approach, the NPD process typically involves phases such as idea generation and validation, preliminary design, final design and prototyping, and pilot production and ramp-up (Wheelwright and Clark, 1992; Russell, and Taylor, 1998). Traditionally, this design process is managed sequentially by personnel from various functions of the organization. A major drawback of this approach to NPD is that the output from one design stage is passed to the next stage with little or no communication. Lack of communication and feedback among sequential stage causes

the process to require too many design changes which causes the process to require longer development time which indeed causes the process to be too slow, too costly, and often of poor quality. The two elements of long delay and design changes during the delay creates a never-ending cycle where time delay causes design change and to accommodate design change it needs more time. The final result is that the designs are often rejected because the design is either outdated due to long development time or it is infeasible in term of manufacturing capability (Blackburn, 1991; Ulrich and Eppinger, 2000).
Unlike traditional "over-the-wall" approach to NPD where functional units work sequentially and downstream functions are not involved until late in the process, IPDD requires early involvement of cross functional teams. It requires that designers, manufacturers, marketers, suppliers, and customers work jointly to design product and manufacturing process in parallel. The design team must truly understand the concept of simultaneous engineering in which activities of product and process design are performed in parallel and in a coordinated manner The objective is to integrate product design and process planning into a common activity (Albers and Braun, 2011; Liang, 2009; Anderson, 2008; Clark and Fujimoto, 1991; Donnellon, 1993; Millson, Ranj, and Wilemon, 1992; Shunk, 1992). Application of IPDD under various manufacturing environments in order to shorten development time, improve quality, reduce risks, and reduce development cost is reported by these researchers (Anderson, 2008; Skalak, 2002; Kowang and Rasli, 2011; Lofstrand, 2010; Moges, 2009). Due to early cross-functional communication, IPDD approach enables an organization to be more innovative in terms of improving design quality, shortening development time, reducing design risks, and reducing development and manufacturing costs (Lynch et.al, 2016; Blackburn, 1991; Ulrich, and Eppinger, 2000; Arora and Mital, 2012; Katzy et.al, 2012; Zirger and Hartley, 1996).

COMPARISON OF LEAN MANUFACTURING AND IPDD FACTORS

For the past few decades, there has been an extensive volume of research in the area of LM. As a result, there is a set of generally accepted guidelines that organizations can follow to achieve manufacturing success. However, there has been limited research on the application of LM principles to NPD and there is no comparable set of guidelines for successful management of NPD process. Recently, a number of world class NPD companies have attempted to apply the principles of lean manufacturing to NPD activities. The company that started the most famous LM system, Toyota Production System (TPS) is also started Toyota Product Development System (TPDS). TPDS employs lean principles and enable the company to bring the highest quality products to market faster than their leading competition. Also, a number research on the application of lean principles to NPD process has shown that achieving certain manufacturing process improvement such as reducing variation, reducing rework and yield loss, solving process bottlenecks, and managing capacity, can significantly reduce NPD times.

Similarities between LM and IPDD for a number of critical factors are shown in Table 1, (Blackburn, 1991; Spencer and Guide, 1995). Following is a brief comparison and analysis of selected factors in Table 1:

Layout

Layout in LM environment is often in the form of product focus and manufacturing cells. This type of layout is necessary because small lot size production requires that the layout to be compact and efficient to ensure smooth flow of materials and close communication between work stations. Unlike conventional manufacturing, where material is pushed forward, the flow in a LM environment is in two directions; material is pulled forward, but information flows backward to provide feedback on performance and material requirements.

In IPDD, overlapping of a large number of activities requires a complete change in layout that facilitates communication and encourages team work. Instead of organizing by sequential functions, IPDD emphasizes on cross-functional integration and the formation of a design team. The design team sits together in one location, creating a type of project layout. A project layout creates an environment for frequent, two-way communication between team members, which encourages concurrent development of a product and its associated processes.

Table 1. Comparison of LM and IPDD Factors

Factor	LM	IPDD
Layout	GT/Cellular manufacturing	Project/Design teams
Process and information flow	Two way flow: material downward, information backward	Parallel activities: Two way flow of information among team members
Set-up/Transition time	Short	Short
Lot size	Small	Small (batches of information)
Quality	Quality at the source, continuous quality improvement, low rework activities	Early detection of design quality problems, continuous design improvement, low redesign activities
Inventory	Low	Low
Manufact./Develop. Cost	Reduced	Reduced
Lead time	Fast delivery	Short development time
Customer focus/Market responsiveness	More responsive to changes in customer demand	More responsive to product design changes
Workeforce empowerment and teamwork	High	High
Workforce flexibility	High	High
Scheduling	Localized team control, team responsibility	Localized team control, team responsibility
Decision making	Manufacturing team	Design team
Supplier involvement	High level of sharing information, quality partners	High level of involvement in product development
Technology	Integrated systems, new technology after process simplification	Integrated CAD, CAE, CAM
Workplace organization	Utilizes 5S practices to organize, clean, and sustain the workplaces	Utilizes 5S practices to organize design team and data for easy access to information to conduct NPD activities
Standardization	Standardization of parts and components is a critical component of LM	Creates a standard method of doing activities (i.e. data collection, flow charting, blue prints, etc.)
Value added	High	High

Lot Size

In contrast to conventional manufacturing, lean manufacturing requires production of small lot-sizes. Production of small lot-sizes is possible by drastically reducing set-up times. It is well documented that production of small lot-sizes in LM is closely associated with improved quality, reduced inventory, faster delivery, and more responsive to market demands.
Similar to LM, IPDD also utilizes small lot-sizes; the only difference is that in LM small lot sizes of goods are processed but IPDD requires small lot-sizes of information. That is, continuous two way communication in IPDD is similar to early release of small batches of information (Blackburn, 1991; White, 1993). With the early release of small batches of information, downstream constituents can begin working on different phases of the design while final design is evolving. The early release of information reduces uncertainty and encourages early detection of problems, which enables organizations to avoid costly, time-consuming changes.

Employee and Supplier Involvement

In LM environment, management encourages employee involvement and team work. The responsibility for job scheduling and quality are often passed to the teams at the shop floor. Due to small lot size production, delegation of authority to the teams at the shop floor is essential for smooth production flow. Also, in LM suppliers work closely with manufacturing organization to improve quality and shorten delivery time.
Similar to LM, in IPDD the responsibility for scheduling of the activities pushed down to product development team at the lowest level. Passing responsibility down to the team is essential to achieve a high level of activity coordination and information sharing among team members. Also, in IPDD suppliers work closely with the design team to reduce development costs, shorten development time, and offer ideas toward improving the quality of the design.

Quality

In LM and IPDD environments, organizations are often proactive and quality means getting it right the first time. In LM, since batch sizes are small quality at the source and continuous quality improvement are the main foundations. Shop floor workers are empowered to become their own inspectors responsible for the quality of their output. In IPDD, because of the teamwork and two-way flow of information between team members, and utilization of quality improvement tool such as six sigma process quality problems are detected earlier and solved before they have a cumulative impact on the rest of the project (Chakravorty and Franza, 2009).

Technology

In a LM system, technology is not viewed as a substitute, or shortcut to process improvement. Rather, technology has been utilized after process analysis and simplification has been performed. The role of technology in IPDD is also enormous; it requires that the design team with diverse expertise makes a large number of interrelated decisions regarding the form, fit, function, cost, quality, and other aspects of the design (Karagozoglu and Brown, 1993). This requires supply and processing of relevant information from multiple sources in a coordinated manner. Successful organizations use technology in their NPD process similarly to the way they use technology in their LM system. In IPDD, the design team utilizes appropriate technologies and tools at various stages of NPD process. Effective use of technologies and tools can dramatically shorten NPD time, reduce number of prototypes, cut costs, and improve quality of the design (McKay et al. 2011; Yamamoto and Abu Qudiri 2011; Roulet et.al (2010). The key to

the success of technology in IPDD is building an effective design team with open cross-functional communication lines.

FACTOR HYPOTHESES

Comparison and analysis of factors in Table 1 show a high degree of similarities between LM and IPDD. To study further, a set of twenty hypotheses (H1-H20) that statistically test similarities between LM and IPDD will be presented. The hypotheses are shown in Table 2. Each hypothesis in Table 2 consists of two parts- a and b. In part a, the test is conducted for LM factors and the corresponding test for IPDD factors is conducted in part b. The last hypothesis examines the overall impact of LM principles on IPDD.

Hypotheses (H1-H20):
There is a high degree of similarities between LM and IPDD factors.

PRODUCT DESIGN AND DEVELOPMENT PERFORMANCES

The following dimensions of quality, time, competency, development cost, and manufacturing cost are used to measure the performance of NPD (Ulrich and Eppinger, 2000; Wheelwright and Clark, 1992):

- **Quality**: Quality is ultimately reflected in the price customers are willing to pay, the market share, and the bottom line profit. In NPD, quality problems are often the results of incomplete information and miscommunication among various functions. Quality often means a minimal number of redesign or rework. In this article, number of design changes during the development process and early manufacturing phase is used as a measure of design quality.
- **Development time**: Development time is the length of time between initial idea generation until new product is ready for introduction to the market. Shorter development time raises the competitive value of new product in terms of premium price, larger market share, and higher profit margin.
- **Development competency**: Development competency is the ability of the organization to develop future products better, faster, and cheaper. Competent workforce and effective use of technologies are important elements of organizational NPD competency. Frequency of new product introduction to the market is used as a measure of development competency.
- **Development cost**: This is the total cost from the early idea generation until the product is ready for manufacturing. For most organizations, development cost is usually a significant portion of the budget and must be considered in light of budget realities and the timing of budget allocations.
- **Manufacturing cost**: Manufacturing cost includes initial investment on equipments and tools as well as the incremental cost of manufacturing the product. There is a close relationship between manufacturing cost and the type of decisions made during the early design stage. Although early design decisions determine about 70 percent of future manufacturing cost, organizations often spend far too little time and resources during this stage (Huthwaite, B. 1991). To save future manufacturing cost, it is prudent for the companies to spend more time and resources during the early design phases of NPD process where critical design decisions are made.

Table 2. Survey Items for Comparison of LM and IPDD Factors
(1=strongly disagree, 5=strongly agree)

1a. In LM, layout is often in form of group technology (GT) or cellular manufacturing (CM).	1b. In IPDD, the layout emphasizes is on cross-functional integration and formation of project or design team.
2a. In LM, GT or cellular manufacturing layout allows smooth flow of materials downward and information flow backward.	2b. In IPDD, project layout formed by the design team allows frequent and two way flow of information among team members.
3a. LM system requires short set-up time.	3b. IPDD requires fast transition (i.e. short set-up time) from one part of the design to another.
4a. LM system requires production of small lot-sizes.	4b. In IPDD, continuous and two-way flow of information among team members is equivalent to releasing small batches of information.
5a. In LM, due to production of small lot-size, quality at the source and continuous quality improvement are essential to the success of the system.	5b. In IPDD, due to simultaneous development of product and process, early detection of design quality problems and continuous improvement of the design are essential to the success of NPD process.
6a. In LM, production of small lot-size is associated with improving quality.	6b. In IPDD, continuous and two-way communication among team members encourages early detection of the design problems, which is associated with improving design quality.
7a. In LM, production of small lot-size is associated with reducing inventory.	7b. In IPDD, continuous and two-way communication among team members associated with reducing unnecessary amount of information among team members.
8a. In LM, production of small lot-size is associated with reducing manufacturing cost.	8b. In IPDD, continuous and two-way communication among team members encourages early detection of the design problems, avoids costly design changes, which is associated with reducing development cost.
9a. In LM, production of small lot-size and smooth flow of materials downward and information flow backward is associated with reducing delivery time.	9b. In IPDD, continuous and two-way communication among team members encourages early detection of the design problems, avoids time consuming design changes, which is associated with reducing NPD time.
10a. In LM, organizations are more responsive to the changes in customer demand.	10b. In IPDD, the design teams are more responsive to the changes in product design.
11a. In LM, management encourages workforce empowerment and teamwork.	11b. In IPDD, management encourages employee empowerment and teamwork.
12a. LM requires high level of workforce flexibility.	12b. IPDD requires high level of design team flexibility.

Table 2. Survey Items for Comparison of LM and IPDD Factors
(1=strongly disagree, 5=strongly agree) (Continue)

13a. In LM, detailed shop floor responsibilities such as job and employee scheduling are passed to the local teams.	13b. In IPDD, detailed design responsibilities such as development activities and employee scheduling are passed to the design teams.
14a. In LM, suppliers work closely with manufacturing teams.	14b. In IPDD, suppliers work closely with the design and development teams.
15a. In LM, close relationship between suppliers and manufacturing teams is essential in improving quality, reducing manufacturing cost, and shortening delivery time.	15b. In IPDD, close relationship between suppliers and design and development teams is essential in improving design quality, reducing design and development cost, and shortening design and development time.
16a. In LM, new technologies such as robots are integrated into manufacturing system after process analysis and simplification has been performed.	16b. In IPDD, new technologies such as IT and CAD are integrated into the design and development process after process analysis and simplification has been performed.
17a. LM utilizes 5S practices to organize, clean, and sustain the workplaces.	17b. IPDD utilizes 5S practices to organize data and design team members for easy access to timely information to conduct NPD activities.
18a. In LM, standardization of parts and components is a critical component of the system.	18b. In IPDD, standard method of doing activities such as data collection and organization is a critical component of the process.
19a. In LM, due to the principles of elimination of wastes, process activities contain high value added content	19b. In IPDD, simultaneous communication among team members, NPD process contain high value added content.
20a. In LM, elimination of wastes and respectful treatment of people are the two main principles.	20b. Similar to LM, the main principles of elimination of wastes and respectful treatment of people are applicable to IPDD.

PERFORMANCE HYPOTHESES

In the second set of hypotheses (H21-H25), the differences between NPD performances for lean manufacturing companies and conventional companies are tested.

Hypotheses (H21-H25):

H21: By utilizing IPDD approach, LM companies are able to design new products with fewer design changes than conventional companies(better quality).

H22: By utilizing IPDD approach, LM companies are able to design new products faster than conventional companies.

H23: By utilizing IPDD approach, LM companies are able to design new products more often than conventional companies.

H24: By utilizing IPDD approach, LM companies are able to design new products with less development cost than conventional companies.

H25: By utilizing IPDD approach, LM companies are able to design new products with less manufacturing cost than conventional companies.

RESEARCH METHODOLOGY

The target population for this study consisted of manufacturing firms in the states of Illinois, Indiana, Ohio, Michigan, and Wisconsin. A sample of 500 manufacturing firms with more than 50 employees was chosen from manufacturers' directories of those states. The sample covers organizations in variety of industries ranging from fabricated metal, communication, electronics, automotive, toots, chemicals, rubber, and paper products. A comprehensive survey instrument based on examination of the literature and critical factors listed in Table I was developed. A panel of practitioners and researchers with experience in LM and NPD was used to validate the survey. In addition to general organization and managerial profile items, the survey contained 40 items (20 paired) regarding similarities between LM and IPDD factors. The twenty paired questionnaire items are shown in Table 2.

[Take in Table 2]

Also, the survey instrument contained a number of questionnaire items on NPD performances for LM companies using IPDD and conventional companies. Out of 91 completed surveys received, 84 surveys were usable resulting in a response rate of 17%. Based on a number of questionnaire items on the principles of LM practices, 33 organizations were grouped as LM companies and 51 organizations were categorized as conventional companies.

The survey data indicates that majority of respondents had various high level managerial positions from organization with less than 500 employees. Presidents and vice presidents accounted for 29% and plant managers accounted for 30% of the sample. About 35% of the sample had other managerial positions such as operations/production managers, quality managers, and the remaining 6% were production line supervisors. In terms of manufacturing and NPD experience, about 28% of the respondents had between 10 to 20 years and 60% had more than 20 years of manufacturing experience. About 72% of the sample had more than 10 years of LM experience and close to 65% of the sample had more than 10 years of NPD experience.

RESEARCH RESULTS

As stated earlier, in the first set of hypotheses the objective was to examine similarities between LM and IPDD for a set of paired factors shown in Table 2. For each item, the null hypothesis was that the mean response for LM is equal to the mean response for IPDD. The differences between the mean responses for LM and IPDD were compared using the statistical t-test. The respondents were asked to rate each element of Table II based on the degree of their agreement (1=strongly disagree, 5=strongly agree) to the question. Table 3 shows the result of similarities between LM and IPDD.

[Take in Table 3]

As shown in this table, overall the respondents strongly agreed with the statements regarding similarities between LM and IPDD factors. The mean ratings for about 70% of the factors for both LM and IPDD are above 3.80. Specifically, out of twenty hypotheses, the respondents agreed that there is a high degree of similarities between LM and IPDD for all except three hypotheses H3, H6, and H8.

For H3, the mean ratings for LM and IPDD are respectively 4.34 and 3.81. This means although the respondents understood that short set-up and fast transition time are the main requirements of successful LM and IPDD, the relationship between short set-up and LM was much stronger.

Table 3. Comparison of LM and IPDD Factors (1=strongly disagree, 5=strongly agree)

	LM		IPDD			
Factor	**Mean**	**SD***	**Mean**	**SD***	**P-Value**	**Correlation**
1. Layout	3.92	0.85	3.62	1.08	0.140	0.74
2. Flow	4.08	1.03	4.06	0.96	0.640	0.83
3. Set-up	4.34	0.70	3.81	0.96	0.003	0.47
4. Lot-size	3.85	0.88	3.55	1.03	0.100	0.65
5. Quality at source	4.23	0.77	4.28	0.74	0.300	0.69
6. Quality Improv.	3.43	0.90	3.89	0.85	0.000	0.32
7. Inventory	4.22	0.80	3.96	0.85	0.150	0.62
8. Manufacturing cost	3.58	0.80	3.94	0.67	0.001	0.45
9. Delivery	4.26	0.75	4.31	0.72	0.280	0.75
10. Customer respons.	4.22	0.73	4.24	0.70	0.480	0.79
11. Teamwork	3.98	0.81	3.83	0.90	0.360	0.76
12. Flexibility	3.86	0.93	3.72	0.96	0.330	0.65
13. Team scheduling	3.72	0.78	3.76	0.78	0.240	0.82
14. Suppliers	3.77	0.79	3.82	0.83	0.350	0.77
15. Suppliers & teams	4.23	0.72	4.02	0.70	0.390	0.73
16. Technology	3.53	0.96	3.68	0.94	0.072	0.69
17. 5S Practices	4.30	0.92	4.12	0.84	0.310	0.71
18. Standardization	4.22	0.87	3.84	0.88	0.320	0.67
19. Value added	4.28	1.12	4.13	0.98	0.160	0.72
20. Overall	4.56	0.93	4.29	0.96	0.140	0.73

* SD = Standard deviation

This is a reasonable result because an average manufacturing manager has longer experience with LM than IPDD. They clearly understood that successful LM requires small lot-size and small lot-size requires short set-up time. However, due to their shorter experience with IPDD and because IPDD is primarily an information processing process, the links between small batches of information and fast transition time is not clear. H6 hypothesizes the relationships between small lot-sizes and quality improvement for both LM and IPDD. For this test, the mean ratings for LM and IPDD are respectively 3.43 and 3.89. This indicates for an average manager it is easier to recognize the relationship between CEID and quality improvement than the relationship between LM and quality improvement. The higher rating for IPDD is perhaps due to continuous and two way communication among design team members, which encourages early detection of the design problem. The LM result is also consistent with the literature because although total quality management and quality improvement are fundamental requirements of successful LM, an average manufacturing manager has difficulty to understand this relationship. The relationships between small lot-size and reduced manufacturing cost in LM and the relationship between small batches of information and reduced development cost in IPDD are examined in H8. The mean ratings for LM and IPDD are respectively 3.58 and 3.94. For the same reasons as H6, this means for an average manager it is easier to understand this relationship in IPDD than LM. The LM result is interesting and also consistent with the literature because reduced manufacturing cost in LM is primarily due to elimination of wastes, a fundamental principle of LM, and an average manufacturing manager has difficulty to see this relationship. The overall impact of lean principles on LM and IPDD is examined in H22. It is

obvious that the data supports the hypothesis as the mean ratings for LM and IPDD are respectively 4.56 and 4.29 indicating strong agreement with the statements that the main principles of waste elimination and respectful treatment of people in LM can also be applied in IPDD.
The last column of Table 3 shows correlation coefficients between LM and corresponding IPDD factors. The correlation coefficients in Table 3 strongly support the above analysis. With the exception of three hypotheses H3, H6, and H8 other coefficients are greater than 0.60 indicating a high degree of linear association between LM and IPDD factors.

The performance hypotheses (H21-H25) state that by utilizing IPDD approach, LM companies are able to design new products with fewer design changes, faster, more often, with less development cost, and less manufacturing cost than conventional companies.

Table 4. NPD Performances for Conventional and LM Companies using IPDD

Factor	Mean Conventional	Mean LM	p-value
Number of design changes	5.36	3.28	0.004
Development time (Months)	37.22	24.73	0.003
Development competency (Months)	49.46	32.72	0.005
Development cost	144.60*	100*	0.005
Manufacturing cost	135.75*	100*	0.005

* data reported in terms of percent improvement

Table 4 provides useful statistical information regarding NPD performances for LM and conventional companies. The average number of design changes for conventional and LM companies are respectively 5.36 and 3.28, a quality improvement of 63%. The average development time for conventional and LM companies are respectively 37.52 and 24.73 months, an improvement of 52%. For development competency, the average time between introduction of new products for conventional companies is 49.46 months and 32.72 months for LM companies, an improvement of 51%. Table IV also indicates that LM organizations enjoy a 45% reduction in NPD cost and 36% reduction in manufacturing cost. From the last column of Table 4, it is clear that the hypotheses are strongly supported by the data as the p-value for all five hypotheses is less than 0.005.

CONCLUSION

The focus of this article was to demonstrate possible links between LM practices and IPDD. First, comparison and analysis of a number of factors showed remarkable similarities between LM practices and IPDD. Second, a set of paired hypotheses was used to test similarities between LM practices and IPDD factors. Statistical results clearly support the hypotheses regarding similarities between LM and IPDD for majority of factors. Specifically, out of twenty two hypotheses, the respondents agreed that there is a high degree of similarities between LM and IPDD for all but three hypotheses. The last pair of hypotheses that examines the overall impact of LM principles is especially important. Statistical results strongly agreed that the main principles of waste elimination and respectful treatment of people in LM is also applicable to IPDD. The correlation coefficients between LM and IPDD factors also supported the same result. Third, statistical results also indicate that compared with conventional companies, LM companies are able to develop new products with 63% better quality, 52% less development time, 45% less development cost, and 36% less manufacturing cost. Also frequency of new product introduction is 51% faster than conventional companies.

In summary, statistical results of the article show strong links between LM practices and IPDD. Managerial implication of the research is that successful implementation of LM principles goes much beyond inventory reduction and frequent deliveries. For LM organizations success in IPDD is the result of knowledge and technology transfer from their LM system into their product design and development process.

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Integrating Drones and Big Data Applications for Supply Chain Efficiency

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ABSTRACT

The integration of drones and internet of things technology has created numerous opportunities for supply chain industry globally. The Big Data collected by Drones working with IoT sensor networks can help logistics companies monitor supply chain visibility, changing weather conditions to study the changing consumer behavior.
KEYWORDS: IoT, Drones, Supply chain, Logistics, Big Data

INTRODUCTION

The supply chain industry globally is being influenced by the digital disruption, thanks to the turbulent ecommerce retail industry. The present day consumer expects a seamless, faster purchasing experience

Today's supply chain industry is undergoing change in a big way, wherein the players are looking at capturing their share of market by delivering the goods to the customer in the shortest possible time at a lower cost. This effort calls for collecting information about the changing requirements of the customers at the speed of light, without which they have a risk of being thrown to the back seat in the ever changing supply chain industry. Hence, the logistics players have started looking for better alternatives to be ahead of their competitors.

OBJECTIVES OF THE PAPER

The basic objectives that would be achieved are:

1. Understanding the importance of big data analytics in the context of supply chain.
2. Understanding the various viewpoints on the need of drones in supporting the last mile delivery.
3. Understand the need and importance of integrating big data and drones into supply chain.

BIG DATA ANALYTICS IN SUPPLY CHAIN

The growth in adoption of supply chain technologies coupled with huge collection of data shifted the management focus from heuristics to data-driven decision making, giving rise to the big data era. Big Data Analytics (BDA) plays an important role in transforming and improving the functions of supply chain and decision making. The present day managers prefer taking decisions based on the data driven insights rather than relying on their intuitions (Davenport, 2006).

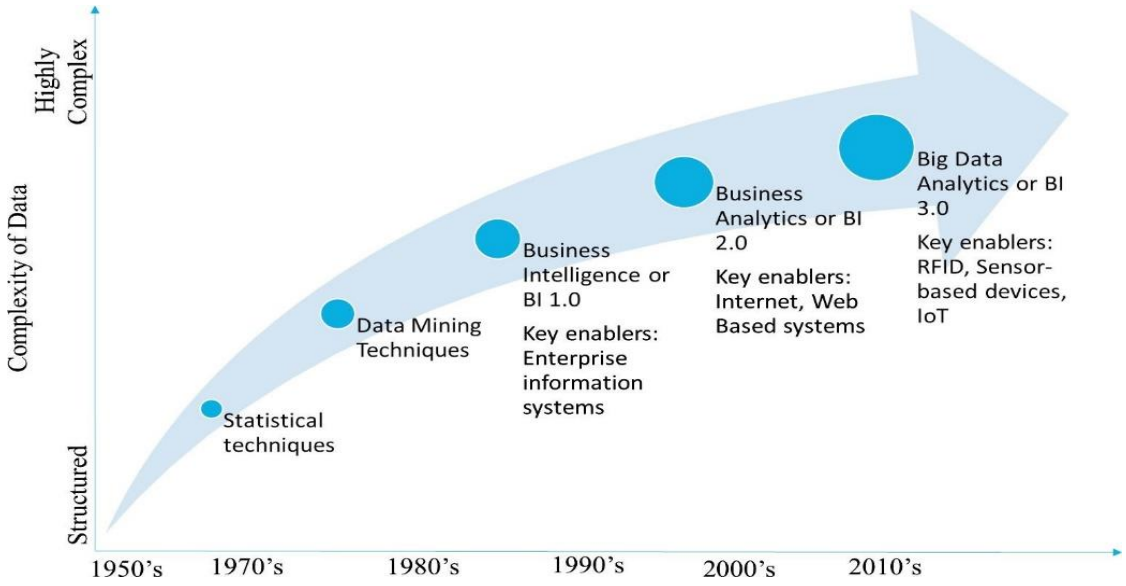
The perceived benefits of BDA have motivated organisations to develop their technical and organisational capabilities to extract value from data. But practitioners face extreme difficulties in understanding the required capabilities to transform data into value. The idea of generating value depends on an organisation's ability to capture, store and analyse a large volume of complex data with the support of advanced analytics (Yesudas et al., 2014). Though the phenomenon of Big Data is used worldwide, it has not emerged to the extent it was expected to be. During the past decade we have seen a tremendous increase in adoption of a variety of Information and Communication Technologies (ICT) for Supply Chain Management (SCM), such as RFID, Enterprise Resource Planning (ERP) to Internet of Things (IoT), etc., which has triggered huge data generation in the supply chain. The continuous efforts of firms to create more sophisticated technology for collecting data at different stages of supply chain have resulted in the new era of big data.

Supply chain signifies flow of information along with material and financial flow (Souza, 2014). With the adoption of ICT technologies, supply chains are enabled to monitor the information flow and inclined towards collecting and analysing a variety of data for efficient management (Chae and Olson, 2013).

A firm's supply chain has to manage the inflow of more than 100 gigabytes of data every day (The Economist, 2010) and about 90% of data available today are generated in the recent past years (Fawcett and Waller, 2014). Estimates shows that the usage of RFID tags would increase rapidly to 209 billion units by 2021 (Marr, 2014; Tachizawa et al., 2015). The number of networked sensors used in automotive, retail and transportation have increased at the rate of 30% per year (Manyika et al., 2011), as it is perceived that the sensor-based technology could substantially reduce the operational cost by 10–25% (Hahn and Packowski, 2015). The volume of digital data is growing exponentially and is expected to reach 35 Zeta bytes by 2020 (Tien, 2015). As a result, companies are increasingly recognising the value of data and advanced analytics tools. Adoption of BDA technologies has the potential to improve organisation's capabilities in the turbulent market environment (Meredith et al., 2012). Hence, to effectively deal with the diffusion of BDA technologies into the supply chain, various issues related to its adoption and practice has to be addressed.

Supply Chain Analytics (SCA) is the term used to indicate Big Data and analytics activities in supply chain management (Wang et al., 2016a, 2016b; Sahay and Ranjan, 2008; Souza, 2014). Chae et al. (2014a, 2014b) argued that there are three sets of resources (Data management resources, IT-based supply chain planning resources, and Performance management resources) collectively constitute SCA. Put together, supply chain analytics is the use of information and analytics tools to support efficient flow of material along the supply chain.

Big Data differs from traditional Business Intelligence (BI) solutions in terms of its scalability and the ability to store a variety of data types (structured and unstructured) in real-time as majority of traditional BI systems are inadequate and only able to store and analyse structured data aggregated at specific time intervals. From 1950 to 2010, the complexity of data has increased gradually, and hence, BDA has emerged as the technology to tackle BD challenges.



Evolution of Big Data Analytics

Big Data is related to technological advancement associated with new kinds of database architectures such as Hadoop, NoSQL, and distributed parallel processing of data. BD technologies can handle volumes of data and also can effectively manage a variety of data types such as textual information from online blogs, customer reviews, etc. (Mortenson et al., 2015). Vera-Baquero et al. (2015) argued that traditional BI systems are insufficient to integrate data from heterogeneous data sources. A widely acceptable definition of BD from Gartner is given as ‘‘high-volume, -velocity and -variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making” [Beyer and Laney, 2012, p. 2].

According to Manyika et al. (2011), ‘‘Big data refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse.” Based on the nature of data, the BD was characterised mainly by three dimensions such as ‘Volume,’ ‘Velocity,’ and ‘Variety’ (Manyika et al., 2011; Sonka, 2014). However, apart from the 3V’s, BD can also be characterised by another two dimensions as ‘Veracity’ and ‘Value’ (Manyika et al., 2011; Neaga et al., 2015; Ge and Jackson, 2014). ‘Volume’ refers to magnitude of data generated; ‘Variety’ refers to ‘‘structural heterogeneity in a dataset” (Gandomi and Haider, 2015, p. 138), ‘Velocity’ refers to the speed at which data is generated, analysed and acted upon(Gandomi and Haider, 2015), ‘Veracity’ or Verification refers to ensuring data quality, verifying unreliable and uncertain data; and ‘Value’ relates to economic benefits of Big Data (Mishra et al., 2016). From the capabilities perspective, BDA is defined as ‘‘the capability to manage and analyse petabytes of data and enable companies to deal with clusters of information that can impact the business” (Hurwitz et al., 2013, p. 22). Hofmann (2015) defined the three V’s of Big Data from capabilities perspective as ‘‘the ability of the organisations to process the volume of data integrated from a variety of data sources at a high velocity”. Richey et al. (2016) empirically explored the perception of SC managers about big data. While practitioners have recognised the Volume, Variety, Velocity and Veracity characteristics of Big Data, but there is no consensus attained regarding its definition.

LITERATURE REVIEW

I. Role of Big Data Analytics in Supply Chain

The literature on Big Data Analytics is reviewed in terms of the following capabilities:

1. Data generation capability

Data Generation (DG) capability is the ability of organisations to seek, identify, create, and access data from heterogeneous data sources across organisational boundaries. Better insights can be drawn from a good quality data through Enterprise information systems (EIS), which are mostly structured and transactional in nature. Adoption of electronic supply chain management (e-SCM) such as Internet-based inter-organisational systems, Internet based electronic data interchange (EDI) has enhanced communication, coordination, and collaboration across organizational boundaries (Lin, 2014). The adoption of these systems would generate volumes of data through data exchange from the members of supply chain network. Supply chain practices such as collaborative planning, forecasting, and replenishment (CPFR) also generate additional data that needs to be stored and monitored (Chae and Olson, 2013). Apart from these, the ability to collect data from the internet and its significance in improving supply chain performance is also addressed recently (Bhattacharjya et al., 2016; Mishra and Singh, 2016).

2. Data Integration and Management (DIM) capability

DIM capability is the ability of organisations to utilise tools and techniques to collect, integrate, transform and store data from heterogeneous data sources. The level of data integration, and ability to integrate different types of data gathered across organisational boundaries in real-time constitutes DIM capabilities.

Integrating vast amount of supply chain data distributed in heterogeneous sources is a big challenge for the firms (Stefanovic, 2014). DIM can be sub-divided into data acquisition, data pre-processing, and data storage. The dynamic supply chains makes it imperative to possess the capabilities of real-time access and scalability of data storage. The complex nature of BD makes the traditional database systems incompatible (Ge and Jackson, 2014). Hence, Chae and Olson (2013) considered that Inter organizational systems (IOS) such as Web-based or cloud-based EDI (Electronic Data Interchange) could be useful for enhancing data integration capability. Data integration capability can improve visibility, responsiveness, and performance of material management, and provide a 360-degree view of manufacturing operations (Xiong et al., 2015). Data storage component includes a set of hardware and software infrastructure that are suitable for scalability, storing data of different types and the systems to support fast querying and retrieval of data (Hu et al., 2014).

In supply chain context, there could be several reasons for reluctance in sharing data among its members. Some of the major barriers to data sharing are sensitivity, fear of losing competitive advantage and problems with access and control of information sharing (Radke and Tseng, 2015). Supply chains are dynamic in nature and prone to environmental uncertainty.

To streamline data sharing process, it is imperative to have data access control with firms in a short relationship and limit the access when the relationship perishes. If data is scattered and not integrated to provide a single point of truth, organisations would lack a valuable resource for decision making i.e. quality data; therefore, SCM demands DIM capabilities.

3. Advanced analytics capability

Advanced Analytics capability is defined as the ability of an organisation to utilise tools and techniques to analyse supply chain data in batch wise, realtime, near-time, or as it flows to extract meaningful insights for decision making. Data analytics techniques are classified into descriptive, predictive and prescriptive analytics (Souza, 2014). With the increase in analytics capabilities from descriptive to prescriptive analytics, organisation's decision-making capabilities at operational (short-term), tactical (mid-term) and strategic (long-term) level would certainly improve. Descriptive analytics is based on the principle of classical statistics methods, whereas

predictive analytics is the combination of statistics, data mining, and machine learning techniques (Blackburn et al., 2015). While descriptive analytics rely on historical data, predictive analytics utilises historical data including external data from other sources. Manyika et al. (2011) discussed various analytical techniques available to analyse Big Data, such as association rule mining, classification, clustering, crowdsourcing (data collected through web 2.0), data fusion and integration, ensemble learning, machine learning, genetic algorithm, network analysis, neural network, predictive modelling, sentiment analysis, spatial analysis, and time series analysis.

The dynamic nature of SCM demands real-time data analytics capabilities, which enables processing of real-time data (such as RFID data) to monitor processes and events (Manyika et al., 2011). Hahn and Packowski (2015) reviewed in-memory analytics application for real-time data processing in supply chain context, and categorised its application into (i) Plan and optimise (ii) Predict and act, (iii) Sense and respond, (iv) Monitor and navigate. Descriptive analytics on RFID and GPS data enables continuous monitoring of material flow in supply chain, increasing the visibility of assets. Predictive analytics helps in sensing and reacting to supply risk, demand risk, and operations risk, and also can be used to predict delivery, asset utilisation, maintenance, productivity, and sales forecast. Data mining techniques are applied in the area of supply chain fraud detection to reduce supply chain risks (Kraus and Valverde, 2014). Similarly, leveraging prescriptive analytics can be beneficial to plan and optimise supply chains either at operational or strategic level using aggregate data from transactions and granular data from day to day business operations.

4. Data visualisation capability

Data Visualisation capability is the ability of organisations to utilise tools and techniques to render information visuals and deliver the data-driven insights in a timely manner to the decision makers. Data visualisation is ‘‘the representation and presentation of data that exploits our visual perception abilities in order to amplify cognition” (Kirk, 2012, p. 17). The two main purposes of data visualization are sense-making (data analysis) and communication of abstract information through the graphical display (Few, 2009). In supply chain context, data visualisation capabilities are important and can be beneficial for SCM in various ways such as monitoring future demand, optimise distribution networks, visualise delivery routes and material tracking. The primary goal of data visualisation is to intuitively represent knowledge and information using various techniques such as tag cloud, graphs, Clustergram, and heat maps (Chen and Zhang, 2014; Manyika et al., 2011). In particular, heat maps which could display geographical information such as consumption location, transaction density, etc. is valuable to develop new distribution strategies (Tachizawa et al., 2015). Tools such as desktop applications, interactive web and mobile applications offer capabilities to executives, decision makers and customers to interact with the analytics ecosystem (Barlow, 2013). The presence of data visualisation capabilities can effectively support the three analytics capabilities (descriptive, predictive, and prescriptive) (Assunção et al., 2015). Highly interactive visualisation would help users to interpret, find patterns and make decisions quickly and effectively from raw data as well as content from analytics system.

5. Data-driven culture

Data-driven culture is an intangible resource representing the beliefs, attitudes, and opinion of people towards data driven decision-making. According to Aho (2015, p. 284) ‘‘The transformative potential of Big Data lies in treating data as an asset.” Aho (2015) argued that Big Data involves extensive change management and development of new organizational culture to transform the organisation. According to Kiron and Shockley (2011), three main characteristics constitutes data driven culture such as (i) Analytics should be treated as a valuable or strategic asset by an organisation, (ii) Top Management should support and

leverage analytics across the organisation, and (iii) Accessibility of Data-Driven insights to decision makers. Real-world case examples have highlighted the significance of the support from the implementation team and top management for developing BDA capabilities (Wamba et al., 2015). Lavalle et al. (2010) conducted a survey to identify the significant barriers to adoption of analytics in organisations, and found that apart from the challenges of technology and data quality, culture and managerial issues are the significant barriers to analytics adoption. Sangari and Razmi (2015) have empirically verified that organisations find it difficult to establish cultural competence in supply chains. Hence, to build transformational BDA capabilities, business and IT leaders in organisations have to work together and develop new strategies to address the needs of technology and business. Finally, Cao et al. (2015) argued that presence of the data-driven culture would facilitate organisations to make decisions based on facts to develop new products and services.

6. Cloud computing capability

Integrating cloud computing capability to leverage BDA for SCM can be of significance to attain maximum value from the investment. Cloud computing infrastructure can support the integration of data from both intra- and inter-organisational sources and provide scalable storage. From Resource Based View perspective, cloud computing is viewed as a complementary resource while BDA being the primary resource for improving performance. Different types of cloud-based service models are available such as infrastructure as a service (IaaS), platform as a service (PaaS) and Software as a service (SaaS), which are further deployed in four different ways such as private cloud, community cloud, public cloud, and hybrid cloud (Bruque Cámara et al., 2015). In the context of a supply chain, cloud-computing services such as IaaS can be deployed on a community level to facilitate data sharing between supply chain partners within the network. Neaga et al. (2015) argued that several business models based on cloud computing such as Analytics as a service (AaaS), Big Data as a service (BDaaS) and Knowledge and information as a service (KaaS/IaaS) can be adopted to leverage BDA. Further, cloud computing can be used to integrate and store structured and unstructured data from different sources, along with cloud-based data warehousing and Cloud-based data sharing (Tien, 2012). Alfaro et al. (2015) argued that to facilitate access of the analysed data and visualise it into cloud, an integrated architecture of personal cloud, supply cloud, manufacturing cloud, warehouse cloud and logistics cloud can be utilised to transfer information in near real time. Hence, integrating BDA on cloud will improve virtual integration causing supply chain boundaries to disappear (Fawcett and Waller, 2014).

7. Absorptive capacity

Absorptive Capacity (ACAP) plays a significant role in both assimilation and extraction of value from BDA. Cohen and Levinthal (1990, p. 128) defined Absorptive capacity (ACAP) as ‘‘the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends, which are critical to its innovative capabilities.” Malhotra et al. (2005, p. 145) perceive it as ‘‘the set of organisational routines and processes by which organisations acquire, assimilate, transform, and exploit knowledge to produce dynamic organisational capabilities.” Moreover, Zahra and George (2002), reconceptualised ACAP into potential ACAP (PACAP) and Realised ACAP (RACAP). According to Roberts et al. (2012), in the context of technology assimilation, ACAP is treated as an asset in the form of prior knowledge possessed by an organisation which foster innovation. BDA as a knowledge infrastructure could enhance knowledge transfer from supply chain partners and increase recipient firm’s ACAP. In the context of extracting value from technology like BDA, ACAP can be conceptualised as a dynamic capability, which could complement BDA capability in generating business value.

8. BDA maturity in supply chain context

Organisations who are better informed of their current state of BDA capabilities are in better position to tackle challenges while adopting it (Lavalle et al., 2010). Maturity models (MM) can help organisations to measure their current state of technological competence benchmarked against industry standards. The term 'maturity' was defined as ''state of being complete, perfect, or ready" (Simpson and Weiner, 1989). Starting from Nolan (1973), several BI and Big Data MM were developed both in academia and industry to help organisations realise their current potential and prepare for future endeavours.
According to Min, Shiwen, and Yunhao (2014), big data typically comprises masses of unstructured data that needs more real-time analysis. Manyika et al. (2011) defined big data as the next frontier for innovation, competition, and productivity (Intel IT Centre – Peer Research, 2012). Richard et al. (2011) in their IDC whitepaper stated that big data technology could be described as a new generation of technologies and architectures, designed so that enterprise organizations could economically extract value from very large volumes of a wide variety of data by enabling high-velocity capture, discovery, storage and analysis. This definition is largely agreed to by many researchers and enterprise industrial R&D managers (Seref and Duygu, 2013; Min et al., 2014; Manyika et al., 2011; Janusz, 2013), although it is also obvious others have different views. The IDC, one of the most influential leaders in big data and its research fields, defines big data in two of its reports (Gantz & Reinsel, 2011; Richard et al., 2011), and outlines some attributes of big data as the four Vs, that is, big data development sources (Variety – V1), big data acquisition (Velocity – V2), big data storage (Volume – V3), big data analysis (Veracity – V4), and finally modulating towards big data value adding or implementation benefits to industry (Value-adding – V5).

II. Drones in Supply Chain
Recently the applications of drones have been proposed for more efficient last-mile delivery (Murray and Chu 2015) (Ponza 2016) (Agatz, Bouman, and Schmidt 2015) (Ha et al. 2015) (Olivares et al. 2015) (Savuran and Karakaya 2015) (Ferrandez et al. 2016) (Wang, Du, and Ma 2014). In this approach, trucks carry some drones in addition to packages. At some points in their routes, drones are launched to deliver supplies to customers. Thus, not only trucks, but also drones are used to deliver supplies to recipients.

APPLICATIONS OF DRONES IN SUPPLY CHAIN
A drone is an unmanned aircraft, more formally known as unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UAS). Essentially, a drone is a flying robot, remotely controlled or can fly autonomously through software-controlled flight plans in their embedded systems working in conjunction with onboard sensors and GPS.
UAVs take different forms, with different control levels, with the capacity to carry a very wide range of payloads. They perform various functions with inbuilt intelligent stabilization systems to keep them flying and can carry sensors, the most common device is a camera mounted on gimbals to obtain high-quality video and still photography. Depending on their lift capacity and payload specifications, UAVs can also carry multiple sensors to extract a wide range of information, increasing the number of possible applications and the business value of their outcomes.
Uses of drones are widespread and include parcel delivery, rural deliveries, surveillance, surveying, and reading barcodes and RFID (radio frequency identification). Drones can have a variety of components added to them; this adaptability allows drone technology to benefit any industry. Business applications aside, drones are being produced as a consumer toy with sizeable markets and growing demand.
Based on a report from market analysis firm Tractica, worldwide sales of consumer drones reached $1.9 billion in 2015, and the market will continue to grow for the next few years.

Tractica forecasts that worldwide consumer drone shipments will increase from 6.4 million units in 2015 to 67.7 million units annually by 2021.
One of the main reasons to use drones is their faster speed and no need for roads. There are many developments taking place globally that can impact the supply chain industry.
The developments fall into two broad categories:
1. Informational/Analytical Innovation:
Cloud computing, big data, and cognitive analytics to capture, store, analyze, and derive insights from data, disseminating and capturing data generated by the Internet of Things (IoT).
2. Physical innovation:
Technologies that take a more physical form, such as drones, driverless vehicles, robotics, smart glasses/augmented reality, and 3-D printing.

The segmentation of the supply chain industry into the two categories is only arbitrary, whereas it is very much evident that the two categories are linked with each other in a big way. The physical innovation along with analytical innovation, enabled through advanced software technologies would optimize the resources. This type of innovation adds visibility to the supply chain coupled with physical devices resulting in improvements in customer service, inventory, cost, and supply chain excellence.
Many companies are using the drone applications for various uses internally within their supply chain operations, which are as given below:
1. Inventory visibility: A drone navigates the entire warehouse and checks the physical inventory by scanning the barcodes and reading the RFID tags. A large amount of inventory data is captured in less time, increasing accuracy and operational efficiency.
2. Facilities inspection: The drones are used to inspect various physical facilities in the entire supply chain, such as truck movement, road and rail routes, traffic congestions, which are used to plan the delivery of goods in advance.
3. Yard management: Transportation vehicles pass through the trailer yards, which is an intersection between transportation and warehousing. Hence, the yard management system is very critical to track and manage the transportation and inventory assets optimally.
4. Service and repair: The drones are used to deliver spare parts to large equipment manufacturers located in remote areas, without incurring huge costs of transportation. This makes the process of servicing large machinery easy and faster.
5. Customer Service: As the e-commerce is growing day by day, the need for a more viable solution to the problem of delivery in heavily congested and confined urban areas is vital for the logistics companies. Last mile delivery becomes difficult in urban areas across many global locations, and hence drones can be used to reach to various locations without being stuck in heavily congested traffic situations.
6. Save Money: According to Bloomberg, human crews make up almost 50% of the cost of operating a cargo ship. If automation can save that amount of money, we expect a major trend toward cargo drones to arrive soon.
7. Eliminate Human Error: The possible errors that can be made by human beings, such as negligence, willful act, etc., can be eliminated by using the cargo drones.
8. Deliver Goods to Places We Wouldn't Normally Go: Remote areas of the world, such as oceanic islands, Arctic regions, or troubled or remote areas are often inaccessible due to poor communications and transportation networks to those locations, where it's either too dangerous or too costly to ship goods there regularly. Unmanned aircraft can perform these tasks efficiently in extreme conditions.

DATA GATHERED BY DRONES
Drones have become digital eyes in the sky, harvesting visual data that computers transform into valuable insights and efficiencies for the users. In the present world, commercial drones are

creating 3D maps of bridges and construction sites, surveying previously unexplored areas, spotting safe places to mine and helping speed disaster relief efforts. They have become the tools for digitizing the real world, and the supply chain companies can use computer technologies and artificial intelligence (AI) to track and manage things.
The drones are programmed with a pre-planned flight plan, and rely on specific locations to trigger the camera, which captures digital images of land and Earth-bound objects, which are assembled into a 3D digital map. They collect thousands of gigabytes of data, which needs to be analyzed properly.
Drones have the potential to enhance many different types of activities previously done by humans. Small-package delivery, land surveys, CAD analysis, videography, herd counting, forest growth measurement, stocking shelves, inspecting well sites, and inspecting rail tracks are just some examples where drone technology can enable employees to work faster and more efficiently.

INTEGRATION OF BIG DATA AND DRONES IN SUPPLY CHAIN

The companies not only have access to data from every link in their supply chain from sensors on the factory equipment to GPS on delivery trucks and bar code scanners in the store, but they can collect the data generated by delivery drones. This large amount of data creates an enormous dataset, the analysis of which can be useful to optimize supply chain, increase end-to-end visibility and drive efficiency for their customer.
The logistics industry stands on the front line with other industries in the Big Data revolution. In a supply chain context, Big Data means companies can analyze not only their own supply chain data in ways never before possible, they can also aggregate their data with other competitors to drastically increase their ability to detect trends in supply chain industry.
The amount of data collected by the shippers has grown significantly. Connectivity gained through Internet of Things (IoT) is producing countless data points, which needs to be analyzed and used in a way that creates value. Shippers can supplement the traditional data with external indicators, such as weather, to predict consumer behavior and identify potential supply chain disruptions. Drawing on data can help to predict when to ship or stage products ahead of a weather event or when to ship items based on demand.

CONCLUSION

Due to capacity constraints and flight range limits, drones are not able to be used as the sole vehicle for distributing supplies. The combination of trucks and drones seem to be an effective approach for last-mile delivery. In this combined system, trucks are used for two purposes: deliver larger packages, carry drones to a location close to the customers' locations and launch them for faster delivery.
As the global supply chain industry is growing and the emphasis is on faster customer service at lower cost, the dependency on third party logistic providers is decreasing and the companies are focusing on making the delivery directly to the consumers on their own. This calls for adopting the usage of drones to achieve the dual objectives of faster delivery and low cost. Hence, the companies should leverage on adopting the usage of big data for competitive advantage by converting huge amounts of data collected by drones into valuable propositions. However, as drone use increases, employees will need to be trained and licensed in drone operation and will need to understand how to operate, manage, and understand the data collected by drones.

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Integrating Supply Chain Simulation Game with Linear Programming Optimization in a Supply Chain Management Course

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Abstract

This paper discusses the use of linear programming optimization in an undergraduate supply chain management class at Christopher Newport University in conjunction with online simulation game. The supply chain management class is a required major class offered to students enrolled in a BSBA program with concentration in management. The class is a broad overview of the supply chain management discipline. In order to provide students with a hands-on experience designing and managing the supply chain, the supply chain simulation game by LittleField Technology is used. The paper provides the game overview, as well as formulation of LP problem in order to design an optimal supply chain to meet customer's demand while maximizing the company profit.

Use of simulation games to illustrate academic concepts is not new. Active learning and simulation-based pedagogy are becoming more prevalent in supply chain management classes. At the same time management science tools and techniques, such as applications of linear programming are oftentimes covered in a separate introductory course. Models, discussed in management science often cover various topics in a piece-meal fashion. Typical material covered includes direct transportation model, transshipment model, assignment problem, and a few others. In order to avoid "silo learning" affect and illustrate the application of management science to solving supply chain problems, this paper describes an attempt to integrate linear programming optimization with the simulation game in an undergraduate supply chain management course. The supply chain simulation game used in the class is offered by Responsive Learning Technologies (www.responsive.net). In the simulation game students are required to manage a two-tiered supply chain company in order to maximize profit. In the course of the game teams of 2-3 students must identify in which locations they want to build production factories, how much manufacturing daily capacity to procure for each factory, and where to construct distribution warehouses. Together with facility locations, students must address which modes of transportation to use between factories and warehouses, as well as between warehouses to customer markets. The assignment implies that supply chain, designed by students, must be balanced, with total production capacity sufficient to meet total demand. Therefore, the starting point of the supply chain configuration is creating a demand forecast for each region where the virtual company operates in the supply chain game. In this paper we propose an exercise where the configuration of the supply chain described above is determined by formulating and solving an integrated facility location and trans-shipment LP problem. Such analysis will provide an application of the management science modeling approach to a simulated scenario which models real business issue. It is important that an introductory class in management science is either a pre- or a co-requisite for such exercise.

DECISION SCIENCES INSTITUTE

Introducing E-health into your Organization: A Case-based Approach
Full Paper Submission

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ABSTRACT

United States healthcare ranked last compared to 10 other industrialized nations based on variables such as quality, access, efficiency, equity, and healthy lives. This paper examines the existing literature in e-health environment, examines five current case examples, then introduces seven key information technology (IT) that should be integrated into healthcare and healthcare system (HAHS) that could improve healthcare and enhances the United States position in the world healthcare system. The seven key IT include (1) the Internet, (2) big data analytics, (3) wearable computing (4) mobile computing, (5) virtual and augmented reality, (6) robotics, and (7) artificial intelligence (Bidgoli, 2018).

KEYWORDS

E-health, healthcare and healthcare system (HAHS), big data analytics, wearable computing, artificial intelligence

INTRODUCTION AND BACKGROUD

According to a study conducted in 2014, United States healthcare ranked last compared to 10 other industrialized nations as follows: (1) United Kingdom, (2) Switzerland, (3) Sweden, (4) Australia, (5) Germany & Netherlands (tied), (6) New Zealand & Norway (tied), (7) France, (8) Canada, (9) United States. The Key variables used in the study were quality, access, efficiency, equity, healthy lives. They are briefly explained below (Unknown, 2014):

Quality- This includes effective care, safe care, coordinated care, and patient-centered care.

Access- Due to high cost and lack of universal healthcare for the nation, healthcare system is not available to everybody compared to their counterpart nations in the study.

Efficiency- Due to high administrative costs, avoidable emergency room use, and duplicative medical testing, efficiency is relatively low.

Equity- Due to high cost the healthcare system is mostly available to wealthier people and those that have full-time employment.

Healthy lives- Measured based on mortality amenable to medical care, infant mortality, and healthy life expectancy.

The United States spends the most on healthcare compared to these other nations. Another study published in 2017 covering 184 countries indicated that U.S. per capita spends far more than other countries with similar life expectancy (Brink, 2017). We believe a proper integration of IT tools and techniques into healthcare and healthcare system can play a major role and offer a positive impact on all of the five key variables mentioned above. We define electronic health (e-health) as: The integration of IT tools and techniques into healthcare and healthcare system in order to reduce overall cost and improve quality, access, efficiency, equity, and healthy lives.

The integration of IT tools and techniques into healthcare and healthcare system in addition to improving healthcare in general, it could also improve reporting, claims processing, data management, and process automation that collectively should reduce the growing cost of HAHS.

THE LANDSCAPE OF ELECTRONIC HEALTH

A recent survey on the status, applications, deployment, challenges, and opportunities presented by e-health reveals interesting facts as follows:

Medical mistakes in the U.S. hospitals and healthcare institutions are the third leading cause of death and nearly 98,000 people annually lose their lives in this way. E-health could significantly reduce this number (Ehteshami, et al. 2013).
The experience of Angelina Jolie, the well kwon actress highlights how cloud computing can help address cancer by cutting the cost of genomic sequencing and enabling data sharing (Puranik, 2017).
The 'doctor's bag of the future could be a 3D printer by allowing doctors to create or make wherever they are, in the space or a remote rural area (Strickland, 2017).
Apple is working with a start-up called Health Gorilla to turn the iPhone into a personal hub for all of its customers medical information, this could add diagnostic data to the iPhone, including blood work, by integrating with hospitals, lab-testing companies such as Quest and LabCorp and imaging centers (Farr, 2017).
Senate bill would pay doctors to use Facetime with patients enabling physicians and other healthcare providers to evaluate patients via video chats such as Facetime (Mearian, 2017).
IBM Watson in conjunction with FDA are exploring blockchain for secure patient data exchange, the initial focus for blockchain will be oncology-related data exchange (a-Mearian, 2017).
IBM Watson artificial intelligence platform has joined forces with researchers at MIT and Harvard to use genomic data to defeat drug-resistant cancers (Mearian, 2016).
Aetna gave away 50,000 Apple Watches to its employees and subsidize others for customers. It is working with Apple on iOS-exclusive integrated health apps for iPhone, iPad, and Apple Watch devices (a-Mearian, 2016).
Artificial intelligence could help diagnose mental disorders using machine learning in order to train software to spot verbal tics associated with schizophrenia, depression, and bipolar disorder (Frankel, 2016).
A toy-like cardboard contraption that sells for less than $20 online from Google, as a virtual reality tool, has helped save the life of a baby who was so sick that doctors told her parents to take her home to die (Cohen, 2016).
Because of the availability and readily access to healthcare data, government and industry leaders caution that medical data must come with context in order to provide meaningful insights for patients and researchers (Corbin, 2014).
As the resistance reduces, IT leaders are helping more and more health care providers move to the cloud from the on-premise IT computing (Linthicum, 2014).
IBM and Pathway Genomics working on a mobile app that uses personal history and genetics to assess risks and plan exercise in order to keep people healthier (Gaudin, 2014).
A recent Pew Internet study suggests that rising smartphone adoption in the United States seems to be motivating people to use mobile health (Eastwood, 2013).
Health care workers in the developing world are using mobile phones to address critical health needs ranging from maternal mortality to HIV testing to clean water (Kim, 2012).
By filtering through 2 billion public tweets, John Hopkins University scientists discovered health patterns, including misuse of medications (Samson, 2011).
IoT medical devices will play a major role in healthcare system, according to recent surveys, healthcare providers, manufacturers, and regulators believe cybersecurity risks of IoT medical devices and connected legacy systems are a top security concern (Kawamoto, 2017).
Many hospitals transmit health records unencrypted due to lack of budget and personnel to address security concerns (b-Mearian, 2016).
Hackers want your healthcare data which is much more valuable than credit card information (Rashid, 2015).
California DOJ report on data breaches shows most losses in healthcare revolve around stolen devices, due to weak use of encryption that, poses greatest risk to healthcare data (Yegulalp,2014).

RESEARCH QUESTIONS

What are critical success factors in design and implementation of an electronic health system?
What are the key IT components of an electronic health system?
Is the adoption of an electronic health system ROI justified?

CONCLUSION

This paper examined the existing literature in e-health environment, reviewed five current case examples, and then introduced seven key information technology (IT) that should be integrated into healthcare and healthcare system (HAHS). This integration should improve healthcare and enhances the U.S. position in the world healthcare system. The seven key IT include (1) the Internet, (2) big data analytics, (3) wearable computing (4) mobile computing, (5) virtual and augmented reality, (6) robotics, and (7) artificial intelligence. The paper also assessed major risks associated with e-health systems including security and privacy of medical records, and risks associated with medical IoT devices and then recommended an e-health plan for implementation. These seven IT tools could improve key variables (quality, access, efficiency, equity, and healthy lives) in the healthcare and healthcare system.

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Inventory Models as a Buyer's Point of View on Supply Chain Delivery Performance

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ABSTRACT

This paper examines the interaction of delivery and inventory models and the effect of delivery performance on the supplier's and buyer's costs in a two-stage supply chain. From a supplier's prospective, the effect of the timeliness of delivery can be described by supply chain delivery performance models. From a buyer's point of view, supply chain delivery can be represented by inventory models. This comparison and supporting analysis bridges existing gaps found in the literature and contributes to linking and coordinating the delivery and inventory sub processes within supply chains. Theoretical and managerial implications of the findings are discussed.

KEYWORDS: Delivery performance, Supply chain management, Inventory models, delivery time, two levels of storage

INTRODUCTION

Supply chain management serves as the foundation of an organization's overall competitive strategy for attaining and maintaining competitive advantage. The Supply Chain Operations Reference-model (SCOR) defines the delivery process as one of five supply chain processes (plan, source, make, deliver, and return). The timeliness of delivery is a key concern to customers and numerous empirical studies have documented the importance that on-time delivery plays in the operation of the supply chain (da Silveira & Arkader, 2007; Iyer et al., 2004; Salvador et al., 2001). This paper herein evaluates an effect of the timeliness of delivery within a two-stage supply chain on both a supplier and a buyer.

From a supplier's prospective, the effect of the timeliness of delivery can be described by supply chain delivery performance models (Bushuev and Guiffrida, 2012). Models for evaluating delivery performance within supply chains can be categorized into two groups: i) index based models (see for example, Wang and Du, 2007; Garg et al. 2006), and ii) penalty cost based models (see for example, Shin et al., 2009; Guiffrida and Nagi, 2006). Both categories of models are similar in that delivery timeliness to the final customer is analyzed with regard to a delivery window whereby a supplier is penalized for untimely (early or late) delivery. As identified in Gunasekaran and Kobu (2007) delivery performance should be measured in financial terms. Therefore, this paper focuses on penalty cost based delivery performance models. Although a supplier cannot guarantee delivery timeliness, it can decide when the product will be shipped and thus increase or decrease probabilities of early and late deliveries. The concept of the optimal position of the delivery window (OPDW) proposed by Bushuev and Guiffrida (2012) extended the research in this area. The concept shows that the optimally positioned on-time portion of the delivery window can minimize the expected penalty costs of untimely (early and late) delivery for any delivery time distribution with a continuously

differentiable probability density function. By applying this concept a supplier can determine when to initiate the shipment of the product so as to minimize the expected penalty cost for untimely delivery. Delivery performance models investigate penalty costs for untimely delivery for a supplier; hence the models can be used as a supplier's point of view on supply chain delivery performance.

On the buyer's side, early and late deliveries introduce waste in the form of excess cost into the supply chain; early deliveries contribute to excess inventory holding costs while late deliveries may contribute to production stoppage costs, lost sales and loss of goodwill. Thus, delivery will affect the buyer's inventory level and inventory models represent the buyer's point of view on supply chain delivery. It is in the buyer's best interest to minimize inventory costs and probability of stockouts. Under the concept of the delivery window used in delivery performance models, the customer sets benchmarks in time which are used to classify deliveries as being early, on-time, or late. In general, when the delivery window is imposed on the underlying delivery time pdf (probability density function), the delivery performance model becomes a stochastic model with three possible outcomes: early, on-time, and late delivery. In classical inventory models, there are two possible outcomes (stockouts and no stockouts) in each inventory cycle that can occur as a result of the demand during lead time. Late delivery contributes to stockouts; on-time delivery contributes to no stockouts. In practice, usually the storage capacity for inventory is limited and industry has a long history of working to address the effects of limited storage space (Kempf et al., 2011). When a limited storage space is considered three outcomes are now possible: stockouts, overloading, and no stockouts and no overloading; where overloading means the level of inventory exceeds the storage capacity. Delivery time is a common element that affects the delivery outcomes (early, on-time, and late) and inventory outcomes (stockouts, overloading, and no stockouts and no overloading). Hence it is an attractive factor for further study.

Two formulation approaches have been reported in the literature for inventory models with limited storage space. The first approach takes the form of a resource constrained optimization problem with storage capacity as the constraining resource (see for example Hausman et al., 1998; Zhao, 2007). A second modeling approach due to Hartley (1976) recognizes that outside storage space can be rented hence the optimization of the inventory decision variables is addressed from a modeling perspective that accommodates two levels of storage: owned warehouse (OW) and rented warehouse (RW). Hence, the models with capacity constraints are just a special case of the models with two levels of inventory with the costs for rented warehouse equal to infinity. Previous researchers mostly focused on deterministic models with two storage facilities (for example, Sarma, 1983; Lee and Hsu, 2009).

Inventory models assume that a reorder point (a time when a buyer places an order) defines when the product will be shipped and, as a result, when it will arrive to the buyer. In reality a supplier ships the product and the time when the product will be shipped is the supplier's decision. How the supplier's delivery decision will affect buyer costs? Could the buyer influence the supplier's delivery decision? The answer can be found comparing delivery and inventory models as supplier's and buyer's points of view. However, the existing literature has a gap between two research streams (supply chain delivery performance and inventory management) and fails to provide a research which considers the problems together. This paper bridges existing gaps found in the literature and contributes to linking and coordinating the delivery and inventory sub processes within supply chains. This paper explains how supply chain delivery performance and inventory models define a supplier's and buyer's points of view respectively and how different points of view affect managerial decisions.

To facilitate the comparison of the models under study we present them sequentially. Initially the delivery performance model, which captures the supplier's point of view, is presented. The inventory model, which captures the buyer's point of view, then follows. This

paper is further organized as follows. Section 2 provides a supplier's point of view based on delivery performance models and defines the optimal delivery decision derived from the models. In Section 3, a new inventory model is developed proposing a buyer's point of view on the delivery. The comparison of delivery performance and inventory models as supplier's and buyer's points of view is presented in Section 4. A buyer's strategy for delivery performance optimization is discussed in Section 5. Section 6 presents a summary and discusses future research directions.

DELIVERY PERFORMANCE MODELS AS A SUPPLIER'S POINT OF VIEW

An integral component found in many supply chain delivery performance models is the concept of the delivery window. Under the concept of a delivery window, contractually agreed upon benchmarks in time are used to classify deliveries as being early, on-time, and late (see Figure 1). When delivery occurs outside the on-time portion of the delivery (early or late), the supplier incurs a contractually specified penalty cost. When delivery is within the on-time portion of the delivery window, no penalty cost is incurred (see for example, Schneiderman, 1996; Freehand, 1991).

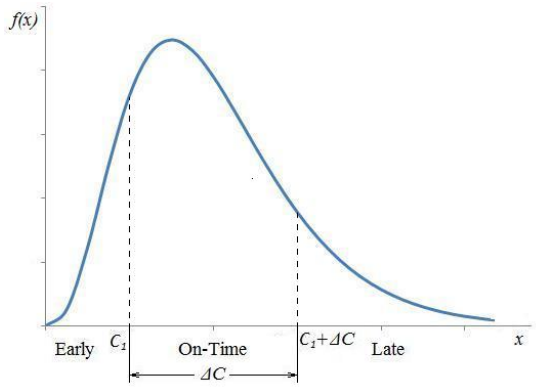

Figure 1. Illustration of a Delivery Window

Legend: *f(x)* is the probability density function (pdf) of delivery time, c_1 is beginning of on-time delivery, Δc is the width of the on-time portion of the delivery window.

Guiffrida & Nagi (2006) defined the expected penalty cost per period for untimely delivery for a two-stage serial supply chain as:

$$Y = QH\int_{a}^{c_1}(c_1 - x)f(x)dx + K\int_{c_1+\Delta c}^{b}(x-(c_1+\Delta c))f(x)dx, \quad (1)$$

where Y = expected penalty cost of untimely delivery,

$QH\int_{a}^{c_1}(c_1 - x)f(x)dx$ = expected penalty cost of early delivery,

$K\int_{c_1+\Delta c}^{b}(x-(c_1+\Delta c))f(x)dx$ = expected penalty cost of late delivery,

$f(x)$ = probability density function (pdf) of delivery time x,
QH = penalty cost per time unit early (levied by the buyer),
K = penalty cost per time unit late (levied by the buyer),
a = earliest acceptable delivery time,
b = latest acceptable delivery time,

c_1 = beginning of on-time delivery,
Δc = the width of the on-time portion of the delivery window.

The model makes the following assumptions: (i) there is a single product with a fixed delivery lot size Q, (ii) the delivery time consists of the internal manufacturing lead time(s) of the supplier plus the external lead time associated with transporting the delivery lot size from supplier to buyer, and (iii) a make-to-order replenishment policy is in effect.

The parameter c_1, the beginning of on-time delivery, defines the position of the on-time portion of the delivery window and together with the width of the on-time portion of the delivery window (Δc) and delivery time distribution parameters establishes the probabilities of early, on-time, and late delivery. These probabilities directly affect the value of the expected penalty cost (Y). As demonstrated in Bushuev and Guiffrida (2012), Y is a convex function of c_1 and the optimal value of c_1 (which is defined as c_1^*) that minimizes Y can be determined by evaluating

$$K \cdot P_{late} = QH \cdot P_{early}, \text{ or } P_{late} / P_{early} = QH / K \quad (2)$$

where $P_{late} = \int_{c_1+\Delta c}^{b} f(x)dx$ is the probability of late delivery,

$P_{early} = \int_{a}^{c_1} f(x)dx$ is the probability of early delivery.

In the supply chain delivery performance model, c_1 defines beginning of on-time delivery with respect to a time when a product is shipped (which is shown on Figure 1 as zero point). Since the on-time portion of the delivery window is fixed by a contract, changing c_1 means altering the time when a product is shipped. In the paper herein we assume that the supplier uses the concept of the optimal position of the delivery window (OPDW) to define the optimal value of c_1 and, accordingly, a time when the product should be shipped to the buyer.

INVENTORY MODELS AS A BUYER'S POINT OF VIEW

In this section, we define the mathematical form for a stochastic continuous review (Q, R) inventory model with two levels of storage. The goal is to find the optimal reorder point (R^*) which will minimize the expected total cost. We assume that the lot size (Q) is not a decision variable in the model to maintain consistency with the delivery performance model which also assumes constant lot size. To construct the model, we employ the following notations and assumptions.

Notations

C_O = Cost of overload (cost of holding extra inventory when inventory level is higher than size of warehouse, \$/unit time);
C_S = Cost of stockout (\$/unit time);
D = Demand (units/unit time);
H = Holding cost per unit per year (\$/unit/unit time);
L = Lead time (unit time), random variable with probability density function (pdf) $f(L)$;
Q = Order quantity (Lot size, units);
Q_{max} = Size of warehouse (units);
R = Reorder point (units);
S = Ordering cost (\$/order).

Assumptions

The following assumptions about the model are made:
(1) Average lead time and its pdf are known.
(2) A single product, instantaneously replenishment, and no quantity discounts.
(3) Stockouts are backordered.
(4) Storage is limited by the capacity of the OW, however additional storage can be purchased at an RW.
(5) Demand is first met from RW until it is empted. Items in OW are used only after RW is depleted.
(6) The transportation cost between warehouses is negligible.
(7) Holding costs are applied to any unit of inventory on hand (at OW and RW).
(8) Reorder point $R > 0$.
(9) No interaction between orders ($0 \le L \le Q/D$).
The last assumption is supported by other researchers, the "interval between placing orders is usually large enough so that there is essentially no interaction between orders" (Hadley and Whitin, p. 203) or the probability of crossover is small enough to be ignored.

The model

As shown on Figure 2, there are three possible (probabilistic) outcomes for the inventory model. These outcomes are:

1. $L > R/D$. Inventory level reaches zero level and in addition to inventory holding cost we are paying for stockouts, because of late delivery.
2. $A/D \le L \le R/D$, where $A = R - (Q_{\max} - Q)$ (*B* area, $B = Q_{\max} - Q$). No stockouts, no overload. Thus, we have inventory holding cost only.
3. $L < A/D$. When delivery occurred, the inventory level will exceed $Q_{\max}$, so we are paying for overloading and inventory holding cost.

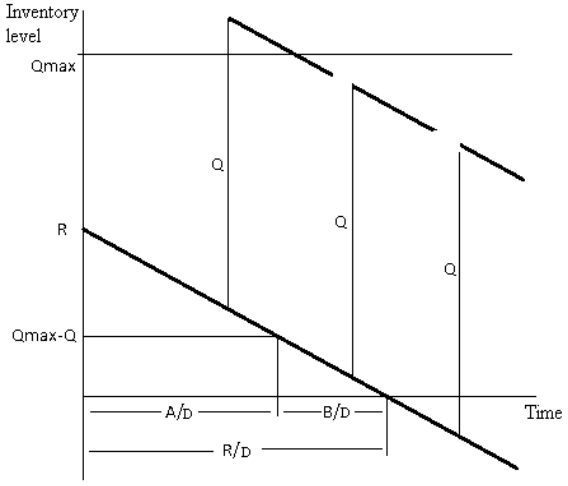

Figure 2. Typical outcomes

The probability of each outcome can be found by integrating the probability density function of lead time over the appropriate outcome specific limits. The probability of late delivery, when stockout occur (outcome 1) is

$$P_{late} = P(L > R/D) = \int_{R/D}^{\infty} f(L)dL \,. \quad (3)$$

The probability of on-time delivery without stockouts and overloading (outcome 2) is

$$P_{ontime} = P(A/D \le L \le R/D) = \int_{A/D}^{R/D} f(L)dL \,. \quad (4)$$

The probability of early delivery, when overload occur (outcome 3) is

$$P_{early} = P(L < A/D) = \int_{0}^{A/D} f(L)dL \,. \quad (5)$$

The total cost per unit time is (see Appendix A for proof):

$$\mathrm{E}(TC) = S\frac{D}{Q} + \frac{H}{2}\left(Q + 2(R - \mathrm{E}(L)D)\right) + \frac{H}{2Q}(Y_{late})^2 + \frac{C_0}{Q}Y_{early} + \frac{C_S}{Q}Y_{late} \quad (6)$$

Where the first element is ordering cost, the second two elements are inventory holding cost, and the last two elements are costs of overload and stockout, respectively.
The reorder point is optimal when (see Appendix B for proof):

$$H\left(Q - Y_{late}P_{late}\right) + C_0P_{early} = C_SP_{late} \,. \quad (7)$$

COMPARISON OF DELIVERY PERFORMANCE AND INVENTORY MODELS

In the previous sections, the costs associated with the delivery process were defined for a supplier and a buyer. Both a supplier and a buyer are interested in minimizing their costs, but that might involve conflicting goals. They have a certain influence on the delivery process attempting to minimize their costs, but neither can change all parameters which affect the cost functions alone. A supplier has control of the time of delivery only and would apply the concept of the optimal position of the delivery window to find an optimal time of delivery. A buyer can affect the supplier's optimal time of delivery by defining the penalties for untimely delivery in the contract which is a common purchasing agreement practice. A supplier would prefer a time of delivery that will minimize its costs and penalties equal to costs of overload and stockout. How can a buyer achieve this goal? Supplier's and buyer's points of view on delivery performance are compared to answer this question.

The supply chain delivery performance model shown in Section 2 describes a supplier's point of view on delivery performance. In Section 3 an inventory model was introduced as a buyer's point of view. Both of these models demonstrate costs related to a product delivery for a supplier and a buyer (equations (1) and (6) respectively). Table 1 summarizes the key parameters in the cost functions of each model and identifies the model commonalities which support a comparison of the points of view of the supplier and buyer.

Table 1. Connection between parameters of supplier's and buyer's cost functions

Supplier	Buyer	Description
QH	C_o	Cost of early delivery / overload ($/unit time)
K	C_s	Cost of late delivery / stockout ($/unit time)
x	L	Random variable: Delivery lead time (unit time)
Δc	$Q_{max} - Q$	Width of on-time portion of delivery window (unit time) / (units)
c_1	R	Decision variable: Beginning of on-time delivery (unit time) / Reorder point (units)

Both models (supplier's and buyer's) have three possible outcomes: early delivery (overload), on-time delivery (no overload and no stockouts), and late delivery (stockouts). These outcomes are related to the same random variable in both models: delivery lead time. This random variable is compared with a decision variable to define the outcomes.

The decision variable in the delivery performance model (beginning of on-time delivery, c_1) is connected with the reorder point (R) decision variable in the inventory model. They have different dimensions, however the ratio $\frac{R-(Q_{\max}-Q)}{D}$ used in the inventory model has the same meaning as c_1 in the delivery performance model. The width of the on-time portion of the delivery window (Δc) is measured in time units in the delivery performance model and in units of product in the inventory model ($Q_{max} - Q$). Through the conversion $\frac{Q_{\max}-Q}{D}$ the common unit of time can be introduced into the inventory model thus enabling a direct comparison between the delivery and inventory models. For further discussion we define R_b^* as the optimal reorder point for a buyer and $R_s^* = c_1^* D + Q_{\max} - Q$ as the optimal reorder point for a supplier. A buyer would prefer to have $R_b^* = R_s^*$, because in this case a supplier choosing an optimal delivery will minimize buyer costs too. Differences between R_b^* and R_s^* are determined by differences in the delivery performance and inventory models.

There are several differences in the models. First, the delivery performance model determines the total cost per delivery while the inventory model finds the cost per unit time. For the inventory model the cost per delivery (cycle) is shown in equation (A.10). The optimal reorder points for both equations (A.10) and (6) are the same, thus the dimension of the inventory cost function does not affect the optimal solution. Hence, the difference does not forbid comparing the optimal solutions of the delivery performance and inventory models. Second, the delivery performance model has one decision variable c_1, while classical inventory models assume two decision variables: R and Q. The lot size Q does not affect the supplier's decision about the time of delivery; therefore Q is not used as a decision variable in the inventory model herein. Thus, the difference was eliminated to keep a connection with the delivery performance model. Third, the inventory model has two extra parameters which are not included in the delivery performance model: S and H which define ordering and inventory holding costs. S does not affect the optimal value of R which is clear from (7).

The value of H defines the difference between the difference between the optimal values for the delivery performance and inventory models and, as a result, the difference between the supplier's and buyer's optimal decisions (R_s^* and R_b^*). If $H = 0$, there are no differences between R_s^* and R_b^* and there is accordance between optimal R and c_1. The higher H the bigger impact of inventory holding cost on the optimal value of R for a buyer and the bigger difference between supplier's and buyer's optimal decisions.

BUYER'S STRATEGY FOR DELIVERY PERFORMANCE OPTIMIZATION

From a supplier's prospective, a delivery strategy is pretty simple. Assuming that the width of on-time portion of the delivery window and penalty costs per time unit early and late are defined by the contract, a buyer should choose a shipping time based on OPDW to minimize its costs. From a buyer's prospective, a delivery strategy is more complicated. In the inventory model that defines a buyer's point of view on supply chain delivery performance, the decision variable is a reorder point which defines a shipping time. Unfortunately for a buyer, they cannot directly force a supplier to ship at the time optimal for the buyer.

Assume the supplier chooses a time when the product will be shipped based on the concept of the optimal position of the delivery window. How will it affect the buyer's costs? What should the buyer do to optimize its own costs? The only way a buyer can influence a supplier's delivery decision is during the contract negotiation process. Assume the buyer has enough power to choose any reasonable penalties for untimely delivery (QH and K). If a supplier has more power than a buyer, then the supplier will ask for no penalties for untimely delivery and will ship the product when it is appropriate from supplier's production prospective. Thus, the buyer should choose the values of QH and K so that the shipping time which is optimal for the supplier is optimal for the buyer too. How to choose these values? There are two questions that should be answered.

The first question is how to choose the ratio QH/K which is optimal for the buyer? From equation 2, it can be concluded that the ratio QH/K defines the optimal value of c_1. Thus, knowing the ratio is enough to find the optimal shipping time for a supplier. The buyer's strategy should be the following:

1. Find an optimal reorder point for the buyer.
2. Based on the optimal reorder point, calculate the ratio of probability of late to probability of early deliveries.
3. Use this ratio to define penalties (QH/K should be equal to the ratio).

The second question is how high the values of QH and K should be? If the values are too low, the possible penalties are too low and will not force the supplier to delivery on-time. If the values are too high, it will affect the willingness of the supplier to sign the contract. The penalties should be reasonable and a buyer should explain why such high penalties should be applied to the buyer. Therefore, a buyer can penalize a supplier based on the buyer's costs of overload and stockout. When an early delivery occurs the supplier is penalized for early delivery and the buyer incurs an additional cost to rent a warehouse. It is reasonable to assume that a buyer will ask a supplier to pay for the rented warehouse and per the model $QH = C_o$. Late delivery will lead to stockouts for a buyer on one side and to penalties for late delivery for a supplier on another. In this case, a buyer can charge its supplier by the amount equal to its stockout costs, then the penalty per unit time is $K = C_s$. On-time delivery does not assume any penalties for a supplier and no additional costs (except inventory holding cost) for a buyer.

Assume a buyer wants its supplier to pay for overloads and stockouts choosing $QH = C_o$ and $K = C_s$. The problem is that if a buyer chooses $QH = C_o$ and $K = C_s$, the supplier's and buyer's optimal decisions will not be the same ($R_s^* \neq R_b^*$) for any $H \neq 0$ and the buyer's costs will not be minimized. Thus, the effect of holding cost on the buyer's optimal reorder point should be counterbalanced by changing the penalty costs for early and/or late delivery. How should the values of QH and K be changed? To answer this question, the effect of holding cost and costs of stockout and overload on the optimal reorder point is investigated in the following propositions.

Proposition 1. A buyer can decrease the supplier's optimal reorder point (R_s^*) by increasing the cost of overload (C_O) (see Appendix C for proof).

Proposition 2. A buyer can increase the supplier's optimal reorder point (R_s^*) by increasing cost of stockout (C_S) (see Appendix C for proof).

Proposition 3. For $QH = C_o$, $K = C_s$, and $H > 0$, the optimal reorder point for a buyer is less than the supplier's optimal reorder point ($R_b^* \leq R_s^* = R_b^*(H = 0)$) (see Appendix C for proof).

From proposition 3, it can be concluded that the supplier's optimal reorder point (R_s^*) should be decreased to be equal to the buyer's reorder point (R_b^*). It can be done in two ways:

- Setting the penalty for early delivery higher than the cost of overload ($QH > C_O$);
- Setting the penalty for late delivery lower than the cost of stockout ($K < C_S$).

If a buyer chooses to increase the penalty for early delivery compared to the cost of overload ($QH > C_O$), it means that the supplier will have to pay for overload more than it requires to cover

rented warehouse costs. Thus, the penalties paid by the supplier will cover some inventory holding costs too. If a buyer chooses to set the penalty for late delivery lower than the cost of stockout ($K < C_S$), the buyer will have to pay the difference in a case of stockout. It could be a combination when a buyer increases the penalty for early delivery and decreases the penalty for late delivery at the same time.

CONCLUSION

The model presented herein coordinates the logistics and inventory management sub systems within a supply chain and represents a generalized modeling approach to the evaluation of supply chain delivery performance. An effect of the timeliness of delivery within a two-stage supply chain on both a supplier and a buyer is evaluated. From a supplier's prospective, the effect of the timeliness of delivery can be described by supply chain delivery performance models. The buyer's point of view on supply chain delivery is represented by inventory models with two levels of storage. In addition to the main contribution, the paper extends research in the area of stochastic models with two levels of inventory. The new model proposed herein differs from existing models by cost dimensions. The optimal solution for the model is found.

The paper explains how supply chain delivery performance and inventory models define a supplier's and buyer's points of view respectively and how different points of view affect managerial decisions. A supplier's optimal decision is based on the optimal position of the delivery window developed by Bushuev and Guiffrida (2012). The OPDW concept minimizes a supplier's costs for untimely delivery choosing an optimal shipping time. The shipping time chosen by a supplier might be nonoptimal for the buyer and the buyer should penalize the supplier such that the supplier's optimal decision is optimal for the buyer too.

Managerial implications of the findings which include a buyer's strategy for delivery performance optimization are discussed in Section 5. It is based on the assumption that the supplier utilizes an optimally positioned delivery window to determine a time when the product will be shipped. The paper suggests a buyer penalize a supplier for untimely delivery based on the costs of stockout and overload ($QH = C_o$ and $K = C_s$). In this case, the penalties will be high enough to cover the buyer's expenses associated with untimely delivery. If the penalties are matched with the costs, the supplier's optimal shipping time is optimal for the buyer only if there is no inventory holding cost. The buyer can force the supplier to choose a shipping time that will be optimal for the buyer by setting the penalty for early delivery higher than the cost of overload ($QH > C_O$) and/or setting the penalty for late delivery lower than the cost of stockout ($K < C_S$).

There are several directions for future research. Since a buyer can have other dimensions of stockout and overload costs, research linking the delivery performance model and inventory models with different cost dimensions should be done. Moreover, the research can be extended to 3-stage and n-stage supply chains and supply chains with several suppliers and/or buyers.

APPENDIX A

We are calculating costs for each of three outcomes (excluding ordering cost).
In the case of on-time delivery we have inventory holding cost only. The cost per cycle is equal to the squares of two trapezoids (see Figure 3 areas A and B) multiplied by holding cost (H)

$$C_{ontime} = H\frac{Q}{2D}\left[\left(R+Q-LD\right)+\left(R-LD\right)\right] = H\frac{Q}{2D}\left(Q+2(R-LD)\right). \quad \text{(A.1)}$$

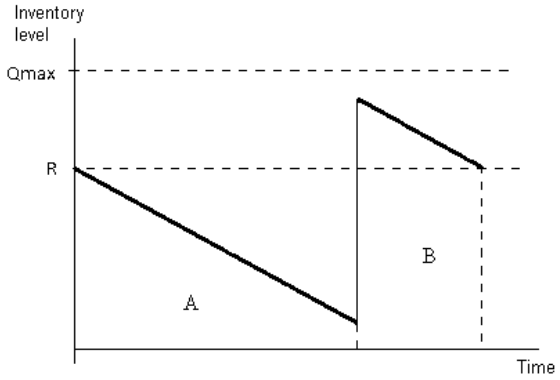

Figure 3. Outcome 2: On-time delivery

The expected cost for on-time delivery is

$$\mathrm{E}(C_{ontime}) = \frac{H}{2D}\int_{A/D}^{R/D} Q\big(Q + 2(R - LD)\big) f(L)dL\,. \tag{A.2}$$

The cost of early delivery includes holding and backordering costs. The holding cost is described the sum of the areas A and B on Figure 4. And the backordering cost is defined by the length C

$$C_{early} = H\frac{Q}{2D}\big(Q + 2(R - LD)\big) + C_O\frac{A - LD}{D}\,. \tag{A.3}$$

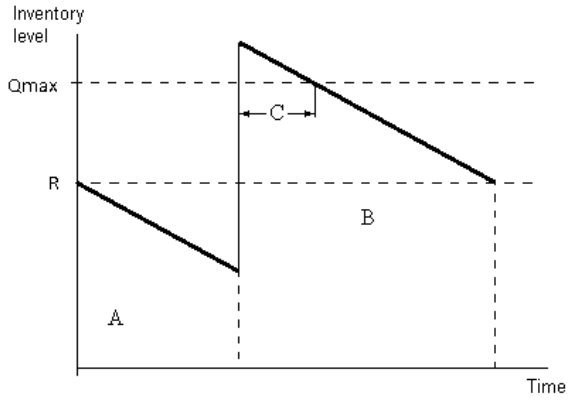

Figure 4. Outcome 3: Early delivery

The expected cost for early delivery is

$$\begin{aligned}\mathrm{E}(C_{early}) &= \frac{H}{2D}\int_{0}^{A/D} Q\big(Q + 2(R - LD)\big) f(L)dL + \frac{C_O}{D}\int_{0}^{A/D}\big(A - LD\big) f(L)dL = \\ &= \frac{H}{2D}\int_{0}^{A/D} Q\big(Q + 2(R - LD)\big) f(L)dL + \frac{C_O}{D}Y_{early},\end{aligned} \tag{A.4}$$

where $Y_{early} = \int_{0}^{A/D}\big(A - LD\big) f(L)dL$.

For late delivery inventory cost is described by A and B areas (Figure 5)

$$C_{Inv\,late} = \frac{H}{2}\left(\frac{Q}{D} - (L - R/D)\right)(Q + R - LD), \text{ or}$$

$$C_{Inv\,late} = H\frac{Q}{2D}\big(Q + 2(R - LD)\big) + \frac{H}{2D}\big(R - LD\big)^2. \quad \text{(A.5)}$$

Knowing that the stockout length of time is equal to C, the cost for late delivery is

$$C_{late} = H\frac{Q}{2D}\big(Q + 2(R - LD)\big) + H\frac{(R - LD)^2}{2D} + C_S\frac{LD - R}{D}. \quad \text{(A.6)}$$

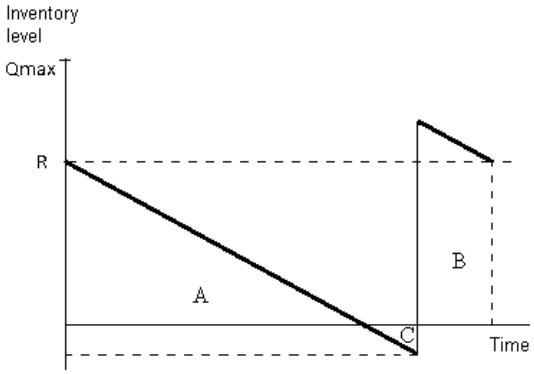

Figure 5. Outcome 1: Late delivery

The expected cost for late delivery is

$$\mathrm{E}(C_{late}) = \frac{H}{2D}\int_{R/D}^{\infty} Q\big(Q + 2(R - LD)\big)f(L)dL +$$

$$+ \frac{H}{2D}\left(\int_{R/D}^{\infty}\big(R - LD\big)f(L)dL\right)^2 + \frac{C_S}{D}\int_{R/D}^{\infty}\big(LD - R\big)f(L)dL = \quad \text{(A.7)}$$

$$= \frac{H}{2D}\int_{R/D}^{\infty} Q\big(Q + 2(R - LD)\big)f(L)dL + \frac{H}{2D}\big(Y_{late}\big)^2 + \frac{C_S}{D}Y_{late},$$

where $Y_{late} = \int_{R/D}^{\infty}\big(LD - R\big)f(L)dL$.

The total expected cost per cycle including ordering cost is

$$\mathrm{E}(C) = \mathrm{E}(C_{ontime}) + \mathrm{E}(C_{early}) + \mathrm{E}(C_{late}) = S + \frac{H}{2D}\int_{A/D}^{R/D} Q\big(Q + 2(R - LD)\big)f(L)dL +$$

$$+ \frac{H}{2D}\int_{0}^{A/D} Q\big(Q + 2(R - LD)\big)f(L)dL + \frac{C_O}{D}Y_{early} + \quad \text{(A.8)}$$

$$+ \frac{H}{2D}\int_{R/D}^{\infty} Q\big(Q + 2(R - LD)\big)f(L)dL + \frac{H}{2D}\big(Y_{late}\big)^2 + \frac{C_S}{D}Y_{late}.$$

$$\mathrm{E}(C) = S + \frac{H}{2D}\int_{0}^{\infty} Q\big(Q + 2(R - LD)\big)f(L)dL + \frac{H}{2D}(Y_{late})^2 + \frac{C_0}{D}Y_{early} + \frac{C_S}{D}Y_{late}. \quad \text{(A.9)}$$

$$\mathrm{E}(C) = S + \frac{H}{2D}Q\big(Q + 2(R - \mathrm{E}(L)D)\big) + \frac{H}{2D}(Y_{late})^2 + \frac{C_0}{D}Y_{early} + \frac{C_S}{D}Y_{late}, \quad \text{(A.10)}$$

where $\mathrm{E}(L)$ is expected value of *L*.

Using that the number of cycles per unit time is *D/Q*, the total cost per unit time is

$$\mathrm{E}(TC) = S\frac{D}{Q} + \frac{H}{2}\big(Q + 2(R - \mathrm{E}(L)D)\big) + \frac{H}{2Q}(Y_{late})^2 + \frac{C_0}{Q}Y_{early} + \frac{C_S}{Q}Y_{late}. \quad \text{(A.11)}$$

APPENDIX B

To find the optimal reorder point we take the derivative of the total cost by *R*. Using that

$$\frac{dY_{early}}{dR} = \frac{1}{D}(A - \frac{A}{D}D)\,f(\frac{A}{D}) - 0 + \int_0^{A/D} f(L)dL = P_{early}, \quad \text{(B.1)}$$

where $\frac{dA}{dR} = 1$, and

$$\frac{dY_{late}}{dR} = 0 - \frac{1}{D}(\frac{R}{D}D - R)\,f(\frac{R}{D}) + \int_{R/D}^{\infty}(-1)f(L)dL = -P_{late}, \quad \text{(B.2)}$$

we have

$$\begin{aligned}\frac{d\mathrm{E}(TC)}{dR} &= 0 + \frac{H}{2}2 + \frac{H}{2Q}\big(2Y_{late}P_{late}\big) + \frac{C_O}{Q}P_{early} - \frac{C_S}{Q}P_{late} = \\ &= H + \frac{H}{Q}\big(Y_{late}P_{late}\big) + \frac{C_O}{Q}P_{early} - \frac{C_S}{Q}P_{late}.\end{aligned} \quad \text{(B.3)}$$

The optimal reorder point is when

$$H\big(Q - Y_{late}P_{late}\big) + C_0P_{early} = C_SP_{late}. \quad \text{(B.4)}$$

To prove convexity of the total cost by *R* we take the second derivative. Using

$$\frac{dP_{early}}{dR} = \frac{1}{D}f(\frac{A}{D}) - 0 + \int_0^{A/D} 0dL = \frac{1}{D}f(\frac{A}{D}), \quad \text{(B.5)}$$

$$\frac{dP_{late}}{dR} = 0 - \frac{1}{D}f(\frac{R}{D}) + \int_{R/D}^{\infty} 0dL = -\frac{1}{D}f(\frac{R}{D}), \quad \text{(B.6)}$$

we have

$$\frac{d^2\mathrm{E}(TC)}{dR^2} = 0 - \frac{H}{Q}\Big(-Y_{late}\frac{1}{D}f(\frac{R}{D}) - (P_{late})^2\Big) + \frac{C_O}{QD}f(\frac{A}{D}) + \frac{C_S}{QD}f(\frac{R}{D}), \quad \text{(B.7)}$$

$$\frac{d^2\mathrm{E}(TC)}{dR^2} = \frac{H}{Q}\Big(\frac{1}{D}f(\frac{R}{D})Y_{late} + (P_{late})^2\Big) + \frac{C_O}{QD}f(\frac{A}{D}) + \frac{C_S}{QD}f(\frac{R}{D}). \quad \text{(B.8)}$$

Because all elements of (B.8) are positive, $\frac{d^2\mathrm{E}(TC)}{dR^2} > 0$ and E(*TC*) is convex by *R*.

APPENDIX C

Proof of Proposition 1.

The follow derivatives are used

$$\frac{dP_{early}}{dC_O} = \frac{1}{D}(dR^*/dC_O)\,f(A^*/D) - 0 + \int_0^{A^*/D} 0\,dL = \frac{1}{D} f(A^*/D)(dR^*/dC_O); \tag{C.1}$$

$$\frac{dP_{late}}{dC_O} = 0 - \frac{1}{D}(dR^*/dC_O)\,f(R^*/D) + \int_{R^*/D}^{\infty} 0\,dL = -\frac{1}{D} f(R^*/D)(dR^*/dC_O); \tag{C.2}$$

$$\frac{dY_{late}}{dC_O} = 0 - \frac{1}{D}\left(\frac{R^*}{D}D - R^*\right) f(R^*/D)(dR^*/dC_O) + \\ + \int_{R^*/D}^{\infty} \left(-dR^*/dC_O\right) f(L)\,dL = -P_{late}(dR^*/dC_O). \tag{C.3}$$

Hence, we have

$$H\left(Y_{late}\frac{1}{D} f(R^*/D)(dR^*/dC_O) + P_{late}(dR^*/dC_O)P_{late}\right) + \\ + P_{early} + C_0\frac{1}{D} f(A^*/D)(dR^*/dC_O) = -C_S\frac{1}{D} f(R^*/D)(dR^*/dC_O), \tag{C.4}$$

$$dR^*/dC_O\left(Y_{late}\frac{H}{D} f(R^*/D) + H(P_{late})^2 + \frac{C_0}{D} f(A^*/D) + \frac{C_S}{D} f(R^*/D)\right) = \\ = -P_{early}, \tag{C.5}$$

$$\frac{dR^*}{dC_O} = -\frac{D \cdot P_{early}}{H \cdot Y_{late} f(R^*/D) + H \cdot D(P_{late})^2 + C_0 f(A^*/D) + C_S f(R^*/D)}, \tag{C.6}$$

All parameters in the derivative (C.6) are always positive. Thus, the derivative is negative, that means that increasing C_O will decrease R^*. ■

Proof of Proposition 2.

The follow derivatives are used

$$\frac{dP_{early}}{dC_S} = \frac{1}{D}(dR^*/dC_S)\,f(A^*/D) - 0 + \int_0^{A^*/D} 0\,dL = \frac{1}{D} f(A^*/D)(dR^*/dC_S); \tag{C.7}$$

$$\frac{dP_{late}}{dC_S} = 0 - \frac{1}{D}(dR^*/dC_S)\,f(R^*/D) + \int_{R^*/D}^{\infty} 0\,dL = -\frac{1}{D} f(R^*/D)(dR^*/dC_S); \tag{C.8}$$

$$\frac{dY_{late}}{dC_S} = 0 - \frac{1}{D}\left(\frac{R^*}{D}D - R^*\right) f(R^*/D)(dR^*/dC_S) + \\ + \int_{R^*/D}^{\infty} \left(-dR^*/dC_S\right) f(L)\,dL = -P_{late}(dR^*/dC_S). \tag{C.9}$$

Hence, we have

$$H\left(Y_{late}\frac{1}{D} f(R^*/D)(dR^*/dC_S) + P_{late}(dR^*/dC_S)P_{late}\right) + \\ + C_0\frac{1}{D} f(A^*/D)(dR^*/dC_S) = P_{late} - C_S\frac{1}{D} f(R^*/D)(dR^*/dC_O), \tag{C.10}$$

$$\frac{dR^*}{dC_S} = \frac{D \cdot P_{late}}{H \cdot Y_{late} f(R^*/D) + H \cdot D(P_{late})^2 + C_0 f(A^*/D) + C_S f(R^*/D)}, \tag{C.11}$$

All parameters in the derivative (C.11) are always positive. Thus, the derivative is negative, that means that increasing C_S will decrease R^*. ■

Proof of Proposition 3.

To prove the proposition, it should be shown that for fixed parameters of delivery time distribution and fixed costs of overload and stockout, order quantity, and size of warehouse, increasing holding cost (H) will decrease the optimal reorder point (R^*).

The follow derivatives are used

$$\frac{dP_{early}}{dH} = \frac{1}{D}(dR^*/dH)\,f(A^*/D) - 0 + \int_0^{A^*/D} 0\,dL = \frac{1}{D} f(A^*/D)(dR^*/dH); \tag{C.12}$$

$$\frac{dP_{late}}{dH} = 0 - \frac{1}{D}(dR^*/dH)\,f(R^*/D) + \int_{R^*/D}^{\infty} 0\,dL = -\frac{1}{D} f(R^*/D)(dR^*/dH); \tag{C.13}$$

$$\frac{dY_{late}}{dH} = 0 - \frac{1}{D}\left(\frac{R^*}{D}D - R^*\right) f(R^*/D)(dR^*/dH) + \\ + \int_{R^*/D}^{\infty} \left(-dR^*/dH\right) f(L)\,dL = -P_{late}(dR^*/dH). \tag{C.14}$$

Hence, we have

$$Q - Y_{late}P_{late} + H\left(Y_{late}\frac{1}{D} f(R^*/D)(dR^*/dC_S) + P_{late}(dR^*/dC_S)P_{late}\right) + \\ + C_0\frac{1}{D} f(A^*/D)(dR^*/dC_S) = -C_S\frac{1}{D} f(R^*/D)(dR^*/dC_O), \tag{C.15}$$

$$\frac{dR^*}{dH} = \frac{D\cdot(Y_{late}P_{late} - Q)}{H\cdot Y_{late} f(R^*/D) + H\cdot D(P_{late})^2 + C_0 f(A^*/D) + C_S f(R^*/D)}. \tag{C.16}$$

Because the denominator is always positive, the sign of the derivative (C.16) depends on numerator.

$$Y_{late}P_{late} - Q = (Y_{late} - Q)P_{late} - Q(1 - P_{late}) = \\ = \left(\int_{R^*/D}^{\infty}\left(LD - R^* - Q\right) f(L)\,dL - Q\int_0^{R^*/D} f(L)\,dL\right)P_{late} - Q(1 - P_{late}) = \tag{C.17}$$

$$\left(\int_{R^*/D}^{\infty}\left(LD - R^* - Q\right) f(L)\,dL - Q(1 - P_{late})\right)P_{late} - Q(1 - P_{late})$$

Because $0 \le P_{late} \le 1$, the only element that can be positive in equation (C.17) is the first integral. Using the assumption (9) No interaction between orders ($0 \le L \le Q/D$), we can write

$$\int_{R^*/D}^{\infty}\left(LD - R^* - Q\right) f(L)\,dL = \int_{R^*/D}^{Q/D}\left(LD - R^* - Q\right) f(L)\,dL. \tag{C.18}$$

The value of $(LD - R^* - Q)$ is always negative for any $R^*/D \le L \le Q/D$, hence the integral (C.18) is negative. Thus, it can be concluded that the derivative (C.16) is negative, that means that increasing H will decrease R^*. ■

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INVESTIGATING THE EFFECTS OF SOCIAL MEDIA USE ON WORK EXHAUSTION

ABSTRACT

As the amount of time people socializing online increases, the influence of social media use in workplace rises up as well. Our observation shows that individuals feel they are experiencing less work exhaustion when socializing with their family members and close friends. Drawing on the theory of involvement and social media interaction, we identify the theoretical connections between vertical interactivity and involvement constructs, which eventually exert an impact on work exhaustion. We then evaluate the interactivity-involvement-work exhaustion model empirically using a survey of 300 social media users. The results indicate that user's perception of support, enjoyment, and personal identification are negatively related to work exhaustion. The resulting theoretical implications for social media research and practical implications for organizations are discussed.

KEYWORDS: Social Media, Work Exhaustion, Social Involvement, Social Network Site (SNS), social media interaction.

INTRODUCTION

Social media are internet-based applications including social gaming, media sharing, discussion forums, reviews, blogs, and micro blogs (Zhang and Mao 2016). Facebook, LinkedIn, Pinterest, and Instagram are the most popular social media sites. The number of social media users in the whole world is nearly 2 billion, about 30% of the global population nowadays. Users devoted 2.53 hours to social media sites (e.g., Facebook, Twitter) on a daily basis. They compulsively check their social media several times a day to satisfy "social update" during their non-work time (e.g., eating, attending, meeting, crossing the street, or driving) (Kwon et al., 2016).

Social media supports personal purposes such as maintaining their relationships with friends, meeting new peers (e.g., Facebook, Google+), participating in groups sharing similar hobbies and interests (e.g., FanIQ and Super Green Me) (Kwon and Wen, 2010). At the same time, social media can also support career-related tasks (e.g., Linkedin and Konnects), informational and educational goals (e.g., the Student Room, Academic.edu). Some users accept social media purely for the personal connection or entertainment purposes, while others may use them for professional purpose. They directly connect professional partners, sharing professional knowledge, and consolidating professional contacts by social media (Salehan et al., 2017). As the usage of social media covers both within and outside of the career-related tasks, the boundaries between work and non-work domains become blurring (Derks and Bakker, 2014). Social media even makes it difficult for employees to disconnect with work even when they are outside of normal work hours (Butts et al., 2015). Thus, although the social media have enhanced the flexibility to employee's work and lives, they may influence the employee's workload and work exhaustion (Armstrong et al., 2015). However, there are few studies concerned the influence of social media usage during non-work time in employee's work exhaustion.

Consequently, we need an investigation to better understand the effects of social media use on users' perceptions of work-related pressure or difficulties that are hard to resolve. Therefore, we address the following research question in the social media context:

Research Question: How does social media use influence work exhaustion?

In this study, we draw on previous work in interaction in social media, the theory of involvement, and work exhaustion to guide the research model. First, as social media are digital platform for interaction (Gunawardena et al. 2009), we identify an important social media interaction – the interaction with family and close friends. Further, as "an object or stimulus associated with the physical characteristic of communication media (TV, radio, and print)" is the crucial antecedents of involvement (Zaichkowsky 1986), social media interaction can influence users' involvement. We classify involvement into two types: cognitive involvement and affective involvement. Then, we examine how involvement leads to work exhaustion. We expect our findings to extend the understanding the effects of social media usage during non-work time on work exhaustion.

LITERATURE REVIEW

Social Media Interaction

Online interaction is defined as "the extent to which users can participate in modifying the form or content of a website in real time"(Steuer 1992). The website interactivity includes mechanical interactivity and social interactivity(Hoffman and Novak 1996). Mechanical interactivity is used to measure the website's usability based on control-related theory (e.g., the flow theory, and information control theory et al.), which reflects the extent to which users' interaction with website technology (Venkatesh and Agarwal 2006). Social interactivity means the website is the electronic media for users, which enables users to engage in social communication (e.g. email or reciprocal communication et al.)(Zhenhui, Chan et al. 2010).

Social media is mainly used for social interaction, especially vertical interaction, which refers to "the need for forward and backward linkages with existing close connections such as family and close friends" (Salehan, Kim et al. 2017). Interactivity in Facebook-style social media is considered to be a form of vertical interaction (Stefanone, et al. 2011). Social media users watch and share entertaining content or maintain close relationships with family and existing friends during the non-work time. At the same time, the user may also establish new social linkage to receive social support and bridge social capital, as is good for their profession. Despite some research has been done attempting to reveal the insights of personal social media use (e.g., hedonic use), these types of behavior remain under-explored. Therefore, this study will concentrate on the dimensions of these types of use behavior.

The Involvement-Related Theories

Involvement is defined as "a person's perceived relevance of an object based on inherent needs, values, and interests" (Zaichkowsky 1985). The application of involvement construct has been extended to websites. Website involvement is defined as the perceived relevance of the website based on the consumers' inherent needs, values, and interests (Mcmillan et al. 2003). Website involvement covers cognitive involvement and affective involvement (Jiang et al. 2010). Social media is internet-based application, which is extended from the websites. Thus we can research social media based on the theory about website involvement. This study will provide valuable insights about the social media involvement by studying the disparate internal processes of social media users.

Cognitive involvement means "rational, thinking" and is motivated by utilitarian or cognitive factors(Park and Young, 1986). Affective involvement means "emotional, hedonistic" and is motivated by value-expressive or affective factors (Putrevu and Lord 2013). Present studies

show that users' interaction with website will induce cognitive involvement and affective involvement. Specifically, merchandise description, the price, delivery and return policy in the website will heighten the cognitive involvement. The colors, animation, sound, and peripheral site information will heighten the affective involvement (Eroglu et al. 2003). However, there are few studies about involvement in social media.

As reviewed above, this paper will explain the effect of interactivity on perceived support from the perspective of cognitive involvement, explain the effect of interactivity on perceived enjoyment and identification from the perspective of affective involvement.

Work Exhaustion

Work exhaustion can influence significantly turn-away intention (Blau 2007). Work exhaustion will happen, as an individual believe that remaining the current profession will not alleviate the career experience. One of the cures of work exhaustion is to change professions (Armstrong et al. 2015). Prior research has verified that perceived workload, autonomy, fairness of rewards influence significantly work exhaustion (Moore 2000).

What's more, social interactivity has a significant influence on work exhaustion (Ahuja et al. 2007). However, few researches have explored the mechanism why social interactivity can reduce or strengthen the work exhaustion. This paper will explain the mechanism from the involvement perspective.

HYPOTHESES DEVELOPMENT

Our research model consists of three pillars: (1) the vertical interactivity; (2) components of involvement; (3) the work exhaustion. There are five constructs in the model explaining the relationships between social interactivity by social media and work exhaustion from the involvement perspective.

The Influence of Vertical Interactivity on User's Involvement

The vertical interactivity means that users watch and share entertaining content or maintain close relationships with family and existing friends by social media during the non-work time. While users vertically interacting by social media, they may achieve a needed support (Lee et al. 2017). For example, users interacting with their peer may achieve social support, as will reduce users' negative emotions(Lu et al. 2012). Users interacting with their family and existing friends will achieve credible personalized recommendations, as will simplify the process of making decisions (Xiao and Benbasat 2007).Thus, The vertical interactivity is a key opportunity to achieve needed support for users.

At the same time, the vertical interactivity is spontaneous, passionate, low cost, and live (Borah and Tellis, 2016). They consume the social media to satisfy psychological needs (Elihu, 1974). For example, users could obtain leisure from vertical interactivity (Ahram et al. 2011). What's more, seeking recreation and friendship by social media is the most important motivation for users to interact online (Ridings and Gefen, 2004). Hence, we hypothesized that:

H1: The vertical interactivity is positively related to perceived support.
H2: The vertical interactivity is positively related to perceived enjoyment.

Social identification is defined as “the degree to which an individual perceives herself or himself as a member of a group or social category, and subsequently conforming to the attitudinal and behavioral stereotypes of that group” (Tajfel, 1981). People are influenced by their friends and family and conform to the expectations of others (Deutsch and Gerard 1955). Social media provides new venues for users to express themselves and perceive the normative and social values from their family and friends (Kwon and Wen 2010). The more users vertically interact with friends and family, the greater they understand the expectations of others. By the direct effect of social media, users may act according to social influence and be identified by their family and friends (Chen 2014). According to the social identities, users will overlay positive attributions (e.g. credibility and attractiveness) onto those in-group members (Clark and Maass 1988; Carr et al. 2013). Furthermore, they will even provide arbitrary cues such as language on social media to guide social identification process (Bigler et al. 1997, Seargeant and Tagg 2014).Hence, we hypothesized:

H3: The vertical interactivity is positively related to social identification.

The Influence of Users’ Involvement on Work Exhaustion

Work exhaustion indicates “a state of physical, emotional, and mental exhaustion caused by long-term involvement in demanding situations” (Malakh-Pines et al. 1981). Work exhaustion is an important indicator of dissatisfaction level about their work, which may lead to turnover intention (Moore 2000). Work exhaustion is caused by having too many pressures, conflicts, and demands combines with too few rewards, acknowledgments, and successes (Kanner et al. 1978). Most people will perceived exhaustion when their life is imposed on more stress than support (Pines 1993).

As far as social media usage during non-work time is concerned, users will received social support from their online friend. Perceived support from social media may balance uses’ stress and support in life. At the same time, perceived enjoyment from social media during non-work will reduce the stress in life (Van der Heijden 2004). Hence, we hypothesized:

H4: Perceived support is negatively related to work exhaustion.
H5: Perceived enjoyment is negatively related to work exhaustion.

Social identification indicates the degree to which an individual perceives herself or himself as a member of a group or social category, and subsequently conforming to the attitudinal and behavioral stereotypes of that group (Tajfel 1981). Social identification consists of cognitive identification and affective identification (Talaga and Beehr 1995). Users who have cognitively identified themselves as “employees should connect with work even when they are outside of normal work hours” may be like to work seriously. According to the definition of affectively identification, Users who have affectively identified themselves as “employees should connect with work even when they are outside of normal work hours” may feel emotional attachment of the class. Employees who connect with work even when they are outside of normal work hours are sometimes being perceived as hard-working (Watanabe and Yamauchi 2016). Hence, we hypothesized:

H6: Identification is negatively related to work exhaustion.

RESEARCH METHOD

Online Survey Method

The data used to test our theoretical model were collected from WeChat, a leading social media application in China that provides a platform for communicating online, creating profile pages and more. To mirror the demographics of a typical online user, the sampling frame we used included users with full-time jobs who interacted on WeChat. We developed an online survey questionnaire that by following these practices: at first, all the items of various constructs were adapted according to our existing research; secondly, we modified the preliminary questionnaire based on the results of a pretest; and finally, we administered the survey online.

The items that related to vertical interactivity were adapted from Jiang and Salehan (Jiang et al., 2010; Salehan, Kim et al., 2017). The items that related to perceived social support were adapted from Liang et al., 2011. The items related to perceived enjoyment were adapted from Chen, 2014. The items related to identification were adapted from Mael and Ashforth, 1992. The items related to work exhaustion were adapted from Armstrong, Brooks et al., 2015. The constructs were measured on a seven-point Likert scale. Due to page limit, we are not attaching the instrument, which is available upon request.

Demographic Profiles of the Sample Data

The questionnaire was distributed to actual WeChat users online. We eliminated disqualified data points by following these criteria: respondents with no full-time job; respondents who provided the same answer to more than 80 percent of all questions; and respondents who completed the questionnaires in under five minutes. This gives us 300 clean data entries. Among these respondents, 44 percent were male and 56 percent were female. The majority (>70 percent) of respondents were between 20 and 30 years of age, while 86.3 percent had a degree in higher education of at least two years. Descriptive characteristics for the respondents are listed in Table 1.

Table 1: Sample Demographics (N=300)

Measure	Item	Count	%
Gender	Male	132	44.0
	Female	168	56.0
Age	≤19 years	33	11.0
	>20 and ≤30 years	201	73.6
	>30 years	46	15.0
Education	High school or below	24	8.0
	2 years of college	105	35.0
	4 years of college	154	51.3
	Graduate school or above	17	5.7
WeChat usage time	Less than 6 months	26	8.6
	6 to 12 months	32	10.6
	1-3 years	196	65.3
	Over 3 years	46	15.3

Occupation	Private Sector	109	36.3
	Government	76	25.5
	Education	82	27.3
	Students	28	9.3
	Other	5	1.6

DATA ANALYSIS

We analyzed the sample data for the study using the partial least squares (PLS) method, since PLS is less restricted in sample data distribution, measurement scales and residual distributions (Chin, 1998). PLS is also better able to maximize the explained variances in defendant variables, as is shown in prior IS studies (Gefen and Straub, 2005). Based on these methods, we first analyzed the measurement model and then tested the structural model to verify our hypotheses.

Testing Measurement Model

Principal components factors (PCF) were used to examine the convergent validity of the study's scales. Bartlett's test of sphericity generated a Kaiser-Meyer-Olkin (KMO) statistic of 0.877, which was significant at 0.01, indicating that the data were suitable for applying principal components analysis. We extracted six factors with six values above 1, which explained 82.466 percent of the total variance. Table 2 presents the factor loadings of the items after applying Varimax rotation. The results show no cross-loadings and good discriminant and convergent validity.

Table 2: Principle Component Factor Analysis with Varimax Rotation

Factors	**1**	**2**	**3**	**4**	**5**
Ver1	**0.914**	0.241	-0.102	0.079	0.071
Ver2	**0.827**	0.279	-0.078	0.157	0.038
Ver3	**0.856**	0.220	-0.032	0.086	0.084
Sup1	0.326	**0.745**	-0.126	0.149	0.183
Sup2	0.324	**0.835**	-0.134	0.227	0.203
Sup3	0.294	**0.793**	-0.174	0.203	0.131
Ide1	0.068	0.192	-0.182	0.292	**0.736**
Ide2	0.099	0.167	-0.208	0.290	**0.747**
Pen1	0.055	0.130	-0.228	**0.592**	0.397
Pen2	0.105	0.219	-0.195	**0.828**	0.246
Pen3	0.189	0.165	-0.213	**0.794**	0.175
Wex1	-0.159	-0.158	**0.815**	-0.226	-0.150
Wex2	-0.134	-0.101	**0.921**	-0.099	-0.097
Wex3	0.066	-0.066	**0.756**	-0.174	-0.151
Eigenvalues	2.191	2.979	2.424	1.989	1.796
Percentage of variance	19.593	15.179	17.587	14.107	13.016
Cumulative	19.593	34.772	52.359	66.466	79.482

Table 3 summarizes the additional validity measures of the scales. The standard loadings of the items were mostly above 0.7. The average variance extracted (AVE) for each construct was

above 0.5, which meant that the scales had a good convergent validity (Bagozzi and Yi, 1988). Composite reliabilities (CRs) were used to evaluate the internal consistency of the measurement model. As shown in this table, the CRs were all above 0.9, indicating that the scales had good reliability. In addition, Cronbach's alpha was above 0.8, indicating that the scales were reliable (Nunnally, 1978).

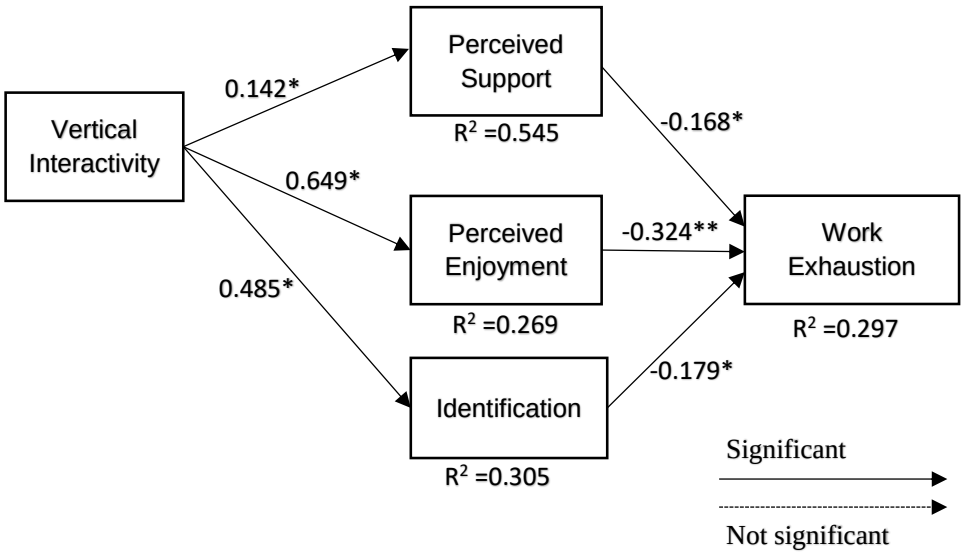
Table 3: Results of Confirmatory Factor Analysis

Factor	Item	Standard loading	AVE	CR	Cronbach's alpha
Vertical interactivity	Ver1 Ver2 Ver3	0.9120 0.9037 0.9111	0.820	0.920	0.957
Perceived support	Sup1 Sup2 Sup3	0.9534 0.9101 0.9097	0.879	0.903	0.955
Identification	Ide1 Ide2	0.9234 0.9486	0.902	0.917	0.848
Perceived enjoyment	Pen1 Pen2 Pen3	0.8995 0.9230 0.9525	0.865	0.929	0.882
Work exhaustion	Wex1 Wex2 Wex3	0.9018 0.9131 0.8597	0.854	0.940	0.899

Testing the Structural Model

We then tested our research model. The findings of the test are summarized in Figure 1. The results were as follows: H1(r=0.142, T-value=2.547), H2(r=0.063, T-value=0.783), H3(r=0.052, T-value=0.869), H4(r=0.649, T-value=12.127), H5(r=0.485, T-value=6.632), H6(r=0.469, T-value=7.100), H7(r=-0.130, T-value=2.195), H8(r=-0.315, T-value=5.253), H9(r=-0.152, T-value=2.510). All the hypotheses were supported. The proportions of variance were 53.7 percent for perceived support; 27.1 percent for perceived enjoyment; 24.9 percent for identification; and 26.1 percent for work exhaustion. All control variables were insignificant.

Figure 1: The Research Model (p*<0.05, p**<0.01)



DISCUSSION AND LIMITATIONS

The ubiquitous use of social media in workplaces has become an issue that concerns practitioners in numerous ways. First, job performance has been studied in prior literature arguing there are connections between online social media behavior and how employees perform in workplace; Second, using social media in personal live may influence professional activities; third, the future development of social media has the tendency to increase the use of social media in professional IT applications. Therefore, our study is timely and important as it is one of the early studies to investigate the above-mentioned issues. This study also positions itself as an extension of prior social media research that focuses on adoption and diffusion (e.g., Qiu *et al*. 2015).

This study makes three new contributions to existing theory. First, by investigating vertical interactivity and horizontal interactivity in the context of social media, this study complements existing research on other types of online interactivity. The study shows that both vertical and horizontal interactivity can affect users' perceived support, while horizontal interactivity can affect users' perceived enjoyment and identification. Next, our study found that perceived support, perceived enjoyment and identification are important factors in alleviating users' work exhaustion, with perceived enjoyment being the most important of those three factors. Although previous studies have shown how social media contributes to users' personal and professional performance (Salehan, Kim et al., 2017), the reasons why have not been studied. Thus, this study complements existing research by discussing the reasons why social media contributes to employees' performance. On the other side, practitioners can borrow our findings to create, modify, and implement managerial improvements that aim to reduce the negative effects of personal social media activities in professional settings, and to enhance the positive impacts that social media usage introduces to the workforce (e.g., reducing work pressure and strengthen coworker relationships).

This study has two main limitations. First, the sample may be biased due to the fact that all respondents were Chinese and most were male. Second, our research focuses exclusively on the effects of involvement. Other relational constructs could also affect work exhaustion. Future studies may examine the influence that constructs such as trust or social inclusion have on work exhaustion (Andrade and Doolin, 2016). In addition, use of social media may have both positive and negative outcomes and the potential negative effects should be a future subject of study. We stressed on the statistical significance in the structural model testing rather than the practical one, which can be addressed in the later studies.

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DECISION SCIENCES INSTITUTE
IoT Technology in the Development of Intelligent Agriculture

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ABSTRACT

With the continuous development of Internet of Things (IoT), Information and communication technology (ICT) and Automation Control System (ACS) in agriculture field, greenhouse and aquafarm management has earth-shaking changes. The introduction of intelligent monitoring and tracking of the whole process from the production of crops, processing, transportation to sales and other procedures can effectively overcome the impact of complex and volatile climate, the geographical limitation, natural disasters, pests and diseases, and other factors to improve crop yields, growing process and production quality. Utilizing social media helps farmers to promote their products to consumers for direct sales and precision marketing.

KEYWORDS: Internet of Things, Intelligent Agriculture, ACS, Greenhouse, Social Media

INTRODUCTION

A country is comprised of its people, and people depend on food." The availability of food is not only essential for maintain life, but also affects the social stability, harmony, and economic development of a country. In recent years, the price of food has risen continuously, and issues such as population growth and land degradation have resulted in losses of arable land. Additionally, crop failures caused by climate anomalies have become increasingly widespread. Relevant experts have also expressed concerns that global food supplies may undergo an unexpected crisis in the near future.

The recent report by the Consultative Group on indicates that the global food crisis is expected to intensify in the next 40 years (Blaikie et al, 2000). Fierce international competition for food has prompted various governments to explore overseas markets and increase domestic self-sufficiency to avoid the problems related to food supply shortages (Friedmann, 1992).

Take the world's biggest agricultural country – China for example, despite a long history of agriculture, China is not immune to this global development. Millions of farmers are limited to farming and producing crops on only 9% of the world's arable land (Ghose, 2014). In addition, the frequent droughts and natural disasters experienced recently have severely impacted local crop growth and harvest yields. Accordingly, since China's reform and opening up, at the beginning of each year, relevant authorities have published a policy document dubbed the "No. 1 Central Document" on agriculture, farming villages, and farmers (Jialing & Jian, 2018). This document demonstrates the central government's emphasis on the complexities of developing farming

villages and sets the tone for China's agricultural growth. For many years, the policy advice has incorporated the latest technology concepts to provide the technological tools for agriculture and promote the integration of agriculture and technology, the mechanization of labor processes, and the inclusion of information technology in agricultural production and management objectives. China's central authority also expects to utilize technological innovations to establish high-yield, high-quality, efficient, safe, and modern agricultural systems. Therefore, it's valuable contribution if we can use new technologies to increase the productivity of agriculture.

In this paper, intelligent agriculture is constructed by using IoT applications which is crucial for prosperous farming villages and sustainable operations. By implementing environmental monitoring and automatic control through the use of sensors, networks, cloud computing, and other advanced technologies, governments can increase agricultural efficiency and develop traditional agriculture into modern technology-based agriculture. Intelligent agriculture concepts can be applied to not only whole grain, fruit, vegetables, and flower crops, but also livestock and aquaculture. Such concepts offer various advance protection measures through the inclusion of real-time energy management systems (EMSs), thereby reducing the risk of infection among livestock.

Although most intelligent applications in the agriculture, fishery, and livestock industries are still in the promotion and advocacy stages, lots of successful implementations have been achieved in recent years by using IoT, ICT, ACS technologies. Furthermore, in many cities and towns in China and Taiwan, transition assistance has been provided to experimental breeding and cultivation units, farmers and fishermen specializing in high value agricultural products, and major electronics manufacturers intending to invest in agricultural production.

LITERATURE REVIEW

The Internet of Things (IoT) and big data are two hot topics with respect to commercial, industrial, and other applications including agriculture. The term "IoT" was coined in 1999 and refers to the world of devices connected to the Internet, which is the method by which much of big data is collected, concentrated and curated (Gubbi et al., 2013). Big data additionally refers to the analysis of this information to produce useful results (John, 2014).

A primary driving force behind the IoT and big data has been the collection and analysis of data concerning consumer behaviors in order to find out what people buy and why. An example of this is the loyalty cards that shoppers use at grocery stores and other retail outlets. Using these cards, retailers and their suppliers can ascertain what customers buy which products, and can then use this information to increase sales and profits. The commercial and governmental sectors are showing how the IoT and big data can be used to improve operations, but how can these concepts be profitability extended into agriculture and other related industrial sectors?

Big data is the new norm for enterprise analytics and it is pervasive across many industries. The data becomes big when the volume, velocity, and/or variety of the data exceed the abilities of your current IT systems to ingest, store, analyze, or otherwise process it. Big data typically conveys an individual perspective of perceived magnitudes of information greater than expected, and may express a conundrum of comprehension and utilization (Provost & Fawcet, 2013).

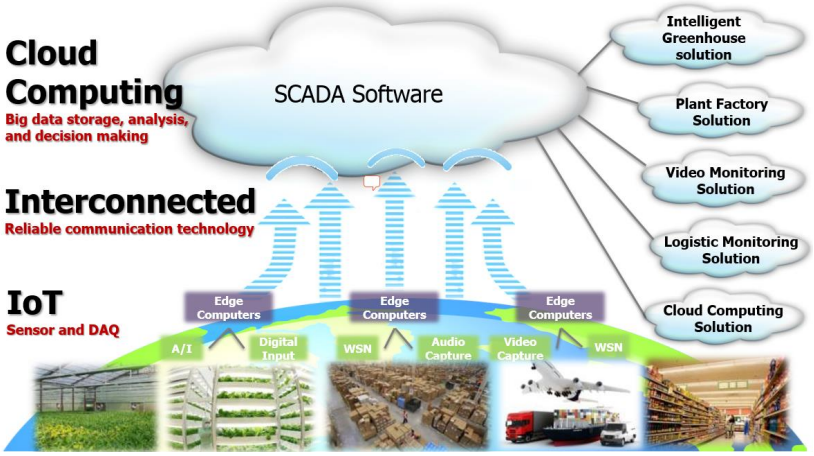
Data input originally came from limited human-based measurements, observations and manual data entry—but most data today is automatically generated by sensors, with the trend of field sensors becoming more numerous and smarter with more reporting capabilities continuing to

grow. Once this rapidly expanding stream of data is collected, it then needs to be concentrated and curated, terms that will be explained in detail later in this article. This curated data must then be visualized and analyzed in order to improve operations, a process that will also be expanded upon.

PROPOSED MODEL AND METHOD

IOT, ICT and ACS technologies that accelerate the burgeoning of intelligent agriculture. Three key elements that growing fast in the past years play the key role of building intelligent agriculture infrastructure – IoT, interconnection and cloud computing as shown in Figure 1.

Figure 1: The infrastructure of intelligent agriculture



In IoT layer, sensors and Data Acquisition Device (DAQ) collect information from field. It's obvious how designers are incorporating sensors into countless devices used throughout our everyday lives. Smartphones react to user inputs by tracking the smallest of gestures, automobiles constantly monitor vehicle motions to achieve stability control, and buildings vary environmental controls to provide both comfort and energy savings. In some ways, the vast availability of sensors and their produced data has provided kindling for the IoT and big data fire, while the automated method of querying these sensors, largely over the Internet, has sparked the fire to life. When looking from a system-wide perspective, the sensing function can be considered to exist at the lowest level, or out on the "edge". Table I offers a list of common sensor types, and shows how the IoT sees the world.

Table I: Types of Sensors

1. Temperature	7. Position, angle, displacement, distance, speed, acceleration
2. Pressure	8. Vision
3. Level	9. Vibration
4. Flow	10. Current, voltage and other power parameters
5. Density	11. pH and other analytical values
6. Proximity	12. Moisture, humidity and other weather conditions

The classic four measurements for production processes are flow, level, temperature, and pressure. Additionally, chemical, pharmaceutical, water treatment, and food industry processes will rely on analytical measurements of pH, dissolved oxygen and many other specific variables.

Environmental and facility control systems will look for temperature, moisture, humidity and other weather conditions. Extending into the mechanics of many types of equipment and machinery, there are various sensors for measuring position, angle, displacement, distance and proximity. Speed and acceleration sensors monitor the change of those same sensed values over time, while vibration sensors monitor the frequency and/or amplitude of motion. For electrically driven equipment, sensing devices report the instantaneous current and voltage values and other related power parameters. Even more esoteric is the use of vision sensing systems to track produced parts, verify quality, or simply read tags. Vision systems in particular can generate huge amounts of image data. Sensors generate numerous types of signals, but these various signals must all be transduced from the raw measurement into a useful signal format for transmission. A classic method of transmitting a single analog value is to use a transducer that scales the value into a 4 to 20 mA signal wired to a control system analog input module.

More advanced “smart” transducers can convert the sensed signal into a standard digital communications protocol, Ethernet-based in many cases. Signal converters are also available that can effectively upgrade legacy type signals and equipment by transforming proprietary or obsolete serial signals to modern open network protocols. “Smart” transducers or sensors are preferred for several reasons. Not only can the primary sensor signal be monitored, but very often there are additional process values available that prove useful. For example, most smart pressure, flow and level instruments include temperature measurement, very useful for signal compensation and general health monitoring. Smart sensors and instruments usually also collect and transmit diagnostic information including device status, alarms and events. Finally, sensors and transducers networked via serial or Ethernet links can provide simplified installation, particularly for wireless variants. There are many paths to collect data, and this data must then be concentrated.

In Interconnection layer, collected information has been concentrated and transferred to data storage. Data typically journeys from networked sensors to some form of data storage or concentration device. This device or devices can exist in a number of locations. Classically, the data would be deposited in large PC server or mainframe systems in a control room or mission control center. Table II identifies some other data concentration options.

Table II: Types of Data Concentrators

1. Data loggers
2. Embedded controllers
3. Embedded PCs
4. PLCs
5. Multi-variable instruments and transducers
6. Smart sensors

Older data loggers, many still in use today, consist of round or scrolling paper charts with ink pens tracing information, similar to an analog earthquake seismograph. Today’s data loggers are fully digital and offer numerous improvements. Solid state data loggers can accept large quantities of input channels, capturing values at defined sampling intervals with the capacity to store tens of thousands of data values in volatile or non-volatile memory. This type of device makes it practical and economical to extend data logging to remote locations. These data loggers may be network-connectable, or may have removable memory cards or USB connectivity for archiving the stored data to a higher-level system. Embedded controllers are often used as a dedicated means to automate equipment. Although primarily tasked with cost-effective machine control, these

controllers often have sufficient memory and processing capabilities to also perform data logging. Similarly, embedded PCs have more than enough power to perform automaton and data logging tasks, and often are configured with rotating or solid state hard drives that can provide significant data storage capacity. PLCs are used in many of the same applications as embedded controllers. Historically, a PLC's strong suit has been reliable, flexible, and high-speed control of machinery. They have also been a common gateway for providing raw data to higher level data concentrators.

Recent years have found PLC processing power and memory capabilities increasing, and in fact the most capable PLCs are now often called process automation controllers. Whatever the moniker, the latest PLCs offer impressive non-volatile storage capabilities, and some even offer historian modules that plug into the PLC chassis. For many cases, this makes the PLC itself a viable option for concentrating data. And looking back for a moment at sensing devices, the most capable of these often have on-board data logging. Often these devices can log to memory cards or USB memory, or they can be networked into a higher level data concentrator. Just as there are myriad options for collecting data, there are more options than ever for concentrating the abundance of this information. Data concentration can be scaled to meet the need, ranging from many smaller field devices all the way up to large centralized or distributed PC-based systems. It's becoming more straightforward to reduce the amount of manual human intervention required to obtain useful data, which in turn drives up the quantity and quality of data available for curation, and eventually interpretation.

In cloud computing layer, information storage, analysis and management – we call it "curation". Once data has been harvested from sensors, and concentrated onto some type of storage system, it becomes important to organize the information in a manner that helps users make sense of it. The activity of "curating" this data typically involves the use of database software. Curating is usually accomplished at the PC server level, since database management is an advanced software function that requires equally capable hardware. Some of the most well-known commercially available business databases include Oracle Database, Microsoft SQL Server, Microsoft Access, SAP Sybase, and IBM DB2. These software packages are used throughout industry for maintaining all sorts of data, and they offer a platform for querying and analyzing information. However, not all data is exactly the same. In the business and commercial world, data often consists of customer information, financial transactions, product stock level, stocking quantities, and shipping information. This transactional data requires very secure data storage, with relatively slow rates of data collection. Interruptions to data access and other functions aren't critical.

When we look at the manufacturing world, we find that a large amount of the information obtained from sensors consists of time-series information where each sample is the value of a sensor with a timestamp. This real-time data is sampled repeatedly. Process data may also include alarm values and discrete process events. Manufacturing data must be stored and accessed in real-time, and uptime is critical. In agriculture field, although the raw data is not as much as manufacturing factory, but there still have large amount of real-time data came from soil water content sensor, temperature sensor, fishpond dissolved oxygen sensor, wind speed sensor and etc. Some of them are critical and some have long term influence on the yield. Curated data is commonly available within an organization over the facility or company network, which is often referred to as an "intranet" or a "private cloud". The Ethernet is considered a "public cloud", but there are secure methods to link multiple facilities or data sources using it.

To a great extent the data collection, concentration, and curation activities occur silently and unseen after initial configuration. These activities must be in place to act as a foundation for visualizing and analyzing information. However, simply presenting users with large tables of values from a historical database will not help most people to understand the data, since most people are more visually oriented towards graphical representations of data such as charts, graphs and other symbols. Data scientist Nate Silver, interviewed by Jon Gertner in Fast Company, relates that “The flood of data means more noise (i.e., useless information) but not necessarily more signal (i.e., truth).” He goes on to state that “People blame the data, when they should be asking better questions” (Nate, 2013). The right data visualization tools can help users understand data and ask the right questions, and to quickly interpret and act upon the answers.

Fortunately, more options than ever are available to display quantities of information and help users make sense of it (Table III). At the field level, many analyzers and data loggers offer local displays or come with associated operator interfaces. These devices often allow users to view trends of data, alarms and events.

Table III: Types of Visualization and Analysis Tools

1. Smart phones
2. Tablets
3. Operator Interface Terminals
4. PC-based HMIs
5. Data loggers
6. Transducer and analyzer displays

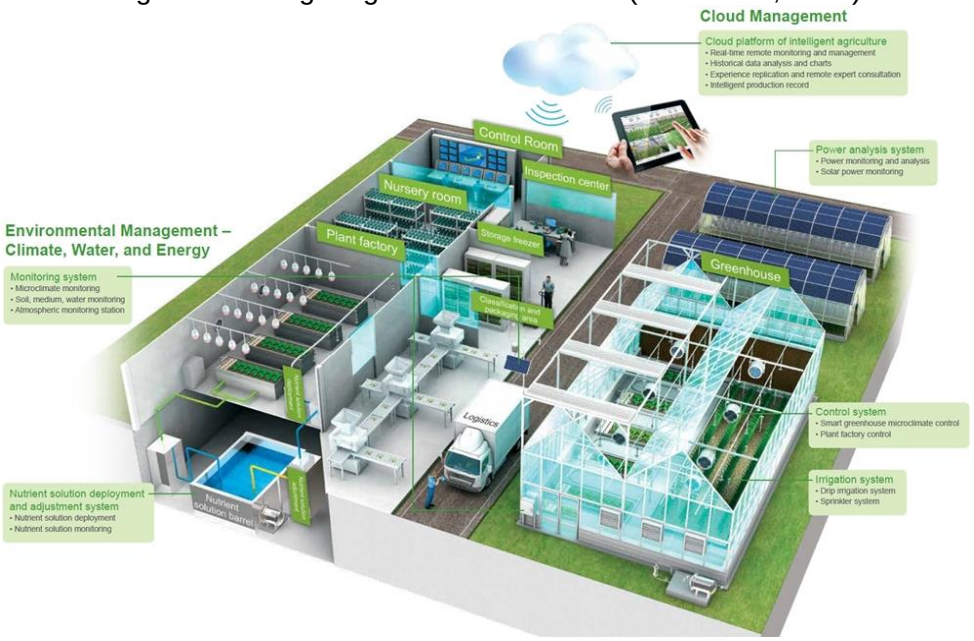
If the controller/OIT is provided by an equipment manufacturer or system integrator, there is a good chance that useful local indications, data logging/trending, and alarming capabilities will be built-in and thus readily available without any extra effort required by the end user. For many applications, the point where visualization and analytical performance really gains traction is when software on a PC platform taps into historical data. The software historians mentioned in the “Curation” section offer their own visualization and reporting tools. Operators can trend various data points over chosen time ranges, and effectively perform their own investigation of the available data (Figure 2). The dashboard distills the key elements to show the most important facts about what is happening, allowing users to quickly interpret conditions and make smart decisions.

Figure 2: Operator interface terminals typically include data

RESULT

To build an intelligent agriculture ecosystem, a series of comprehensive intelligent farm, greenhouse, plant factory, and aquaculture and livestock solutions can be developed by IoT technologies. Here we illustrated the typical smart greenhouse solution as shown in Figure 3.

Figure 3: Intelligent greenhouse solution (Advantech, 2018)



This solution includes sub-systems as following:

i. Monitoring Systems

- Soil, medium, and water monitoring
- Monitor soil/media for pH, conductivity, temperature, humidity etc. for the best growing conditions
- Monitor water quality including pH, conductivity, temperature, dissolved oxygen etc.
- Provide optimal settings and send warnings via SMS/e-mail when incidences occur so that optimum conditions can be maintained
- View historically stored data and produce graphs to view trends
- Microclimate monitoring
- Use sensors to monitor environmental aspects such as temperature, relative humidity, sunlight, carbon dioxide, wind speed and produces images of crop growth
- Provide optimal settings and send warnings via SMS/e-mail when incidences occur so that optimum conditions can be maintained
- View historically stored data and produce graphs to view trends
- Atmospheric monitoring station
- Use sensors to monitor atmospheric conditions such as: temperature, relative humidity, wind speed, wind direction, rain, snow and sunlight
- Improve the efficiency of greenhouses by analyzing the difference between internal and external temperatures
- Use historical analysis to predict short-term changes in the atmosphere to enhance the stability of the indoor climate

ii. Control Systems

- Intelligent greenhouse microclimate control
- Use sensors to monitor indoor and outdoor atmospheric data and automatically adjust the temperature, humidity, shade nets, insulation curtains, fans, skylights etc.

• Configure devices separately for multiple crops
• Adaptive greenhouse management for a wide range of controls
• Reduce labor costs and errors and diseases for greater quality and stability

Plant factory control

• Use sensors to monitor temperatures, relative humidity, carbon dioxide concentration using air conditioning systems, circulating fans, artificial light sources etc.
• Use indoor air conditioning to save 70% of water consumption
• Adjust artificial light to shorten production time and increase capacity

iii. Power Analysis Systems

• Power monitoring and analysis
• Use sensors to see and record the greenhouses' electrical status
• Use recorded power data to calculate and analyze the cost of each device
• Automatically use shade nets to reduce the intensity of the sunlight and reduce power usage
• Analyze independent power sources and adjust their use depending on the requirements
• Calculate the total cost of electricity generation and its use

iv. Irrigation Systems

• Drip irrigation system
• Use drip irrigation sensors to monitor soil moisture conductivity, pH levels etc.
• Use soil moisture sensors to control conditions and quality
• Permeability ensures that water from the pipeline is used
• Drip devices, plugged into a PE pipe, automatically regulate the flow
• With no water between crops, weeds can't grow
• Drip irrigation systems are: labor, water, energy & yield improving
• Irrigating water and fertilizer directly on the soil, crop roots maintain the optimal conditions to increase production
• Sprinkler system
• Soil moisture sensors control the sprinkler system
• The analog sensors' signals are converted from analog to digital for saving
• Convert signals to the same value as the soil moisture tension meter to become linear
• Monitor soil moisture conductivity, pH and other sprinkler data for the best conditions
• Provide strategies for control conditions, schedule and quantity
• Automatic correction of salinity during freezing temperatures
• Low construction cost, and rapid foliar absorption, increases greenhouse humidity and reduces temperature
• A low-cost and labor-saving irrigation management system

v. Nutrient solution deployment and adjustment Systems

• Nutrient solution deployment
• Effectively monitor and control the deployment of the nutrient solution, and manage routine work, including water quality used to modulate the conditions
• Adjust the proportion and concentration of the nutrient solution, and then send the information to the irrigation
• Crops grow at different rates, automatically adjust the nutrient solution for better growth nutrient solution adjustment
• Real-time monitoring of various conditions, means that changes can be made as soon as an issue is seen

- Get the benefits of circulating nutrients and use a clean room to increase fertilization & yield, and prevent diseases
- Automatically adjust the nutrient solution schedule according to the crops' requirements

vi. Cloud platform of smart agriculture

- Real-time remote monitoring and management
- Remotely check real-time information and control next line through computers, tablets, mobile phones, and other devices
- Manage distributed systems, nutrients, temperatures etc. across multiple greenhouses
- Provide different workers with different levels of authority
- Get real-time information via SMS and e-mail alerts
- Analysis of historical data and charts
- Integrated charts for analysis & problem identification for enhanced crop cultivation
- Sensor data's automatically uploaded to the cloud for future analysis and queries
- Provides private cloud and public cloud
- Remote expert consultation
- Share greenhouse experiences and data with other greenhouses to get advice
- Improve farmer education by providing the latest green innovations
- Experts can provide objective & accurate diagnosis
- Intelligent production record
- Record details of the production system eg. location, farmer, soil quality, growth, harvesting time, fertilizer use etc.
- Automated production of records for an exact record of quality control, pesticide residue etc.

CASE STUDY AND SUMMARY

In 2016, the output value of agricultural products in Taiwan was $17.18 billion, an increase of $0.42 billion (+2.6%) over the previous year, of which the output value of agricultural products was approximately $8.88 billion, accounting for 51.7% of the total output value of agricultural products; the output value of livestock and poultry products was approximately $5.54 billion, accounting for 32.2%; fishery product output value of approximately $2.77 billion yuan, accounting for 16.1%; forest production value of approximately $6.7 million; agricultural product output value ratio in the past 10 years is roughly maintained at about 40~50% of agricultural products, 30% of livestock products, and 20% of fishery products.

Edible corn is one of the major vegetables in many countries and one of Taiwan's representative grain crops. According to the Taiwan Agricultural Commission's comprehensive statistics, in the Republic of China 104 years, the domestic corn planting area was 27,000 hectares (ha), accounting for 83% of the total grain planting area. The consumption of corn was divided into sweet corn, waxy corn and white corn. The 104-year output value of the Republic of China was 1,918,738 thousand yuan, with a growth rate of 15%. Sweet corn was used for fresh food, processing and canning, threshing and freezing, while waxy corn and white corn were fresh or baked. Among them, sweet corn is the favorite of consumers due to its high sugar content in the milk ripening period, crisp texture, good flavor, and rich nutrition. The sweet corn flavor is most influenced by the content of grain sugar and the thickness of the peel, but at present, the quality of sweet corn in Taiwan is mostly classified by appearance.
In Taiwan, government encourages and supports the implementation of intelligent agriculture solution. The biggest project of intelligent agriculture in past 5 years is provided by Advantech and its Eco-Partners in Figure 4 and this project is scheduled to close in the end of 2018. It's planned to integrate of expert systems and intelligent computing as shown in Figure 5.

Figure 4: The structure of intelligent agriculture solution

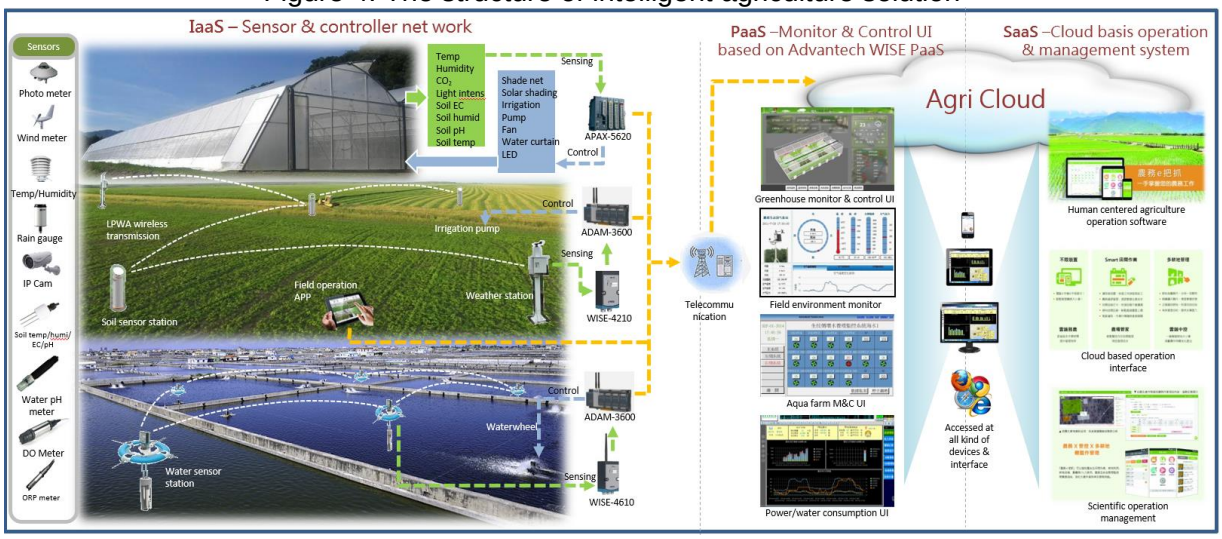
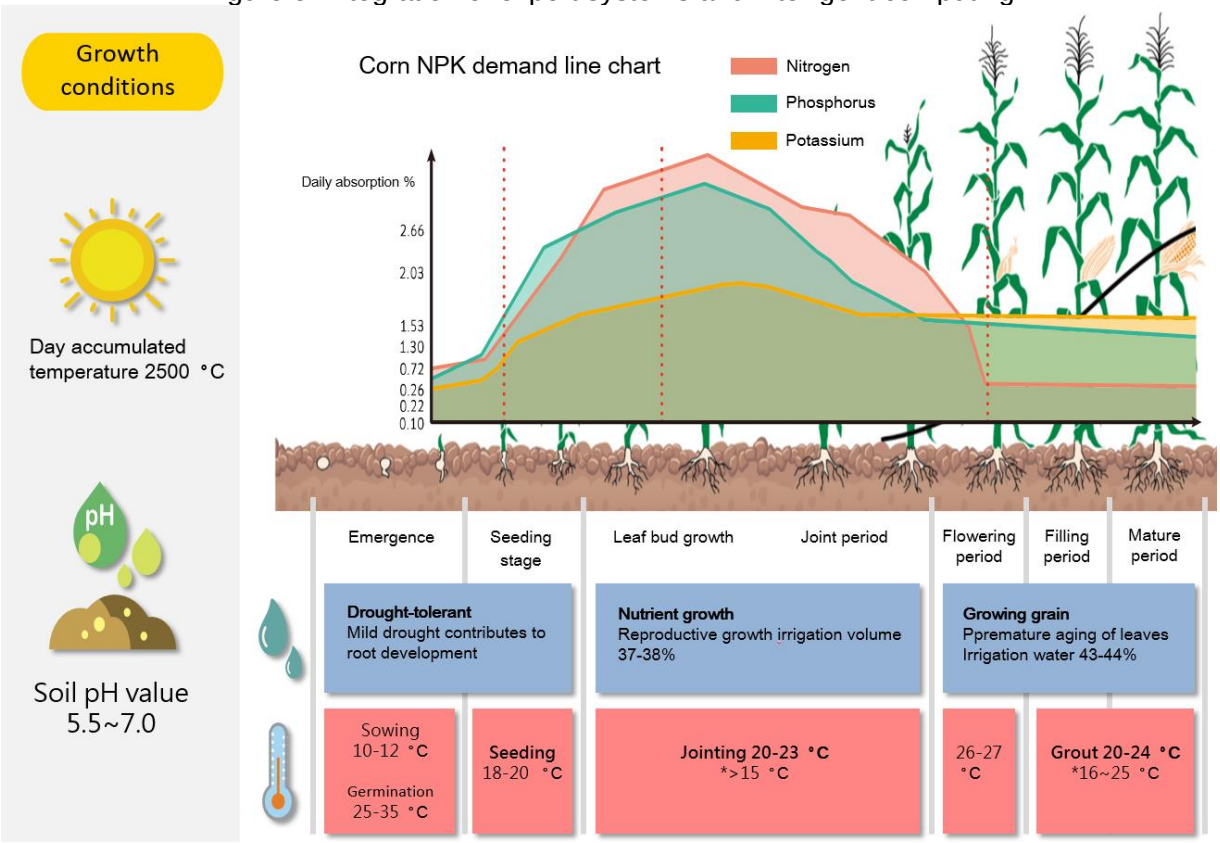
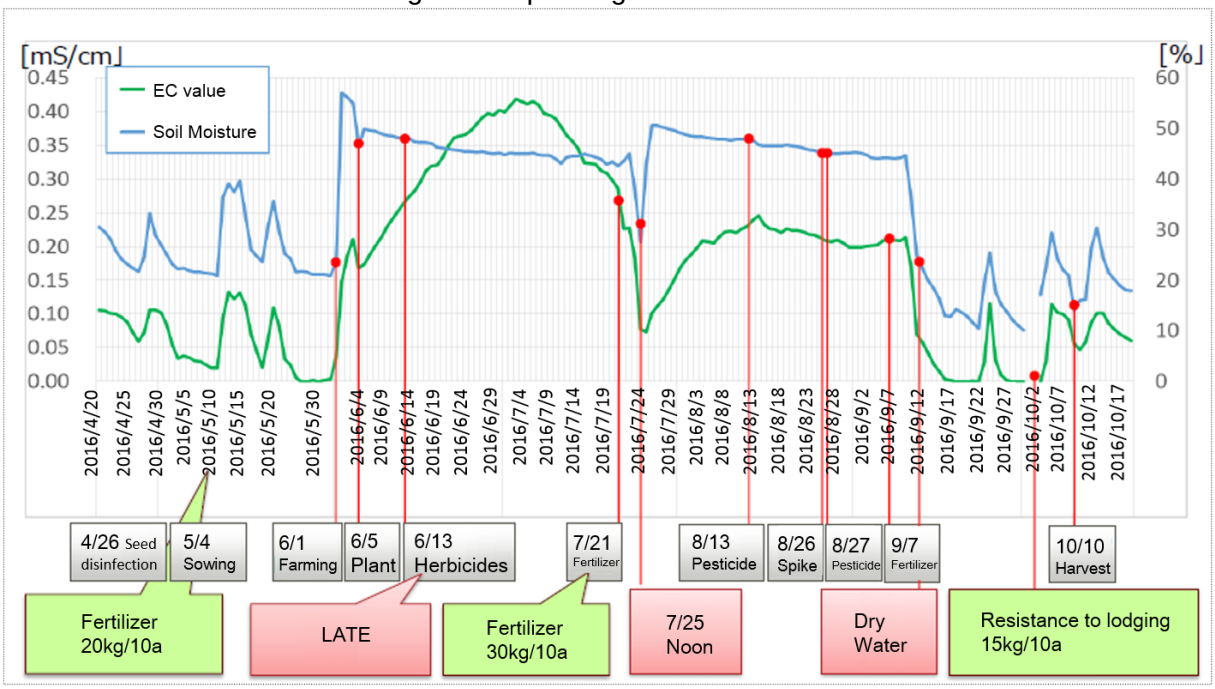


Figure 5: Integration of expert systems and intelligent computing



Nowadays, Software as a Service (SaaS) company plays an important role for domain-focus analysis. In Figure 6, there is another case of rice growth predictive analysis by combination of real-time data and past historical average data of growth curve to provide data-driven insight to farmer to adjust the environment to conform optimal growth condition.

Figure 6: Optimal growth conditions



CONCLUSION

An increasing number of 2nd generation farmers are expressing willingness to adopt technological products, and numerous technology giants have made investments in the agriculture industry. Supported and promoted by the governments of several countries, relevant IT hardware and software technologies are ready for deployment, and the development of intelligent agriculture is expected to attract substantial attention in the future.

Intelligent agriculture can also create unexpected economic synergy. The software and hardware required for industrial upgrades, as well as warehousing, logistics, transportation, and online shopping applications will undoubtedly prompt the development of various industries. While social media becomes popular as an advertisement tool in the past years, it facilitates agriculture business transformation from traditional way to e-commerce (Topsümer & Yarkin, 2018). Through online marketing, it expand business opportunity to domestic and international. Farmers promote their crop products by story-telling to end customers or consumers for direct sales and precision marketing. In Figure 7, it shows the target of intelligent agriculture.

Herewith, we truly believe that “Intelligent agriculture” is extremely meaningful for governments, farmers, relevant industries, and even the public.” The revolution of agriculture accelerated by IoT and cloud computing technology will be booming in the coming years.

Figure 7: Target of intelligent agriculture

(Source: Photo by LoveToTakePhotos on Flickr - used under Creative Commons license)

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Influence of Culture and Generation on Transformational Leadership

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ABSTRACT

This study investigates the impact of both generations and culture in relation to the trust in transformational leadership. Using a polynomial regression analysis, we demonstrate that congruence between leadership style and cultural setting fits better for Generation X than for Generation Y. We also tested the county difference on relationship between transformational leadership and trust for each generation.

KEYWORDS: Generation, Transformational Leadership, Trust, Culture

INTRODUCTION

A review on transformational leadership and trust literature indicates trust plays different roles in the leadership process: as an outcome of leadership (Bass & Avolio, 1995; Podsakoff et al., 1996), a mediator (Yukl, 1989; Jung & Avolio, 2000; Podsakoff, MacKenzie, Moorman & fetter, 1990), and a moderator (Bass & Avolio, 1994; Nichols, 2008). This study build on previous research investigate 1) how different generations understand leadership differently; 2) how people from different cultural settings perceive their leaders differently and trust their leaders at a different level.

GENERATION, TRANSFORMATIONAL LEADERSHIP, TRUST, AND CULTURE

Generation refers to a cluster of people born in the same certain period of time who share similar values and attitudes thereby representing the characteristics of that specific era (Rogler, 2002). The common experiences tie a generation's members can be reflected in the way they view work and workplace (Schewe & Evans, 2000). Generations should be considered by leaders and their organizations as one of the important parts of the diversity mix (Arsenault, 2003). Social scientists differ somewhat on how to name and segment the generations.

The theory of transformational leadership originated with the work of Burns (1978) and later was developed by Bass (1985, 1998). The major premise of the theory is the leader's ability to

motivate followers to accomplish more than they planned to accomplish (Krishnan, 2005). Effective transformational leadership may not be realized if trust is absent.

Culture is crucial to understand leadership (Hofstede, 1991).In this study, we test a model and suggest that each dimension of culture is significantly related to leadership. Different generations perceive these situations differently. Trust in their leaders depends on the match between the situation and generation. Specifically, we propose that individualistic and low uncertainty avoidance culture provide a favorable situation for a strong transformational leadership.

Individualism/Collectivism

Individualism/Collectivism dimension describes whether the culture values individuals' goals or group goals (Hofstede, 1980).in individualistic culture, a weak transformational leader combines with collectivistic culture, creates a favorable situation where Generation X works better than Generation Y. In collectivistic culture, Generation Y is full of confidence in interacting with his/her leaders. Generation Y is expected to perceive more trust in leadership than does Generation X in collectivistic culture. Thus, we propose that:

H1a: When transformational leadership is weak, Generation X perceives more trust in leadership than does Generation Y in collectivistic culture, while Generation Y perceives more trust in leadership than does Generation X in Individualistic culture.

H1b: When transformational leadership is strong, Generation Y perceives more trust in leadership than Generation X does in collectivistic culture, while Generation X perceives more trust in leadership than Generation Y in Individualistic culture.

METHOD

Sample

Data were collected from full-time employees in USA and in China who worked in a range of occupations. The response rate was 86%. We obtained valid data from 153 American and 150 Chinese full-time employees. On average, they were 53.8% female, 49.3% Generation X, with 5.62 years of full-time work experiences. Of the employees, 33.82% has a high school diploma, 26.96% has an associate's degree or technical certificate, and 32.84% has a Bachelor's degree.

Measures

We adopted transformational leadership scale developed by Podsakoff et al. (1990).The measures of trust was borrowed from existing literature (Podsakoff et al.,1990; Casimir et al.,2006). Culture was measured by using scales developed by Hofstede's (1991, 2001). Generation is a categorical variable having two categories: Generation X and Generation Y.

RESULTS

We used polynomial regression analysis to test the moderation effects proposed in this study. The results indicate that the relationship between transformational leadership and trust varies across two generations and individualistic/collectivistic culture. In addition, the R^2 change

associated with the interaction term (i.e., ΔR^2) is 0.0138. We applied MatLab to plot two 3-D surfaces for Generation X. The results provide support for Hypothesis 1a and 1b.

DISCUSSION

This study contributes to the growing literature on transformational leadership by investigating a previously unexamined factor, generation. The study also offers new insights regarding whether culture factors impact trust in transformational leadership. In addition, we examined the congruence effect between generation and culture. The study helps to better understand the use of contingency leadership in East cultural.

LIMITATIONS AND CONCLUSIONS

The current research has several limitations. First, relatively small samples and second, some other factors such as job design and other demographic variables may influence the leadership-effectiveness relationship. In conclusion, the study shed some lights on implications for managers who work in different cultural settings and facing different generation employees.

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References available upon request.

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Justification of Lean manufacturing for sustainable competitive advantage: Analytic hierarchy process approach

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ABSTRACT

Market requirements are changing very fast. To compete under such business environment, organizations are trying to adopt emerging advanced manufacturing practices to reduce different kind of wastage in their operations. Lean manufacturing system has emerged as an important approach to enhance value addition in production systems. However, it has been observed that many small and medium enterprises (SMEs) particularly in developing countries are still reluctant in implementing lean manufacturing practices. By using the analytic hierarchy process (AHP) approach, study has tried to justify the implementation of a lean manufacturing system for Indian small manufacturing organizations.

KEYWORDS: Lean Manufacturing, SMEs, AHP, Competitiveness

INTRODUCTION

Due to globalized market, competition is in terms of low manufacturing cost, lesser delivery lead time, and new product features. Organizations are trying to adopt new advances in manufacturing systems. Hall (1983) and Schonberger (1982), have discussed about an approach developed by Japanese known as Lean Manufacturing to increase the production rate and decrease overall cost in the manufacturing units. It was previously known as the Toyota Production System (TPS) or the Just-in-Time (JIT) system (Toyota, 1988; Womack et al., 1990). In the United States, Lean manufacturing has become very popular in academia and also in industry. In recent time, many automobiles and other manufacturers are actively adopting the lean manufacturing concepts. According to Maccoby's (1997), one-fourth of United States manufacturing firms have tried to adopt the lean manufacturing system in their processes. Lean manufacturing tries to reduce wastage in production, inventory, human resource, etc. Some researchers (Cusumano and Takeishi, 1991; Womack and Jones, 1996b) have observed that when we shift from traditional manufacturing system to lean manufacturing, it had a significant positive impact on the performance of manufacturing units. It has been observed from the

literature that SMEs are still lagging behind in application of these lean manufacturing principles to become competitive. Therefore, objective of this study to identify major benefits of lean manufacturing and to justify its application in Indian SMEs.
Remaining part of the paper is organized as follows. Section 2 deals with literature review, Section 3 deals with research methodology i.e. AHP and finally section 4 is results and discussion with concluding remarks.

LITERATURE REVIEW

The term "lean manufacturing" was first coined by Womack et al. (1990) in their book "The Machine That Changed the World". The lean manufacturing describes the profound revolution that was initiated by the Toyota Production System against mass production system. Womack and Jones continued their research in lean manufacturing and studied those companies which use lean manufacturing in their second book, "Lean Thinking" (Womack and Jones, 1996). They explained that lean manufacturing is a way of thinking, and the whole system approach that creates a culture in which everyone in the organization continuously improve operations. In his most recent book about the Toyota system, Liker (2004) describes the management principles of Toyota.
According to Sohal and Eggleston (1994), lean manufacturing increases the net profit because it reduces the wastages in the production system. Lean manufacturing increases productivity of the plant so that production rate increases (Philips, 2002). Shingo (1989) states that lean manufacturing decrease waste in the plant. Lean manufacturing eliminates the non value adding process so that wastage get decreased. Gilson et al. (2005) have observed that Lean manufacturing improves the quality of product because it uses the standard process to make a product. According to Lian and Van (2007), lean manufacturing improves the flexibility in production systems. According to Azharul and Kazi (2013), the amount of inventory gets reduced in industry by using lean manufacturing. With the help of Lean manufacturing, lead time gets reduced because it decreases the set up time of machine.
List of benefits after the adoption of modern lean manufacturing in place of traditional manufacturing are summarized in table 1.

Table 1: Benefits of Lean Manufacturing

SN	Abbreviation	Benefits of LM	References
1	INP	Improve Net Profit	Karim and Zaman (2013),Sohal and Eggleston, (1994), Standard and Davis (2000)
2	IP	Improve Productivity	Carlborg et al. (2013),Philips (2002)
3	WR	Waste Reduction	Nawanir et al. (2013),Ghosh (2013)
4	IQ	Improve Quality	Gilson et al. (2005), Molleman, E. (2000)
5	IF	Improve Flexibility	Womack, J. et al. (1990), Allwood and Lee (2004), Chavez et al. (2013)
6	IR	Inventory Reduction	Nawanir et al. (2013),Suzuki, T. (1995) Shen and Wacker (1997)
7	LTR	Lead Time Reduction	Al-Najjar and Alsyouf (2000),Ghosh (2013),Tajiri and Gotoh (1992)

RESEARCH METHODOLOGY

To justify the lean manufacturing vs. traditional manufacturing for SMEs, AHP approach has been used. Saaty (1980) had suggested analytic hierarchy process (AHP) to solve complex

problems. Kodali and Chandra (2001) used AHP for justification of total productive maintenance. Study has four phases, as follows:

1. Structuring the problem and building the AHP model
2. Collecting data from expert interviews
3. Determining the normalized priority weights of individual factors and sub factors
4. Synthesis-finding solution to problem.

Phase 1: Structuring a hierarchy model of benefits

In this phase, we formulate the appropriate hierarchy of AHP model. AHP model consist of goal, main factors and result. The goal of our problem is to justify the lean manufacturing over traditional manufacturing. This goal is placed on the first level of the hierarchy as shown in Figure 1. Second level consists of seven major benefits. The third and last level consists of two alternatives, i.e., lean manufacturing and traditional manufacturing. AHP model is shown in Figure 1.

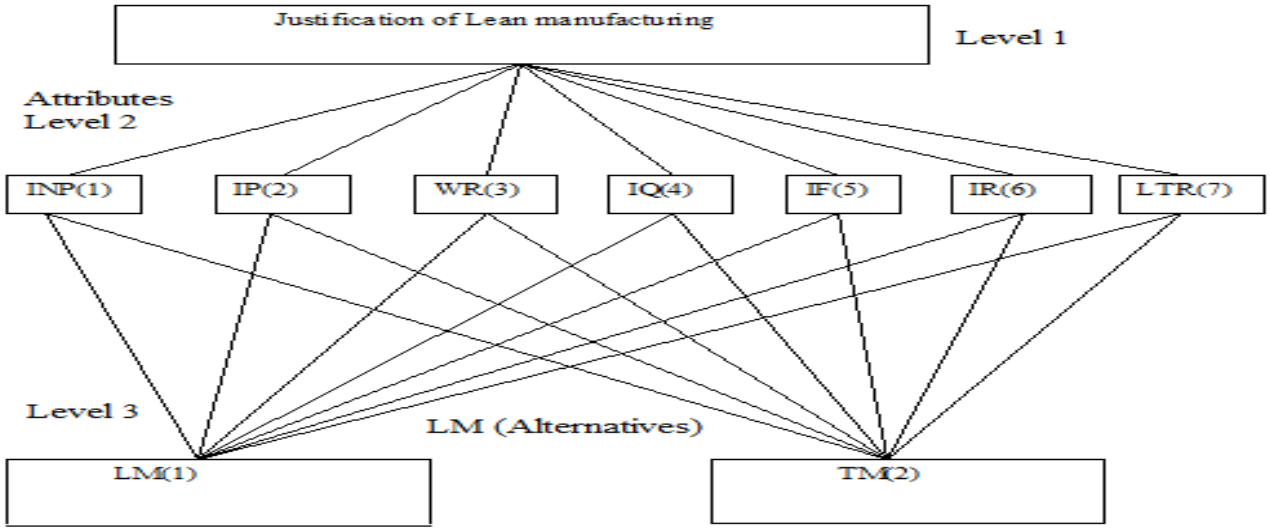

Figure 1: AHP model (Source- Adopted from Singh, 2012)

Phase 2: Measuring and collecting data

After building the AHP hierarchy, next step is measurement and data collection. It was done by a team of experts. This team assigns pair-wise comparison to the main factors used in the AHP hierarchy. We use nine-point Saaty's scale (Table 2) to assign relative scores to pair wise comparisons amongst the main factors. Team consisted of twelve experts of varying relevant field experience. Bayazit (2005) used AHP approach in decision making for flexible manufacturing system by having a team of six experts from various departments. Zaim et al. (2012) also used a team of five decision experts while selecting maintenance strategy. Singh (2013) used AHP for prioritsation of factors in coordinated supply chain.

Table 2: Thomas Saaty's nine-point scale

Intensity	Importance of one factor over other
1	Equal Importance
3	Weak Importance
5	Strong Importance

7	Demonstrated Importance
9	Absolute Importance
2,4,6,8	Intermediate values between the two adjacent judgment
Reciprocals of above non-zero	If activity *i* has one of the above non-zero numbers assigned to it when ompared with activity *j* then *j* has the reciprocal value when compared with *i*

Source: Saaty (1994)

Phase 3: Determine normalized weights

In order to find out the relative importance of seven major benefits of lean manufacturing, pair wise comparison judgment matrices are made with the help of experts' opinion. Table 4 shows the pair-wise comparison matrix for level 2 criteria.In pair wise comparison, we use the Consistency ratio (CR) to measure the consistency level. Saaty (1994) has suggested the acceptable level of Consistency ratio (CR) for different matrices. For 3×3 matrix acceptable Consistency ratio (CR) is 0.05 and for 8×8 matrix is 0.08 and for large matrix is 0.1. If consistency level with in the acceptable range, then weight result is valid. We check the consistency of judgments by following steps:

• Let the pair-wise comparison matrix is denoted by P1 and principal matrix is denoted by P2

• Then define P3 = P1 * P2; and P4 = P3 / P2

• $\lambda_{max.}$ = average of the elements of P4

• Consistency index (CI) = $\frac{(\lambda_{max} - n)}{n-1}$

• Consistency ratio (CR) = CI / RCI corresponding to n. ……. (1)

Where RCI = Random Consistency Index and n = Numbers of elements (Table 3)

Table 3: Average random index values

N	1	2	3	4	5	6
RCI	0	0	0.58	0.90	1.12	1.24

Source: Saaty (1980)

If CR is less than 10%, judgments are considered consistent,

If CR is greater than 10%, the quality of judgments should be improved.

So, CR should be ≤ 10% for consistent results

RESULTS AND DISCUSSION

A set of global priority weight can be determined for each of the lean manufacturing and traditional manufacturing by multiplying local weight of lower factors with weight of all the parent nodes above it and then adding all the products for corresponding alternative.

Table 1 shows seven main factors/benefits of lean manufacturing. AHP model developed as shown in Figure 1 is used for justification of Lean manufacturing in SMEs. Then we make pair-wise comparison judgment matrices to find out the normalized weight. Pair wise criteria comparison matrix shown in table 4. This table shows all the seven major benefits of lean manufacturing. After that we calculate the CR value to check the degree of consistency of the pair wise comparison matrix. CR for level 1 is shown in table 5. Then we follow same procedure to find the PV and CR for other levels. Table 6 shows the results. It is observed from table 6 that all seven benefits of lean manufacturing have more PV in comparison to traditional manufacturing. CR value is also less than 0.1 for all decision factors. Local weight of attributes

for alternatives shows in table 7. Global weight of major benefits for lean manufacturing are shown in table 8.

Out of seven major benefits of lean manufacturing, lead time reduction has highest global weight (0.33832). Less lead time is required to obtain maximum profit because lead time decrease production increase. Second highest global weight is to increase productivity (0.22258). If productivity increases then net profit would also increase. So we increase the productivity in such a manner that overall cost of operation decrease. Improved flexibility has third highest global weight (0.15218). If flexibility increases in production system then profit increased. Fourth highest global weight is improves quality (0.07793). With the help of lean manufacturing, quality of product also increases. Waste reduction is the fifth benefit of lean manufacturing with global weight is 0.04861. With the help of lean manufacturing we can eliminate non value added process so that our wastage is reduced. Sixth benefit of lean manufacturing is inventory reduction and its global weight is 0.03804. With the help of lean manufacturing, raw material and work in process inventory get decreased because of standard process and JIT. Next benefit of lean manufacturing is increase in net profit. Therefore lean manufacturing help in production increase, inventory decrease, waste decrease, lead time decrease, increase flexibility and improved quality. Global desirability index of lean manufacturing and traditional manufacturing are shown in table 3.9. Global desirability index of lean manufacturing is 0.89568 and traditional manufacturing is 0.10431. So this analysis shows that application of lean manufacturing is better for Indian SMEs for being competitive in global market.

Table 4: Criteria pair wise comparison matrix (level 2)

	INP	IP	WR	IQ	IF	IR	LTR	P.V
INP	1	1/9	1/5	1/5	1/8	¼	1/9	0.02025
IP	9	1	6	5	3	6	¼	0.24732
WR	5	1/6	1	1/3	1/5	2	1/7	0.05556
IQ	5	1/5	3	1	¼	3	¼	0.08907
IF	8	1/3	5	4	1	4	1/3	0.16908
IR	4	1/6	1/2	1/3	¼	1	1/8	0.04279
LTR	9	4	7	4	3	8	1	0.37591

Following steps are used to normalize the table of seven main benefits and to calculate the CR value.

Let P_1 is pair wise comparison matrix and P_2 is principal vector matrix

$$P_2 = \begin{Bmatrix} 0.02025 \\ 0.24732 \\ 0.05556 \\ 0.08907 \\ 0.16909 \\ 0.0428 \\ 0.37591 \end{Bmatrix}$$

Then $P_3 = P_2 \times P_1$

$$P_3 = \begin{Bmatrix} 0.1502595 \\ 2.0663064 \\ 0.4008324 \\ 0.671103 \\ 1.3440995 \\ 0.3117478 \\ 3.142288 \end{Bmatrix}$$

$P_4 = P_3/P_2$

$$P_4 = \begin{Bmatrix} 7.420271 \\ 8.35473 \\ 7.214518 \\ 7.534481 \\ 7.949064 \\ 7.284357 \\ 8.359096 \end{Bmatrix}$$

Average of elements of P_4 ($\lambda_{max.}$) = 7.7309308

Now consistency index (CI) = $\frac{(\lambda_{max} - n)}{n-1}$ = 0.121822

And consistency ratio (CR) = CI / RCI = 0.092289

Table 5: Consistency ratio of comparison matrix

CR	0.092289

So CR is less than 0.1, result is consistent.

Table 6: Pair wise comparison judgment matrices for Alternatives

Alternative analysis with respect to [INP]			
	LM	TM	P.V.
LM	1	8	0.8889
TM	1/8	1	0.1111
TOTAL	1.125	9	**CR<0.1**
Alternative analysis with respect to [IP]			
	LM	TM	P.V.
LM	1	9	0.9
TM	1/9	1	0.1
TOTAL	1.1111	10	**CR<0.1**

Alternative analysis with respect to [WR]			
	LM	TM	P.V.
LM	1	7	0.875
TM	1/7	1	0.125
TOTAL	1.4285	8	**CR<0.1**
Alternative analysis with respect to [IQ]			
	LM	TM	P.V.
LM	1	7	0.875
TM	1/7	1	0.125
TOTAL	1.4285	8	**CR<0.1**
Alternative analysis with respect to [IF]			
	LM	TM	P.V.
LM	1	9	0.9
TM	1/9	1	0.1
TOTAL	1.111	10	**CR<0.1**
Alternative analysis with respect to [IR]			
	LM	TM	P.V.
LM	1	8	0.8889
TM	1/8	1	0.1111
TOTAL	1.125	9	**CR<0.1**
Alternative analysis with respect to [LTR]			
	LM	TM	P.V.
LM	1	9	.9
TM	1/9	1	.1
TOTAL	1.111	10	**CR<0.1**

Weights of attributes for alternatives are calculated by using the equation 2. Table 7 shows weights of attributes for alternatives.

Table 7: Weights of attributes for alternatives

S.NO.	ATTRIBUTES	Level 2 Wt. (P.V.)	LM Wt. (P.V.)	TM Wt.(P.V.)
1	INP	0.02025	0.8889	0.1111
2	IP	0.24732	0.9	0.1
3	WR	0.05556	0.875	0.125
4	IQ	0.08907	0.875	0.125
5	IF	0.16908	0.9	0.1
6	IR	0.04279	0.8889	0.1111
7	LTR	0.37591	0.9	0.1

Desirability index of alternatives global weight of lean manufacturing and traditional manufacturing is calculated by using the equation 3. Table 8 shows desirability index of alternatives global weight.

Table 8: Desirability index table of alternatives global weight

S.NO.	ATTRIBUTES	LM GLOBAL WT.	TM GLOBAL WT.
1	INP	0.01799	0.00225
2	IP	0.22258	0.02473
3	WR	0.04861	0.00694
4	IQ	0.07793	0.01113

5	IF	0.15218	0.01690
6	IR	0.03804	0.03759
7	LTR	0.33832	0.104316

Global desirability index of modern maintenance management and traditional maintenance management is calculated by using the equation 4. Table 9 shows the global desirability index of alternatives.

Table 9: Global desirability index of alternatives

GLOBAL DESIRABILITY INDEX OF LM	0.89568
GLOBAL DESIRABILITY INDEX OF TM	0.10431

Global desirability index of lean manufacturing is 0.89568 and global index of traditional manufacturing is 0.10431. So lean manufacturing is justified for SMEs to become globally competitive.

CONCLUDING REMARKS

Lean manufacturing had been very popular tool in eliminating waste across all functions. Bigger organizations are using different tools of lean manufacturing to become competitive. However, in small and medium organizations are still in nascent stage in implementing lean tools across different functions. SMEs are not well organized and are reluctant for any up gradation due to resource constraints. The present study has tried to identify seven benefits of lean manufacturing. These are improved productivity, waste reduction, improved quality, improved flexibility, inventory reduction and lead time reduction. Based on priority weights of these benefits, study has tried to find the global desirability index for lean manufacturing system and traditional manufacturing system for SMEs. It has been found that desirability index for a lean manufacturing system is quite high as compared to traditional manufacturing system. Therefore, it may be recommended based on the findings that lean manufacturing is very useful for making SMEs competitive in the global market.

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Key Elements for Developing the Momentum of Self-Sustained Economic Development

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ABSTRACT

This work attempts to find the fundamental elements for developing countries to detonate desired economic takeoff, a challenge the mainstream economics is unable to answer. Other than using anecdotes and methods of data mining, this paper employs the thinking logic of systems science and the rigor of game theory. After successfully establishing two theorems, a list of key elements is provided for a developing economy to possess in order to develop its momentum for a self-sustained economic development. Other than its theoretical value, this work is expected to produce practical economic benefits for developing nations that desire to prosper economically.

KEYWORDS: consumer good, industrial good, market fermentation, holistic thinking, first law on state of motion

INTRODUCTION

In the last century, countries from around the globe attempted to modernize and to industrialize themselves. Although their GDP grew tremendously, they failed to develop a self-sustaining momentum of economic growth (Acemoglu & Robinson, 2012; Breslin, 2009; Chang, 2003; Rostow, 1960). By studying the industrial revolutions in England, the United States of America, Japan, and modern China, Wen (2016) discovers that most factors, considered crucial for kick-starting an industrial revolution (Lipton, 1977; Studwell, 2013) are actually not relevant much; instead to be successful, one nation has to start humbly in its rural areas within a politically stable environment.

Poverty tends to be self-perpetuating; growth tends to generate its own momentum, once an initial growth is started (Hartwell, 2017). To build a self-sustaining momentum, the initial growth needs to occur in the rural area (Mendels, 1972), which simultaneously helps nurture the coordination and specialization of labor, improve the wages and purchasing power of grassroots population, and ferment the formation of markets (Gilboy, 1932). Considering the present state of world affairs, this might be the only way for a developing nation to succeed in its attempt of developing a self-sustaining momentum of economic growth.

Only when markets of sufficient purchasing power and sophisticated distribution network exist, mass production appears (Fleischman & Parker, 2017; Smith, 1776). Here, the market and distribution network are developed with the manufacturing sector and commerce function as

employers and producers of wealth, and transfers resources from agriculture to industry and services (Deane, 1957).

This paper contributes to the literature of development economics in several different ways. First, by answering Hartwell's call in (1965), this work develops a scientific methodology that can be employed to derive sound, reliable, and practically duplicable conclusions in economic history. Second, two results on the dynamics of market competition are established rigorously. One result says that with a profit opportunity, there will appear competition(s) even although the incumbent firms also pursue after the opportunity. The second result explicitly shows how intensifying market competition stimulates innovation or market expansion or both have to occur. Third, on top of these results the systemic yoyo model is employed to uncover a list of key elements necessary for a developing nation to develop a self-sustaining momentum of economic growth.

The rest of this paper is organized as follows: Next section introduces the basics of systems science and the yoyo model to be used in the rest of the paper. Two theorems based on systemic intuition and game theory are shown in the following section. The main section details the key elements necessary for developing a self-sustaining momentum of economic growth. The last section concludes this presentation.

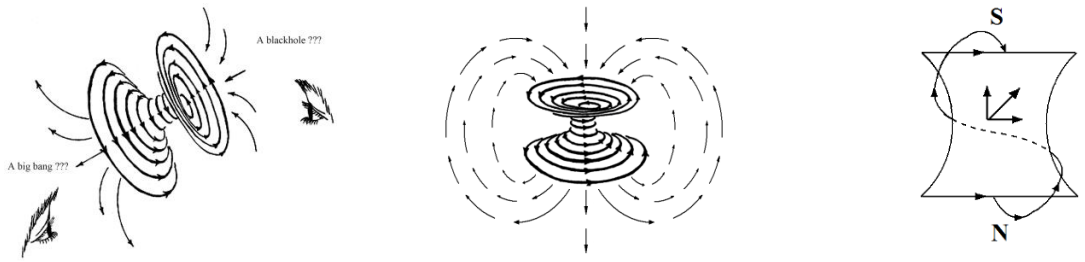
BASICS OF SYSTEMS SCIENCE AND YOYO MODEL

To make this paper self-contained, this section looks at the basics of systems thinking and the systemic yoyo model.

Because the fundamental character of economic entities is their organization, to explain and to understand organization behaviors one has to look at the entities holistically instead of focusing on individual parts and processes (von Bertalanffy, 1924; Rostow, 1960). In the past 90 plus years, studies in the language of systems science and systems thinking have brought forward brand new understandings and discoveries to some of the major unsettled problems facing the very survival of the mankind (Klir, 1985; Lin, Y., 1999).

Similar to how numbers and algebraic variables are originated from collections of things, the concept of systems exists within every object, event, and process. For instance, behind collections of objects, say, employees working for a particular company, one has the abstract numbers, such as 0 (employees), 1 (employee), 2 (employees), etc. And behind each business organization, a market, or a regional economy, a system vividly emerges; it relates the whole, component parts, and the environment with their interconnectedness being emphasized. In fact, it is the interconnected whole, parts, and the environment, the totality is known as a firm, market, industry, economy, etc.

The importance of systems science is manifested in its capability of solving problems that have been either difficult or impossible for the traditional science to deal with. The particular speaking language and thinking logic of systems science is the systemic yoyo model (Lin, Y., 2007), Figure 1, similar to how the Cartesian coordinate system plays its role in the development of modern science (Kline, 1972).



(a) (b) (c)

Figure 1. (a) Eddy motion model of the general system; (b) The meridian field of the yoyo model; (c) The typical trajectory of how matters return

Specifically, on the works of Wu and Lin (2002), Lin Y (1988) and Lin et al (1990), the concepts of inputs, outputs and converging and diverging eddy motions are coined together in the model (Figure 1) for every system of concern. That is, each system is a multi-dimensional entity that spins about its axis with Figure 1(a) being the specific case in our 3-dimensional space, where some of the outputs return to the system as inputs (Figure 1(b)).

This systemic model implies that each organizational entity, be it tangible or intangible, can all be seen theoretically as a realization of a multi-dimensional spinning yoyo with an eddy field, which spins perpendicular to the axis, and a meridian field, which revolve parallel to the axis. The fields stay in constant motion (Figure 1(a)). When the motion stops, the entity will no longer exist as an identifiable system. Figure 1(c) shows that the interaction between the eddy and meridian fields makes all the returning outputs travel along a spiral trajectory.

COMPETITIVE INVITATION OF THE MARKET

To describe the dynamics of market competition, assume that an oligopoly market is occupied by *m* firms, *m* = 1, 2, … They provide consumers with mutually substitutable products, and enjoy their respective shares of loyal consumers who purchase only from their firms as long as the price is not more than their reservation price 1. To potentially increase their consumer bases, these incumbent firms compete over the switchers with adjustable prices charged to their customers. Assume that these firms produce their products at constant marginal costs, which are set to zero without loss of generality, and that the managements of these *m* firms are well aware of each other's pricing strategies and have established their best responses by playing the Nash equilibrium through pure self-analyses.

Appearance of New Competition

For this oligopoly market, we have the following result regarding when the market actually invites new competition.

Theorem 1. In the Nash equilibrium, an if-and-only-if condition for one firm to enter the market profitably, as a competitor of the incumbents, is that the magnitude of market segment of switchers is greater than zero.

Because the entrant does not have any royal consumer in the particular product market, it is natural for it to uniformly randomizes its price P over the interval [0,1] as long as the firm could make profits on the average. Here, the constant marginal costs of this entrant are set to zero without loss of generality. And intuitively, the market is a systemic yoyo field. If seen from

above either the input side or the output side, the yoyo body in our 3-dimensional space is a pool of spinning media of all kinds, such as goods, information, money, credit, etc., that appear and exist in business activities (Figure 2).

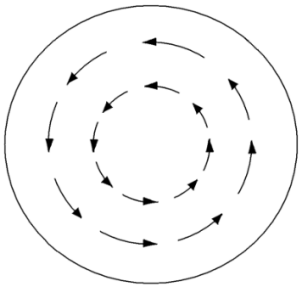


Figure 2. A systemic view of the marketplace

Now the dishpan experiment (Hide, 1953; Fultz, et al., 1959) indicates that when the movement of the media within the systemic pool in Figure 2 is under enough pressure created by either a sufficient speed of rotation or sufficient difference in the temperature between the center and the periphery of the dish, the uniform movement in Figure 2 will become chaotic, in Figure 3. So, it means that the media within this spinning dish has to be disturbed either orderly or chaotically. That is, local patterns of flow appear inevitably.

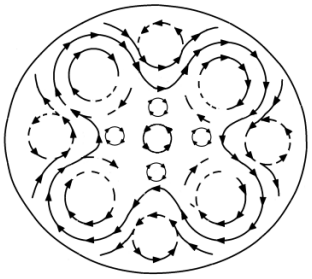


Figure 3. Asymmetric flow observed in Fultz's dishpan experiment

Practically Theorem 1 implies that with demand supplier(s) will appear to fill the market need. The following result shows how the base of loyal customers can deteriorate with intensifying competition and explains why in the current globalizing economy the market landscape changes faster and customers become less patient than before.

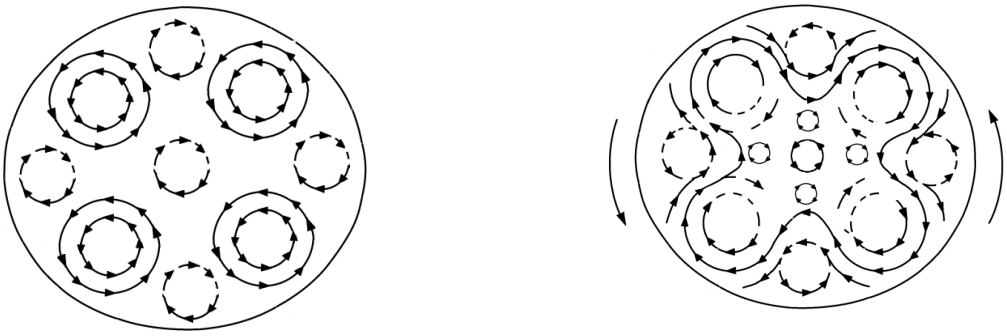
Theorem 2. In the Nash equilibrium, when the market grows with an increasing number of incumbent firms, the base of loyal customers for each of these firms will diminish.

All the detailed proofs of Theorems 1 and 2 are omitted to limit the length of this paper.

How is a Market Formed over Time?

Based on the systemic yoyo model, initially family-based workshops (the small eddies in Figure 4(a)) gradually evolve into a sizable market (the overall dish in Figure 4(b)). At the beginning, no regional commerce existed or the scale was ignorably small, so the overall circular dish in Figure 4(a) does not spin. With development of transportation and communication, the region becomes connected through transfers of goods and information, the originally unrelated small shops become connected, Figure 4(b), where the spin of the dish models the fact that goods

and knowledge are now travelling across the region and the original shops, the local eddies, are also serving the entire market. The greatly increased market demands motivate the originally small shops to evolve into large factories employing advanced technologies. In the meantime, the greatly increased supplies of goods and services spoil customers, making them pickier than before.



(a) Small related local shops (b) A formed market

Figure 4. Initial market development

SELF-SUSTAINING MOMENTUM OF ECONOMIC GROWTH IN DEVELOPING NATIONS

This section looks at how to cultivate a desired self-sustaining momentum of economic growth in an impoverished developing nation. For the convenience of communication, let us first characterize the developing nation: It is assumed to be autarkic and unorganized without any of the symbols of a modern society, such as factories, cars, highways, shopping malls, etc. After having bought food, people have almost nothing left for their wants. See (Cipolla, 1994, p. 25-26) for a vivid description of the preindustrial Europe.

Peasants are tied to the land and have to spend long hours daily on the land to maintain their subsistent livings. Natural disasters generally cause great losses to the land and people. Because land size and population size under control signify power and wealth, rulers use all means to gain the monopoly power to expropriate others (Ebrey, 1999). In such a nation, family is the basic unit of the society and has to produce everything for daily lives. It is risky for any family to specialize in producing just one type of household good and to depend on different sources for other necessities (Smith, 1776, Chapter III).

Merchants, as a class, are treated negatively; the nation, as a whole, suffers from political instability and social trust. So, the transaction cost of contracting is prohibitive high because of the lack of a legal system, making it hard or even impossible to put together large tracts of land, to ensure reliable supply of materials and related supports, and to get created products into the market. Without a unified domestic market and a well-organized commercial network in the international market, the few existing small proto-industries cannot grow to the critical level and density of the so-called proto-industrialization (Kriedte, et al., 1977). The government is absent in the formation of large regional and national markets, which makes the costs of social coordination impossible to overcome. That is, this nation does not have unified domestic markets for the exchange of goods, labor, and finance.

The socio-economic situation of this nation can be well modeled as a static dish with many local, isolated eddy pools representing the unrelated small workshops, Figure 4(a), that provide for their respective families without much exchange with the outside world. When the nation is trapped in the Malthusian poverty equilibrium, its yoyo structure stays forever in the same pattern as in Figure 4(a).

To the developing nation, acquiring a self-sustaining momentum of economic growth represents a process that not only changes the mode of production at all different levels, but is also an endeavor of nation development and strengthening. The process represents a huge systemic project that requires large-scale coordination among all social classes and interest groups, mobilizes all citizens, and utilizes resources in ways never seen before. If successful, it creates economic prosperity, organizational consolidation, and projecting capacity of influences.

Since the Industrial Revolution of England in the late 18th century, scholars have tried to uncover the exact causes underneath the dramatic social-economic changes in order to help developing nations to kick-start their own self-sustaining momentum of economic growth (Hartwell, 2017; Gerschenkron, 1962). However, all of these studies suffer from major weaknesses, such as the lack of relevant data (Fleischman & Parker, 2017), suggestions that are not practically operational (Lipson, 1949), the constraint of linear thinking (Soros, 2003), and the missing of holistic thinking (Hartwell, 2017). So, contrary to what is done in the literature, this paper utilizes the results established in the previous section and in (Lin & Forrest, 2011) to clarify what the key elements are in successfully producing self-sustaining momentum of economic growth in the impoverished developing nation. Based on the literature and what has be established earlier, we provide the following list of key elements for the developing nation to have in order for it to produce the desired self-sustaining momentum.

Element 1: Establish an unwavering national goal to become wealthy and powerful;
Element 2: Constantly aim at raising the basic standards of living;
Element 3: Purposefully support the fermentation of markets;
Element 4: Stimulate the development of primary target industries; and
Element 5: Always look at the next stage of momentum building.

An Unwavering National Goal

Similar to the management of large corporations (McGrath, 2013), an unwavering long-term development goal and related strategies are absolutely needed for the developing nation to produce its self-sustaining momentum of economic growth. In fact, powerful nations throughout history have always purposefully reshaped the world. By studying the history, Kyrkilis and Simeon (2015) and Wen (2016) recognize that not having any long-term national goal of economic development is a recipe for failure; and the lack of such a national goal generally means that the nation is unable to muster the support of its capable citizens to organize the population through creating jobs, maintaining social order, and political stability. Consequently, the government officers of different levels would most likely become problem solvers busy with urgent crises one after another without any vision on the long-term development. In short, only a focused, strong government could possibly ensure political stability and social order of the nation and defend its interests (Stein & Arnold, 2010).

When the developing nation is modelled as the dishpan in Figure 4(a) or Figure 4(b), the population is naturally distributed over the entire dishpan with some individuals located within a local pool while some others along the periphery. That implies that in making a long-term development goal, equality and prosperity for the population cannot be achieved simultaneously. So, to entice the entire population to participate, wealth creation (or the local eddies in Figure 4) has to be the priority. And because the local pools in Figure 4 is created by distribution unevenness of the ‘fluid’ within the dishpan, this model implies that for the developing nation to produce its self-sustained momentum of economic growth it has to naturally develop market exchanges with the support of central planning. The central planning is reflected as the spinning speed of the dishpan. The systemic mechanism that is in the play is that the formation of market exchange and central planning interact with each other as a feedback system, Figure 5.

Strategy 1 in the systemic model is market exchange and Strategy 2 the central planning, or vice versa. The feedback mechanism helps the economy to produce the desirable output.

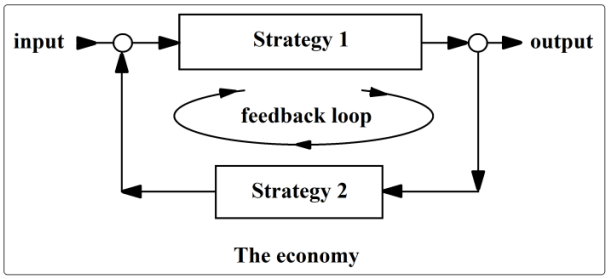


Figure 5. How a feedback system works to produce desired outcomes

Constantly Aim at Raising the Basic Standards of Living

In Figure 4 with the formation of the market 'fluid particles' have to be relocated in the strengthening spin of the local pools. This fact implies that the important first step in producing the desired self-sustaining momentum is to free up labors from the land by increasing the supply of crops. To maintain political stability and fight against foreign aggressions, the increased supply of crops should be materialized through domestic production, which can generally be accomplished through policies and technologies. The former is a consequence of central planning. For example, Crespi et al (2016) show how tax policies impact firm level investments. And the latter reflect how market exchanges play their roles. As for technologies, they have to be introduced at levels appropriate to the quality of the labors in order to produce tangible benefits. In summary, the agricultural output has to be increased so that a large proportion of the available labor can participate in industrial and commercial activities without jeopardizing the secure supply of food.

With central planning, the infrastructure necessary for producing the desired self-sustaining momentum, such as irrigation systems, road networks, and power grids, will be constructed and maintained. It is because all of these projects need to be organized, coordinated, and financially supported by various levels of the government.

The reason why the flow pattern in Figure 4(a) evolves into that of Figure 4(b) is because of the increasing difference in the forces acting on the 'fluid's' particles located along the periphery and at the center of the dish. That means that when a financial system appears across the land, the national economy emerges and local firms beyond the boundary of family are formed, where money is appropriately seen as the 'fluid' in the 'dish' of the economy. To maintain the difference between the periphery and the center of the dish increasing in order to eventually reach the state in Figure 4(b), the government needs to encourage commerce and merchant activities and when necessary to directly participate in them. Such determined efforts of the government based on unified beliefs and promoted values will mobilize the population so that primitive firms will evolve into a large-scale rural industrialization, leading to the formation of unified domestic markets of light consumer/industrial goods and labors. Now, Theorem 1 implies that with the purchasing power of the population increasing and responding to the growing market demand, firms will automatically emerge due to the spirits of entrepreneurs; and with accelerating exchange speed of money and goods, local, then regional markets will appear, followed by the formation of national markets

What the attempt of constantly aiming at raising the basic standards of living accomplishes is to establish a tight association between the government and its people, as shown in Figure 6 where the government is modeled by the axis of spin and the population the

layers of the spinning field. The government (the axis of spin) exists because of and for the people (the spinning field). By connecting the people through creating domestic markets (the meridian field that holds the eddy fields together), the yoyo structure of the nation becomes more solidified than before.

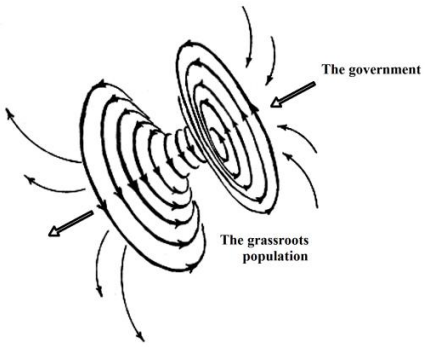


Figure 6. By connecting the people, the nation becomes more solidified

Purposefully Support the Fermentation of Markets

When the dish in Figure 4(a) spins faster, the earlier unrelated local pools will become connected and start to interact, Figure 4(b). That is, with beliefs unified, labors of individual families are organized into teams so that coordinated production becomes possible, the local pools in Figure 4(b). That is, the initially isolated eddies in Figure 4(a) are growing through the leadership of local governments so that the prohibitive transaction costs of contracting in the developing society can be practically overcome. Although the developing nation does not have a powerful class of merchants to play the role of market creators, the fact that the spin of the dishpan in Figure 4 affects the entire dish implies that local government officials, serving as public “merchants”, can fill into this missing link. These officials help create local, regional, national, and international markets for local businesses through supporting village firms in whatever means necessary. In short, all levels of the government, under the national mission, facilitate the creation and expansion of firms and the creation of markets.

With the spin in Figure 4 accelerating, the earlier stagnant and isolated local eddies (Figure 4(a)) grow larger and become connected. That is, with the combined effect of the population’s desire to improve quality of life and the government officials’ mandate to develop their local economies, rural industries flourish and the nation will soon experience rapid proto-industrialization and economic takeoff.

In summary, our systemic modeling and Theorems 1 and 2 imply that to successfully develop the market, the key includes: a national push for a mercantilism ideology; government’s participation in the effort of proto-industrialization; encouragement and protection of commercial activities; transformation of autarkic peasants into cooperation-based manufacturing and industrial organizations; and creation of high purchasing power for the grassroots population. And market fermentation is important because it simultaneously evolves with mass production, which in turn helps the developing economy to transit into a more advanced stage.

In theory, what purposefully supporting the fermentation of markets does is to strengthen the meridian flows – sufficient purchasing power – of the yoyo field - the nation (Figures 1(b) and 6) – that help speed up the spin intensity of the yoyo body. When a market of goods appears, firm(s) will surface to meet the demand, making the competition of the market more intensified, as implied by Theorem 1.

Stimulate the Development of Primary Target Industries

The evolution of the local eddies from what is shown in Figure 4(a) to those in Figure 4(b) models the deepening rural industrialization and an expanding market of manufactured goods and services. With the increase of households' incomes and that of the purchasing power of market, profit-driven activities are invited and encouraged. That transforms part-time peasant workers into full-time workers, and scattered local firms into factories. That is when large-scale mass production, mass distribution, and mass exchange emerge with the competition for market shares. As the market depth of manufactured goods, the purchasing power of the market players, and the mastery of skills of the converted peasant-workers improve over time, triggered will be a dramatic transition from an economy of family-based, autarkic, agrarian production to one that is factory-based industrial mass production. To make the transition successful, there is a need for parties to focus on several primary target industries and a class of light industrial goods, which are income elastic and do not initially require much capital input and know-hows.

Among all imaginable products, food, cloth, and shelter are the most basic for survival. Comparing the productions of these three necessities of life, spinning and weaving are the one that is not constrained by weather, season, and daylight. And the textile market is the largest and most income-elastic when compared to other light consumer goods, such as jewelry, pottery, furniture, etc., as Deane (1979, p.66) puts: "(Cotton textile) was cheap enough to come within the budget of the lowest income groups and fine enough to be desired by rich as well as poor; it was salable in tropical as well as in temperate climates; …" Therefore, this market can grow rapidly, support easily mass production and stimulate innovation under competition. In other words, the textile and clothing industry should be one of the nation's primary target-industries for promotion.

Similar to what is analyzed above, other target industries should also possess the following characteristic: The production can be separated into intermediate stages, each of which can be entertained by workers without much training. When those production stages that require mechanical motion are identified, they will then be replaced by machines operated by natural power. As a domino effect, one particularly mechanized production stage naturally creates demand for mechanization of other stages in order to keep the demand/supply of intermediate-stage goods stay in synch. That is actually how the entire production becomes mechanized.

To summarize, what the development of primary target industries accomplishes includes: 1) The government coordinates the expansion of small firms and the development of market of manufactured goods; 2) the mechanization of production and functionality of markets stimulate each other; 3) new varieties of the existing goods, new consumer goods, intermediate goods, and even raw materials are discovered and invented (Theorem 2); and 4) if the domestic market does not have enough magnitude, the developing nation will have to rely more heavily on the international market.

Always Look at the Next Stage of Momentum Building

When its capacity to mass-produce goods reaches a threshold level, the developing nation's markets, both domestic and foreign, should have been developed immensely. Now the following law on the state of motion will come into play.

First Law on State of Motion (Lin, 2009): Each imaginable and existing entity in the universe is a spinning yoyo of a certain dimension. Located on the outskirt of the yoyo is a spin field. Without being affected by another yoyo structure, each particle in the said entity's yoyo structure continues its movement in its orbital state of motion.

This law implies that the growth momentum of the manufacturing sector and the market of the developing nation will continue. That in turn will make the mass production of modern goods immensely profitable. In other words, a wide-ranging economic boom, driven by the growth momentum, will spill over to many different sectors of development, which is the so-called moment of economic *takeoff* (Rostow, 1960).

CONCLUSION

If we model the developing nation's government as the axis of spin and the grassroots population as the yoyo field in Figure 6, then we can see that both of them coexist such that the former is a reflection of the latter. That is, the government is determined by the grassroots population; if the government sees the need for the population to evolve in a particular way, then the government has to first mobilize the population so that they can evolve simultaneously.

Specifically, this paper shows theoretically that after forming a primitive market, competition will naturally intensify; and the intensifying competition will encourages innovation in production and expansion of the market. That will help develop the desired momentum of self-sustained economic development. Implicitly, this paper shows that the eventually successful development of the desired momentum of economic growth needs to be started in the rural area with the grassroots population, where humble, labor-intensive, and low-value-added products are produced to meet the needs of the grassroots populace (Mendels, 1972), while a large market that can absorb the massively produced goods emerges.

Because the successful develop of the desired momentum of economic development comes as a consequence of coordinated efforts of many participants and of synchronized allocation of resources, the government has to be in the play actively. The government needs to support a mercantilist ideology, employ its administrative power, upkeep the creation and maintenance of markets, and build infrastructure (Ashton, 1970).

Other than its theoretical results, this paper also contributes to the literature with its new methodology, based on a particular way for researchers to utilize their intuition, followed by rigorous reasoning. Because of this, this new methodology is expected to be widely useful in the study of historical economic events, where Hartwell (1965) had realized the deficit in language-based expositions.

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Knowledge and Access to Information on Hypertension among Urban Poor in Resource Constraint Settings: A Grounded Theory Approach

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ABSTRACT

Hypertension is a serious health problem globally. Hypertension information program for individual decision is critical to sustainable health. Unfortunately, few studies exist on hypertension information among vulnerable urban poor in developing countries. This study adopted interpretative paradigm and grounded theory methodology to answer two questions: what are the knowledge of hypertension among urban poor? And, how urban poor access hypertension information?. Inductive analytical processes of open coding, axial coding and selective coding was employed to analyze data. Findings suggest that knowledge of hypertension among urban poor conflicted with orthodox medical knowledge and they access hypertension information informally via strong ties

KEYWORDS: Health Information, Access to Health Information, Hypertension, Health Epistemology, Health Ontology

INTRODUCTION

Globally, cardiovascular diseases accounts for approximately 17 million deaths annually, out of which 9.4 million cases resulted from complications of hypertension. Hypertension is responsible for at least 45% of deaths due to heart diseases and 51% of deaths resulting from stroke (WHO, 2013). Hypertension is one of the major causes of premature deaths worldwide and the figure appears not slowing down. For instance, it is estimated that by 2025 there will be1.56 billion adults living with high blood pressure (WHO, 2013), and Africans are more genetically predisposed to developing high blood pressure (Adebayo, 2013).

Hypertension is a global health concern as 1.13 billion suffer from hypertension (Cable News Network, 2016). Hypertension information and communication programs has been developed and implemented in several countries with the objectives of educating communal members about the dangers of hypertension (Pan American Health Organization and World Health Organization, 2017). While there are abundance of studies on hypertension in developing regions (Feng, Pang and Beard, 2014), most of these studies are not focused on knowledge of hypertension and how individuals access information on hypertension in context and situations. Specifically, very little is known about what urban poor know about hypertension and how they access information on hypertension. To save life and reduce the adverse consequences of hypertension there is the critical need to uncover the knowledge of hypertension among urban poor and how urban poor in resource constrain setting of

Africa access information to answer their concerns, worries, and questions about hypertension. This study is significant to public health officials for designing evidence based hypertension information, education, and awareness program.

The Problem Focus and Significance of the Study

Africa has the highest prevalence of hypertension estimated at 46% of adults aged 25 and above, there were approximately 80 million adults with hypertension in sub-Saharan Africa in 2000 and projections based on current epidemiological data suggest that this figure will rise to 150 million by 2025 (WHL, 2014).
In Africa, low-socioeconomic persons are more susceptible to illnesses, including hypertension and cardiovascular diseases (Wilson, Kliewer, Plybon, and Sica, 2016, Kurtzleben, 2012, Adebisi and Somali, 2013, Cable News Network, 2016). In particular, hypertension is very prevalent in Africa compared to Europe and USA (AU, 2013). The high prevalence of hypertension in Africa is a source of worry. To reduce hypertension and the risk associated with it among the urban poor, early diagnosis is very important.

Early diagnosis of hypertension is associated with improved long-term survival (Lau, Hubert and David 2015). In the same vein studies indicate that though there is no cure for hypertension, but it can be effectively managed for life when the patient is diagnosed earlier. Unfortunately, despite the importance of early diagnosis in preventing and controlling the prevalence of hypertension the number of urban poor living with high blood pressure is scary. For instance, in Nigeria about 57 million suffer from hypertension (Gachomo, 2013). Of the 57 million diagnosed with hypertension only one percent knew that they had high blood pressure. There is therefore the compelling need to investigate the knowledge of hypertension among urban poor in Nigeria. To help reduce the adverse consequences of hypertension this study investigates the knowledge of hypertension among urban poor and how urban poor access information on hypertension.
This study is significant because a grounded theory methodology and method (Glaser and Strauss, 1967) was adopted to answer questions related to knowledge of hypertension among urban poor and how urban poor in resource constrain setting access information on hypertension, In line with grounded theory approach (Glaser and Strauss, 1967) findings of the study were translated into 2 conceptual models—one depicting the knowledge of hypertension among the urban poor and the other depicting a conceptual model of how urban poor access information on hypertension. The two conceptual models offer scholarly insights of hypertension in the context of urban poor case study of a developing country. The models is potentially useful for public health policy makers and public health information and communication practitioners in designing evidence-based hypertension information and communication programs that are suitable to urban poor in resource constrain settings. More so, findings of the study can spur interest among global and public health policy makers to conduct further empirical inquiries about knowledge of hypertension among urban poor in developing regions of Africa, Asia, and Latin America

LITERATURE REVIEW

This study is about knowledge and access to information on hypertension. Conceptually knowledge is rooted within the scholarly content area of epistemology and ontology. Ontology refers to the study of the existence, nature, or being of a certain entity. It also refers to philosophy of reality (Khushf, 2016). Epistemology on the other hand refers to the body of philosophy that involves the study of knowledge (Maraqah, 2014). It addresses how people know and how people know what they know (Kruss, 2005). Accordingly, health

ontology and health epistemology refers to people's knowledge, attitudes and associated behaviors which pertain to diseases, illnesses, and their prevention, and treatment (Encyclopedia of Medical Concept, 2012). Health ontology and health epistemology are related to epistemological beliefs (Bientzle, Cress and Kimmerle 2014).

Epistemological beliefs are the cognitions (i.e., understandings) individuals have on knowledge and knowing and how (new) knowledge is perceived and processed *(*Bientzle, et al. 2014). Studies indicate that people's epistemological beliefs influence how they deal with health knowledge *(*Bientzle, et al. 2014).

Epistemological beliefs represent important concept for investigating health information behaviours, specifically, the concepts can be used by scholars to uncover individual knowledge about diseases and how individuals in specific contexts access information on disease and illnesses. This is critical because (Spancer, Phillips and Ogedegbe, 2005) states that people whose ontological and epistemological beliefs are discordant with traditional biomedical concepts of hypertension have poor blood pressure control than those whose beliefs are concordant with the biomedical paradigm. Closely related to health epistemology and health ontology is the notion of information, health information, and access to health information.

Information

Information was discussed and characterized by Buckland, (1991) he characterized information as process, as knowledge and as thin, as a process when it perform the function of informing, which involve transmitting information from a source to a recipient, information as a knowledge when it perform the function of imparting knowledge to an individual, and information as a thin when it is tangible. Likewise, Feynman (2006) noted that "Information is not simply a physical property of a message: it is a property of the message and your knowledge about it." In essence, Rubin (as cited in Aina 2004) states that information is process data from which meaning arises and it is communicated.

Health Information

Health information denotes quality information about physical, metal and social wellbeing (WHO, 2017). They further explained that health information is a national asset that can be used by policy-makers, planners, health care providers, development partners and the general public to track health-system performance, to support better health policies and make effective health- related decisions. In other words, the goal of health information is to contribute to attaining universal coverage of quality services for improved health outcomes through improved access and utilization of health information.

Access to Health Information

Access to health information is the ability of a person to access published and unpublished knowledge on all aspects of health and healthcare (Edewor, 2010). In essence, access to health information is a crucial factor to healthy life and critical to many facets of health care design and delivery Okwilagwe (as cited in Edewor, 2010). Also, Klinedinst, (2012) stated that access to reliable health information is potentially the single most cost-effective and achievable strategy for sustainable improvement in health care. Furthermore, (Health Information Exchange, 2013) itemized the benefit of access to health information as improve health care quality and patient outcomes by reducing medication and medical errors, reduce unnecessary tests and services and improve the efficiency of care by ensuring everyone involved in a patient's care has access to the same information, access

to health information reduce administrative costs by making many administrative tasks simpler and more efficient, it increase patient involvement in their own health care and reduce the amount of time patients spend filling out paperwork and briefing providers on their medical histories, and access to health information coordinate with and support public health officials to improve the health of your community.

Previous Studies: Health Information, Knowledge, and Access to Health Information

Several empirical inquiries were undertaken to determine health information, knowledge, and access to health information. For instance, Chang (2013) conducts a study to explore patient's perception and knowledge regarding hypertension and hypertensive guidelines on sodium intake and lifestyle modification in a work environment in the republic of Panama. Health Beliefs Model was use as a theoretical frame work for the study. The study research questions sought to uncover patient's perception of being hypertensive, knowledge about the hypertensive guidelines, patient perceived barriers to follow lifestyle modification, patient's perceptions and knowledge regarding sodium intake, and perceived barriers to follow sodium intake recommendation. This qualitative study used an exploratory approach and semi structured in depth interviews to answer the research question. Emerging themes illustrated that participant's perspectives of hypertension had become their drives towards the management of their disease and through their daily lives constant different factors played the role of motivation or discouraging their non pharmacological treatment. Participants had also given a list of barriers and coping strategies in order for them to keep their disease management.

In another similar study, Guatam (2012), studied the health knowledge and health beliefs about cardiovascular disease among students. The study sought to determine the risk of developing cardio vascular disease (CVD) in the population and to assess correlation between knowledge, health beliefs, and personal risks. Five questions were asked in the research which sought to uncover the overall levels of knowledge and health beliefs about CVD, the relationships between knowledge, knowledge subtypes, and health belief about CVD, the personal risks of developing CVD, personal variables that predicts CVD, and personal variable that predicts CVD individual health beliefs. The Health Belief Model provided the theoretical framework for this study. Findings revealed that knowledge about cardiovascular disease was low among the study participants, and that perceived susceptibility, severity, and barriers regarding CVD were low.

A study by Robinson (2012) examines the relationships between hypertension (HTN) management behaviors and beliefs about HTN among a sample of African American Adults who self report having a diagnosis of HTN, by applying the constructs of the Health Belief Model. Two questions were asked in the research which sought to uncover significant differences in HTN management behavior among African American and combination of the independent variables that will account for the most variability in self reported HTN management behaviors among African Americans. One hundred and sixty nine African American adult residents from four public housing apartment building in inner-city Cleveland, Ohio, completed a 46- item questionnaire. Multiple regression and one-way ANOVA with Turkey's HSD criterion analysis were used. Findings revealed that hypertension management behavior among participants between age fifty one to seventy were significantly higher than that of participant less than fifty years, and HTN management behavior of those who were diagnosed more than five years ago where significantly higher than those who were diagnosed less than one year ago. Finding also revealed that the best combination variables accounting for the most variability in self reported HTN management behaviors as perceived barriers, age and self efficacy.

Wheeler (2011), undertakes a study to examining the knowledge and perceptions of

zoonotic disease risk and information-seeking behavior amongst small and mixed animal owners in the inter Mountain West. Health Beliefs Model (HBM) Serve as a theoretical frame work for the study. The study contains the following research questions 1. Which of the HBM constructs effectively predict the adoption of prophylactic behavior? 2. Do the HBM constructs found to predict the adoption of prophylactic behaviors in this study follow the pattern found in previous preventive health behavior studies using this model? 3. Is knowledge of MRSA and Salmonella associated with greater compliance with prophylactic behaviors? 4. Are veterinary health care professionals the preferred source for clients seeking information about health risks related to zoonotic disease? 5. Does a difference in risk perception and protective behavior exist between mixed animal owner and small animal owners? 6. Does a difference in information seeking behavior exist between mixed animal owners and small animal owners? 7. Do demographic trends in this study population reflect trend in the general population? 8. Are the information seeking behaviors found to be most prominent among the study population reflective of trends in the general population?. One thousand names were randomly selected from the client lists of the James L. Voss Veterinary Teaching Hospital at Colorado State University. Four hundred participants responded to a mailed. Descriptive analysis was used for this study. Findings revealed that, adopting protective behavior is best achieved by perceiving greater benefits to adopting the recommended behavior, perceiving fewer barriers, and receiving more cures to action. Results also found differences between small and mixed animal owners in several area of enquiry, including knowledge of disease, perception of risk, perception of cues to action and information seeking behaviors.

Summary of the Review

The literature review discusses health ontology and health epistemology, access to hypertension information, and previous studies on knowledge were reviewed. The objectives of their studies, the methodology they used and their findings in respect to the theory were highlighted

In spite of the many researches already carried out in a variety of fields especially on knowledge, awareness, and perceptions, to the best of my knowledge there is lack of data specific on knowledge of hypertension among urban poor in Zaria when this current study is being conceptualize. Factors affecting diagnosis behavior are unique to individuals and are context specific, and therefore, studies done in other countries may not apply to circumstance surrounding Zaria metropolis.

METHODS

Research paradigms are based on varying philosophical foundations and conceptions of reality, each paradigm, in turn is implemented by associated methodological approaches and strategies Lincoln and Guba (as cited in Villiers, 2005). This study adopts interpretive paradigm, interpretivist beliefs human thoughts and behavior are shaped by the meanings attributed to it within a particular culture, at a given moment in time (Dilthey, 2010). Therefore, this study uses qualitative approach to answer the following research questions:

RQ1. What are the knowledge of hypertension among urban poor in Zaria? To answer this question, the researchers asked the following sub questions

a. Please share with me your knowledge on causes of hypertension?
b. Share with me your knowledge on prevention of hypertension?
c. What types of symptoms can make a person believe he/she has high blood pressure at the moment?
d. Kindly share with me your knowledge about people who are likely to have

hypertension?
RQ2. How does the urban poor access information on hypertension? To answer this question the researchers asked this sub question
a. How do you come across the information you share with me on hypertension?
The questions above were asked in order obtain a naturalistic depiction of urban poor knowledge and access to information on hypertension using Grounded Theory methodology.

GROUNDED THEORY APPROACH

The Grounded Theory approach was first developed by Barney Glaser and Anselm Strauss in their 1967 book title The Discovery of Grounded theory, one of the goals of the book was to provide legitimate approach for undertaking qualitative research (Johnson, 2008). Grounded theory is an approach for developing theory that is "grounded in data systematically gathered and analyzed' (Strauss & Corbin, 1994)
In essence, Grounded theory is a research method that will enable you to develop a theory which offers and explanation about the main concern of the population of your substantive area and how that concern is resolve or processed (Scott, 2009). Furthermore, Glaser (1978) states Grounded theory is use to 'get though and beyond conjecture and preconception to exactly the underlying processes of what is going on, so that professionals can intervene with confidence to help resolve the participant's main concerns'. Crooks (2001) explained further that Grounded theory is Ideal for exploring integral social relationships and the behaviour of groups where there has been little exploration of the contextual factors that affect individual's lives. Hence, this study explored knowledge and access to information on hypertension among the urban poor in Zaria in order to come up with construct that can be use by hypertension information professional to design hypertension information program for the urban poor in Zaria.

Scope of the Study

This research focused on knowledge and access to information on hypertension among the urban poor in Zaria. The participants are mainly the urban poor living on or below average poverty line for developing countries ($2) two dollars a day (World Bank, 2015) and reside in Zaria metropolis.

Selection Criteria and Study Area

Eligible study participants met the following criteria: The urban poor living on or below average poverty line for developing countries, ($2) two dollars per day (World Bank, 2015). And must reside in Zaria, **Exclusion criteria include the following**; Resident of Zaria living above average poverty line for developing countries, ($2) two dollars per day (World Bank, 2015). Zaria is a major city in Kaduna State, north west Nigeria, as well as a Local Government Area formerly known as Zazzau, Zaria is located about 75km north of Kaduna, the state capital. Zaria was one of the seven Hausa city states. The 2006 Census population was 408,198 (Bugaje, Yakubu and Ogala, 2008)

Sample

Study participants were recruited using an exponential non-discriminative snowball sampling technique. A snowball sample is a non-probability sampling technique that is appropriate to use in research when the members of a population are difficult to locate.

(Crossman, 2015). Snow ball sample technique is use for this study because most Nigerians usually do not disclose their earning.

Data Collection

A semi-structured, open-ended interview questions to elicit narrative responses from participants was used. This choice is based on the following considerations: 1. The semi-structured design gives the participants ample time and scope to express their diverse views and allows the researcher to react to and follow up on emerging ideas and unfolding events (Nohl, 2009). 2. Semi-structured interviews allow not only for assessing the participants opinions, statement and convictions, they also allow to elicit narratives about their personal experience (Creswell, 2009)

Procedure for Data Collection

The researcher identified one Zaria urban poor with income less than two dollars per day that was willing to participate in the study, the first subject recruited to the sample group provides multiple referrals. Each new referral was explored until primary data from sufficient amount of samples are collected. Research assistant were only use as an interpreter from Hausa language to English language for two respondents. In addition to the purpose of the study and the study procedure, the following information was discussed with the participant: potential risks and benefit, cost, compensation, voluntary participation /withdrawal and confidentiality. Data are collected from participant in the following geographical location in Zaria; 2 participants from Emanto, 5 participants from Gaskiya, 7 participants from Tukurtukur, 3 participants from Congo, and 3 participants from Sabo.

Data Analysis

The researcher and professional transcriptionist was use to transcribed the interview, the transcription was done individually and collectively. The goal is to achieve naturalistic transcriptions, thematic analysis was use as the data analysis strategy to guide verbatim participant transcript. This method is recommended for a comprehensive and organized summary of qualitative descriptive research, it identifies, analyzes and reports patterns within data (Braun and Clarke, 2006)
This qualitative thematic analysis began with a thorough reading of transcripts followed by organization of their content according to each interview guide question number. In specific, the researcher followed analytic inductive process described by Creswell (2013) each of the 20 interviews was transcribed and examined back and forth between themes and the database until the researcher has established a comprehensive set of themes. The researcher use quantitative analysis to determine the frequency of occurrence and percentage of categories and sub categories.

RESULTS

The researcher conducted a thematic analysis of 20 qualitative interviews with Zaria urban poor in order to investigate and explore their knowledge about hypertension. The responses provided multiple views and insights into complex socio cultural factors relevant in understanding knowledge and access to information on hypertension among the urban poor in Zaria.
One hundred and seventy nine (179) narratives explaining knowledge of hypertension were highlighted and recorded in Microsoft word. Highlighted narratives were coded using

iterative analysis method which involves series of steps as informed by Krathwoli (cited in Musa, 2013), following these steps, the researcher read through the data looking for variance and similarities in the narratives. The descriptions of the 5 categories were presented in (See table 1), while (table 2) display 5 categories arranged by sub-categories, frequencies, and percentages of frequencies. (Table 3 & 4) presented the coding template

Table 1: Descriptions of Five Categories		
S/N	CATEGORIES	DISCRIPTIONS
RQ1	What are the knowledge of hypertension among urban poor in Zaria?	
1 2 3 4	Knowledge about Causes of Hypertension Knowledge about Hypertension Prevention Knowledge about Symptoms of Hypertension Knowledge about Who are likely to suffer from Hypertension	Comments related to knowledge of hypertension
RQ2	How does the urban poor access information on hypertension	
5	Inter subjective discourse and Reading	Comments related to hypertension information access

Table 2: Categories arranged by sub-categories, frequencies, and percentage of frequencies				
RESEARCH QUESTION	CATEGORY	SUB - CATEGORY	FREQUENCY	PERCENTAGE
	1) knowledge about cases of Hypertension	1.1) Emotional Discomfort	17	11.4864
		1.2) Stress	4	2.7023
		1.3) Poverty	3	2.0270
		1.4) Unhealthy eating behavior	8	5.4054
		1.5) others	2	1.3513
		Group Total	34	22.9729
	2) Knowledge About Hypertension Prevention	2.1) Avoid Emotional Distress	16	10.8108
		2.2) Eating Healthy	8	5.4054
		2.3) Taking Medical Measures	4	2.7023
		2.4) Others	5	3.3783
		Group Total	33	22.2972
What are the knowledge of Hypertension among urban poor in Zaria	3) Knowledge About symptoms of Hypertension	34.1) Headache	9	6.0810
		3.2) Body Temperature	5	3.3783
		3.3) Palpitation	4	2.7023
		3.4) Subconscious	4	2.7023

		3.5) Abnormal Sleep	3	0.0270
		3.6) Loss of Appetite	3	2.0270
		3.7) Swollen of some part of the Body	2	1.3513
		3.8) Others	6	4.0540
		Group Total	36	26.3243
	4) Knowledge about who are like to have Hypertension	4.1) Aged People	8	5.4054
		4.2) Poor People	4	2.7083
		4.3) Hypertension can affect any Body	5	3.3783
		4.4) Fat people	3	2.0270
		4.5 Children	2	1.3513
		4.6) Pregnant Women	3	20270
		People Experiencing Emotional Discomfort	7	4.7297
		People with unhealthy eating behavior	5	3.3783
		Others	6	4.0540
		Group Total	43	29.054
How do urban poor in Zaria Access information on Hypertension	5) Inter Subjective Discourse and Reading	5.1) inter-Subjective discourse with Informal Relations	15	62.5
		5.2) Inter-Subjective discourse with Medical Practitioner	8	30.7692
		5.3) Reading	3	11.5384
		Group Total	26	100
		Grand total	174	97.2067

The Knowledge of Hypertension among the Urban Poor in Zaria

In order to understand knowledge of hypertension among urban poor in Zaria, a series of question were asked so they could elicit their actual thoughts about hypertension. The

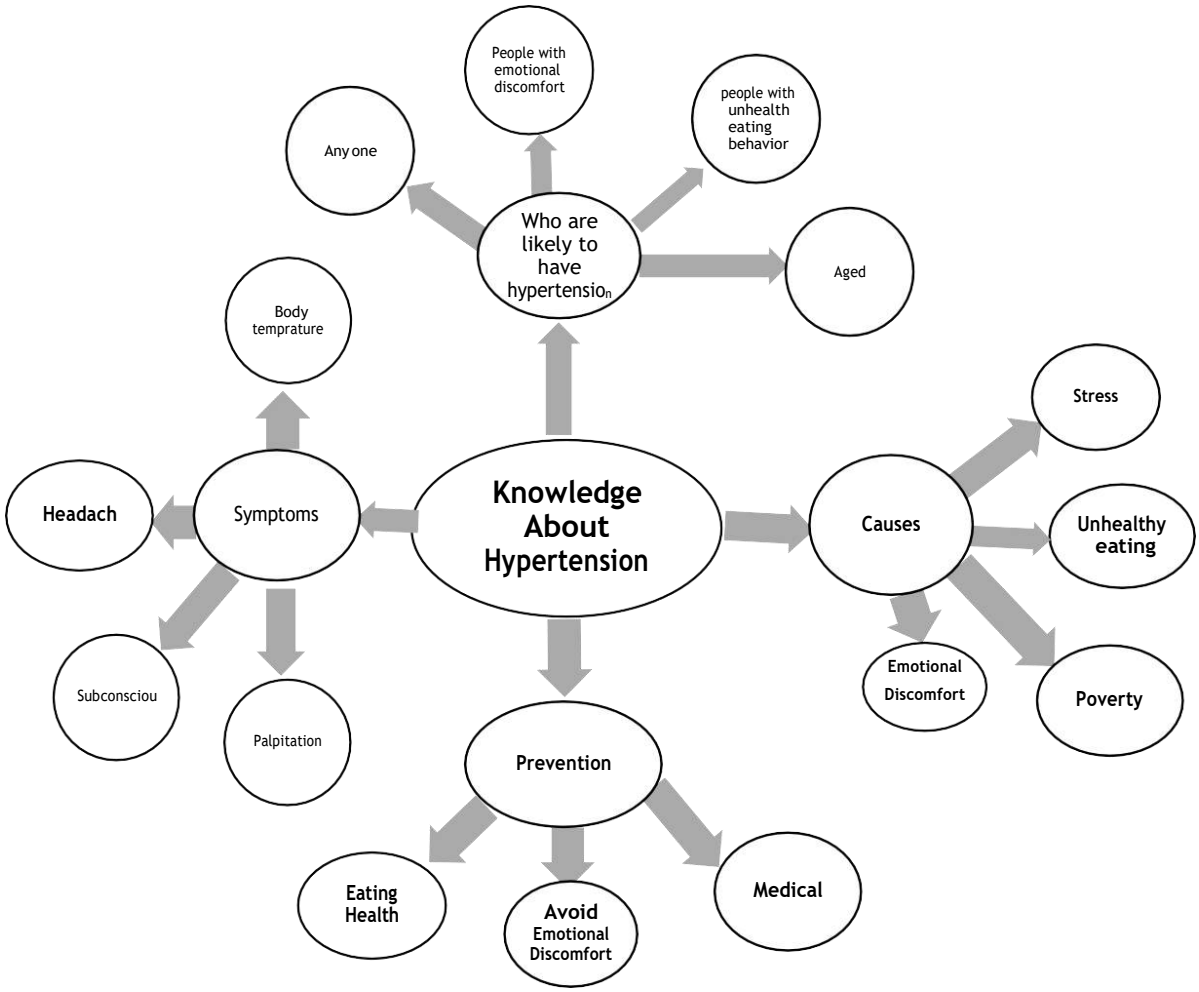
knowledge of hypertension among the urban poor in Zaria appears in four categories as follows:(1) knowledge about causes of hypertension (2) knowledge about how to prevent hypertension(3) knowledge about symptoms of hypertension and (4) knowledge about who are likely to have hypertension. (See table 3 and Illustration 1)

Table 3: Knowledge about Hypertension

RESEARCH QUESTION 1	SUB – QUESTION	SUB CATEGORY	CATEGORY
What are the knowledge of hypertension among urban poor in Zaria	Can you please share with me your knowledge on causes of hypertension	-Emotional Discomfort - Stress -Poverty -Unhealthy Eating Behavior **Others:** Infected food by cockroaches If somebody is entering sun too much	Knowledge about cases of hypertension **Others**
	Share with me your knowledge on prevention of hypertension	-Avoid Emotional Discomfort Eating Healthy Taking Medicine **Others:** -Preventing cockroaches from entering food Government intervention Avoid entering Sun too much Wash mouth every morning Sleep in a well ventilated room	Knowledge about hypertension prevention **Others**
	What types of symptoms can make a person believe he/she has high blood pressure at the moment	Headache Body temperature Palpitation Unconscious Abnormal Sleep Loss of Appetite Swollen of some part of the body **Other's** loss of energy -soliloquizing Fatness Always sweating Shivering Blood reduction	Knowledge about symptoms of hypertension **Other's**

	Kindly share with me your knowledge on who are likely to have hypertension	Aged people Poor People Hypertension can affect any body Fat people Pregnant women Rich people Children People Experiencing Emotional Discomfort People with unhealthy eating behavior **Others**: Destiny Inheritance	Knowledge about who are likely to have hypertension **Others**
		those that use to smoke People with criminal mind People that stay under sun for too long	

Illustration 1: Knowledge about Hypertension



The categories are discussed below.

Category One- Knowledge about C**auses of Hypertension** (32/148; 21.6)

This category describes narratives related to knowledge about causes of hypertension. There are four sub-categories explaining causes of hypertension as knowledge of the urban poor in Zaria, the categories are (1) emotional discomfort (17/148, 11.4%), (2) Stress (4/148 2.70%), (3) poverty (3/148 2.02%) and (4) unhealthy eating (8/148; 5.40%). These four subcategories are explained below

Emotional Discomfort

This sub-category depicted narratives related to knowledge on causes of hypertension. The researcher finds that most of the respondents have knowledge that hypertension is associated with thinking too much, worries, anger and bothering. A participant noted that "like when somebody use to think he did not use to associate with people, he sit in a different place and he will always be thinking." In another similar narrative a part states "to my own experience and opinion actually hypertension has a lot of causes, the major cause is deep thinking, sometime isolating yourself, then the second one is being angry or being in agony or being in bad relationship."

Stress

This sub-category reveals stress as knowledge of the urban poor in Zaria about the causes of hypertension, respondent notes that "What I can say, you see, for now, the kind of environment, the community we are in there are so many stress, the people living in this society face stress which means the difficulties which people are in is one of the major factor causing this hypertension." Another one observe that "too much thinking and stress in working place also cause hypertension"

Poverty

The sub-category showcases narratives related to poverty as knowledge of the urban poor regarding cause of hypertension. It reflects poor economic situation in which one finds himself, A participant noted that "family that are not well to do, poverty is one of the great factor that assist smooth running of the disease" he further explained that "a person can have wives, 11 to 20 children and he need to take care of them, their schooling, education, feeding, you see all these "ehn" all for him to cater for them, this kind of thing can probably lead to hypertension"

Unhealthy Eating

Apart from emotional discomfort, stress and poverty, the urban poor in Zaria also have knowledge that unhealthy eating is a cause of hypertension. The narratives included knowledge on what people eat and how we eat food like salt, oil, sugar, kola nut etc were mentioned by respondents. A participant stated that "I don't know if salt use to cause hypertension because if people have hypertension they use to ask them to stop eating salt." Another respondent also explain that "Our mother use to eat kola nut, the doctor advice us that we should try our best to stop her from eating too much kola nut, because it is one of the causes."

Others (2/148; 1.35%)

This explains other knowledge about causes of hypertension which are only mention by a single participant. This consists of (1) Infected food by cockroaches (1/148 0.6%). (2) staying under sun for too long (1/148 0.67%). The following narratives were noted from some of the participant "If you finish cooking you need to cover your pot if you don't cover it and cockroaches enter hypertension can catch you" "If somebody is entering sun too much can cause hypertension"

Category Two- Knowledge about Hypertension Prevention (28/148; 18.9%)

The category reflects knowledge on ways to prevent hypertension. The category consists of three sub-categories; Avoid emotional distress (16/148; 10.8%), eating healthy (8/148; 5.40%), medical (4/148; 2.70%), the three subcategories are explained below.

Avoid Emotional Distress

The urban poor in Zaria narrated that avoiding emotional distress is a major way of preventing hypertension, avoiding emotional distress include narratives on recreational activities, avoid thinking too much, exercising, avoiding loneliness and taking rest. A respondent notes that "How to prevent this hypertension is to avoid engaging in some commitment and avoid engaging with somebody that will make you angry and also make yourself to rest in one place, you just have to go far away from somebody who will make you angry." Another participant notes that
Always try to feel free, free your mind don't even try to start thinking about things that happen to you in the past. Do not have someone at heart it will not help you, always be free. Do not isolate yourself live together with people, try to bring topic for discussion and always contribute to discussion, at the same time laugh with people. Apart from this you can watch football, play football, exercise regularly, and make sure you join people to watch football. If you are alone try to read novel, books, newspaper keeping yourself busy. Are you getting me? Books, particularly if you are a Muslim you have to be reading Quran.

Eating healthy

This sub-category portrays narratives related to eating healthy as knowledge of the urban poor in Zaria about hypertension prevention, it includes narratives related what people eat. A participant mentioned that "If doctor say you should stop eating something you should stop eating it, like salt, me am not eating salt, when am going to cook food am going to put star magi I will not put salt at all, my husband is not complaining because even him is having the same problem" another respondent said "you use native oil or substitute it with oil that does not contain cholesterol like turkey oil"

Medical

This subcategory depicts narratives related to taking medicine and taking advice from medical practitioners as knowledge of the urban poor in Zaria regarding hypertension prevention. A respondent explained that "like this Moringa am holding now is a herb, we use to boil it, is a medicine of hypertension, scientist research about it, this Moringa you boil it until the water change, if you keep on boiling inside pot you observe for one to two hours of boiling, then you remove the leave one after the other you sieve the water inside cup allow the water to cool and then drink at once, later you can now eat the leave, this will help to prevent hypertension*"* another respondent also noted that "the ways I think we can reduce hypertension is to seek advice from those that are in the field, go to hospital for advice and check my blood pressure"

Others **(5/148; 3.37%)**

This explains other knowledge on prevention of hypertension which could not be discussed above because they are mention by one participant. They are (1) preventing cockroaches infection (1/148 0.6%) (2) Government intervention (1/423 0.6%), (3) avoid staying under the sun for too long (1/148; 0.67%), (4) wash your mouth every morning (1/148; 0.67%) and (5) sleeping in a well ventilated room (1/148; 0.67%). The following narratives were noted from the subcategories "cover your pot of food so that cockroaches will not enter" "You should avoid entering sun too much is not

good" "if you wake up in the morning you need to wash your mouth"
If government will create job the difficulties that most of our people who are not employed by the government will be reduced if not eradicated, income should also be increased. Government should try to provide medication for ill people, they should provide therapy that will counsel people, and you know some are illiterate. Now we are in a modern technology, we have TV, Handset, and website so you see they can use radio, TV, and the rest so that there can be a program which people can take necessary precaution.
for instance if you want to sleep find good place, a place that have ceiling fan, once you have hypertension you cannot sleep in a warm room, you understand room that does not have fan, air condition or any other thing. Once you have hypertension, you should find a good place to sleep. Let say a place that have fan, the important thing here is fan, if you don't have money to buy air condition you should buy fan.

Category three- Knowledge about Symptoms of Hypertension (31/148; 20.9%)

The category includes narratives related to knowledge on symptoms of hypertension. The category consists of seven sub-categories which include headache (9/423; 6.08%), borody temperature (5/148; 3.37%) palpitation (4/148; 2.70%), subconscious 4/143; 2.70%), abnmal sleep (3/148; 2.02%), loss of appetite (3/148; 2.02%), swollen of some part of the body (2/148; 1.35%), the subcategories are explained below

Headache

This sub-category describes narratives related to headache, most urban poor in Zaria identify headache as a symptom of hypertension. Respondent noted that "Symptoms are as follows like I told you my mother is facing the problem although is not all the time that if the problem arise I will be present, but some time she will start telling us that she is feeling headache are you getting the point, so headache is one of the symptoms of it."

Body Temperature

This subcategory portrays narrative related to body temperature as knowledge of the urban poor about symptom of hypertension. A respondent noted that "Any body that has it will be feeling heat in the morning and in the afternoon he will be catching cold" another said "most of them have high fever, your body will always be abnormal"

Palpitation

This sub-category portrays narratives related to heart beating as knowledge of the urban about symptoms of hypertension. One respondent narrated that "that time if I go hospital to complain that my heat is beating they will give me drug and it will normal, then later if am going on the road may be a car just pass I will be scare" another respondent observe that "when it become chronic some time you will be having difficulty in breathing, you will always be breathing abnormal and when it keep on like that you can easily fall down."

Subconscious

The sub-category considers narratives related to symptoms like fainting and dizziness as knowledge of the urban poor regarding blood pressure check. A respondent stated that "symptoms of the illness emm, there are many symptoms one is dizzy, that is when you are feeling like falling down because my mother is suffering from it, when we realize that she is having that we quickly take her to hospital

and the moment we got there the doctor diagnosed she is having this hypertension, we then realized is one of the symptoms of hypertension". In another narrative a respondent said "My father use to tell me that sometime when you are walking you felt dizzy."

Abnormal Sleep

This sub-category refers to narratives related to not sleeping well as knowledge of the urban poor in Zaria pertaining to symptom of hypertension. A respondent stated that "the symptom is lack of sleep even when he sleep, middle of the night he will wake up and he will no longer feel sleep" another respondent also asserted that "there are so many symptoms identified with hypertension most especially laziness, too much sleeping"

Loss of Appetite

The sub-category explains loss of appetite as knowledge of the urban poor about symptom of hypertension. It includes narratives related to having less desire for food or drink. A respondent is of the opinion that "some time you can lost appetite, and not feeling the actual taste of what your are eating"

Swelling of some Part of the Body:

Depicts narratives related to abnormal swollen part of the body as knowledge of the urban poor in Zaria pertaining to cases of hypertension. A respondent noted that "once you observe somebody, you can observe may be his leg or her leg, you find the leg swollen that is the symptom or sign of hypertension." another respondent also stated that "Swollen in neck, sometime chest, all are symptom which we can use to identify people with hypertension"

Others **(6/148; 4.05%):**

This explains other knowledge on symptoms of hypertension which could not be discussed above because they are narrated by one participant. These includes lose of energy (1/148; 0.67%), soliloquizing 1/148; 0.67%), fatness (1/148; 0.67%), always sweating (1/148; 0.67%), Shivering (1/148; 0.67%) and blood reduction (1/423; 0.67%). The following responses were noted from the subcategories "Lost of energy because you can find yourself in a situation whereby you cannot do something" "actually the first symptoms is you see a person behaving inhuman, you see a person going usually you see him talking to himself" "fat women that think too much, they can collapse suddenly" "So this symptoms, when you see a person some time is always sweating" "at time you find the person shivering also I think fever headachy and the rest" "You will feel headache, fever, no appetite, your blood will reduce small"

Category four- Knowledge about People who are likely to have hypertension (37/148; 25)

This entry reflect knowledge on who are likely to suffer from hypertension, the category explains the kind of people that are likely to be infected with hypertension. The category is divided in to eight sub-categories: (1) aged people 8/148 5.40% (2) poor people 4/148 2.70% (3) hypertension can affect any one 5/148 3.37% (4) fat people 3/148 2.02% (5) pregnant women 3/148 2.02% (6) children (2/148; 1.35%) (7) people experiencing emotional discomfort (7/148; 4.72%) (8) people with unhealthy eating behaviour (5/148; 3.37.40%). These subcategories are explained below.

Aged

According to the data many urban poor in Zaria have knowledge that elderly people are liable to hypertension, narratives in this sub-category reflects old people as a group that might likely suffer from hypertension. Respondent explained that "Most cases, in my opinion, they are not young people they are old people, the reason is that due to age, the age is already high and their commitment is much." Another respondent stated that "all those people that I have seen that are having hypertension are old people."

Poor People

Knowledge of the urban poor in Zaria portrays another group of people that might likely have hypertension as the poor people. This subcategory reveal narratives related to poor socio economic status. participant noted that "let say poor man he does not have money to feed his family he can have hypertension" In a similar response another participant explained that "poverty contribute a lot in hypertension because when somebody has family wife and children and he has to provide for them, As a result of small thinking it will continue before you know is already worst, thinking about how to pay children school fees, lack of social amenities. One of the participants also narrated that like guys now for instance, let me tell you one thing now because as I told you is thinking that cause hypertension like guy now, a person who want to buy car and has no money to buy and he put his mind that he must buy the that car, for instance I give you little example. A person doesn't have money to buy trouser shirt to make himself guy, you understand? And he does not want to steal, or beg, he doesn't have work to do and his friend living fine, put on good cloth everything nice and he does not have those things, from there he will start thinking about how to get money, that thinking can cause hypertension

Hypertension can Affect any one

Narratives from this subcategory depict that anybody can fall victim of hypertension as knowledge of the urban poor regarding who are likely to fall victim of hypertension. One participant observed that "anybody can have hypertension due to some conditions you engage yourself either you are poor or rich." Another participant also stated that "Anybody can catch the disease either you are old or young, male or female".

Fat People

The subcategory reflects knowledge about those that are likely to have hypertension as fat people. A participant narrated that "most of the times are those that are fat and those that have too much fat in the body, even slim person can have it but most are fat."

Pregnant Women

This sub-category depicts narratives related to pregnant woman as knowledge about cases of hypertension. The sub-category reveals narratives related to women most especially pregnant women as a group that might likely suffer from hypertension. A participant notes that "there is one of my sisters throughout her pregnancy she will be hypertensive till she deliver". Another participant observed that "majority of those who have hypertension are women, If you observe and research, you will find or if you go to the hospital you will find out that majority are women, for instance some pregnant women."

Children

The sub-category explains that children are also group that can suffer from hypertension as

knowledge of the urban poor. A participant said "yes, yes am sure you may know that people that are very old are common with hypertension, am sure that has to do with old age "ko" but for now most of our people now you can see small children when they get to hospital they might be diagnosed with hypertension." Another participant notes that "imagine a baby have hypertension, is a blood, anybody can have hypertension."

People Experiencing Emotional Discomfort

The sub-category shows that people experiencing emotional discomfort are liable to hypertension, it's depicts narratives related to people that think too much, people that undergo frustration and people that worry a lot. Participant narrated that "deep thinking especially when you are in agony when you keep on worrying, when you keep on thinking about things that border you"

People with Unhealthy Eating Behaviour

The sub-category presents group of people that might likely fall victim of hypertension, the sub-category include narratives related to people with unhealthy eating behaviour as knowledge of the urban poor in Zaria. It depicts narratives related to what people eat or drink like alcohol, taking kola nut, expired food taking too much salt and magi. One of the participant narrated that "there is one of our neighbor is a doctor, is a medical doctor we take our mother there he tell us that when somebody is taking hot drink, alcohols, like whiskey, he also mention kola nut because he ask our mother is she taking kola nut, and she answer yes she is taking, he also ask our mother to stop taking kola nut that it may cause hypertension to her" Another participant noted that "some time is the type of food we are eating most especially expired food, you know some have no knowledge of it, many people don't know the actual deadline of the product because they are not educated even the people selling it they don't know the expiry date of the product and they are selling it to people. This kind of product can even cause hypertension that is what the doctor said".

Others (6/148; 4.05%):

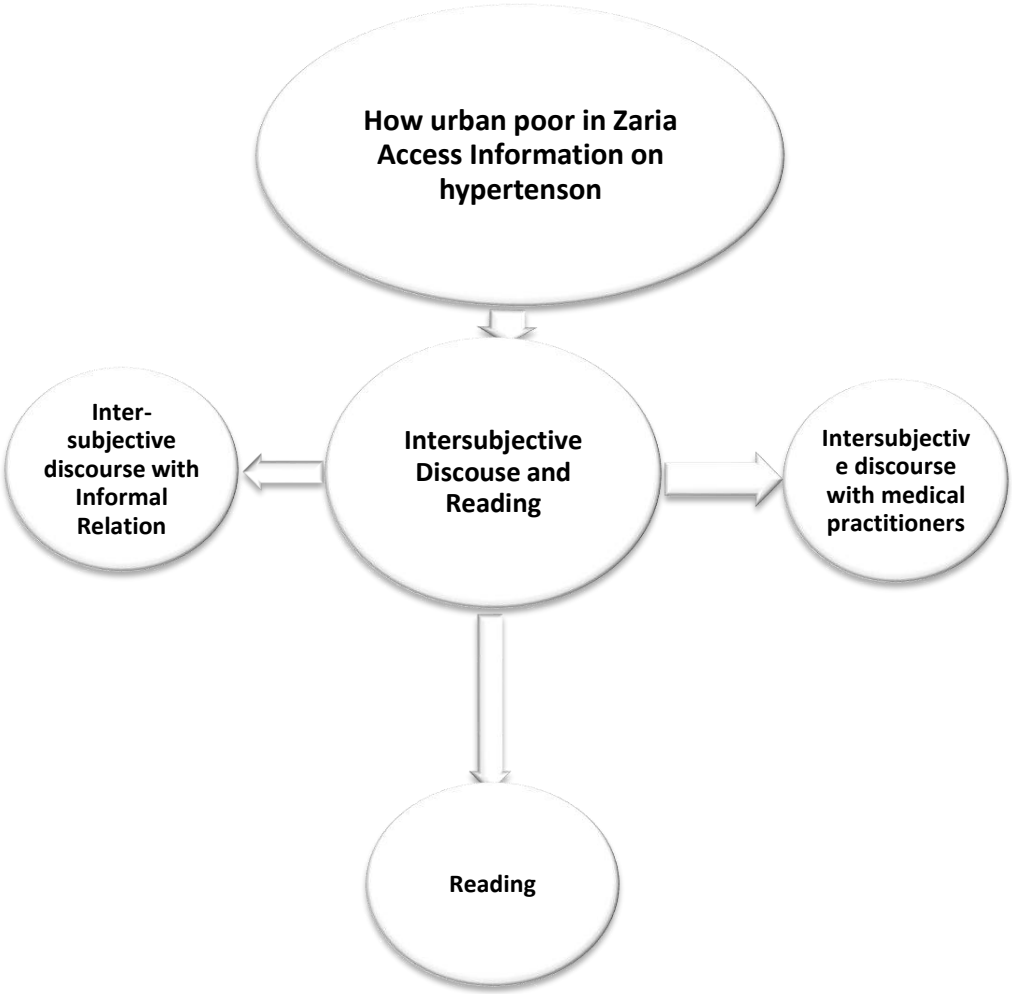
This explains knowledge of the urban poor in Zaria about other group of people who might likely suffer from hypertension which could not be discussed above because they are view of one participant. They are: (1) rich people 1/148 0.67% (2) smokers 1/148 0.67% (3) people with criminal mind (1/148 0.67%) (4) destiny (1/148 0.67%) (5) Genetics (1/148 0.67%) (6) people that are staying under the sun for too long (1/148; 0.67%). The following narratives were noted from some of the respondents "If it is rich man let say let say in term of family, let say in his commitment, let say too much of money, in term of sharing his own money he can have hypertension" "those that use to smoke can have it" "another set of people that can have hypertension are people with criminal activities because they always commit crime, Are you getting me? Because a person suppose to live freely but a criminal person usually after committing crime later he realize the negative effect of it" "Frankly speaking there is no such stage of human development that could be said that they normally have hypertension because some time I see it as a destiny if Allah wishes you. You will never run away from the cycle of destiny" "It could be probably inherit" "people that are trekking in the sun and inhaling dust can have hypertension"

Access to Information on Hypertension among the Urban Poor in Zaria

In order to identify hypertension information access among urban poor in Zaria, a series of question were asked so they could describe their ways of accessing information about hypertension. Hypertension information access among urban poor in Zaria appears in one category: inter-subjective discourse and reading. (See table 4 and illustration 2 below).

Table 4: Hypertension Information Access			
Research Question 2	Sub Question	Sub Category	Category
How do urban poor in Zaria access information on Hypertension	How do you come across the information you share with me on Hypertension	- Inter subjective discourse with informal relations - Inter subjective discourse with Medical Practitioner - Reading	Inter subjective and Discourse reading

Illustration 2: Hypertension Information Access



The category is discussed below.

Category One- Inter Subjective Discourse and Reading (26/26; 100%)

This category include narratives related to how urban poor in Zaria obtain information on hypertension, it explains the source related to friends, family, medical personnel and reading. The category is divided into three sub-categories; (1) inter-subjective discourse with informal relation (15/26; 6.25%) (2) inter-subjective discourse with medical practitioner (8/26; 30.7%) (3) reading (3/26; 11.5%) . The subcategories are explained below

Inter subjective Discourse with Informal Relations

This sub-category depicts narratives related to source of information from relatives and friends, it accounts the source as father, mother, aunty, cousin, grand parent, and family friends. A participant said “I am telling you all this because am having grandmother that is suffering from the same problem, she is having hypertension up till now, it is from her I got all what am telling you now.” Another one stated that “there is one of my cousins that is having hypertension, she mostly explains to me.” In addition to these, one of the respondents narrated that

“let say my mother, let me give you example of my mother, so, my mother is having hypertension as result of that she has already died and she was pregnant then. From the test they discover that she was having hypertension, what we thought about that is that some time we children we use to make her angry all the time, we use to disobey her this make her fall in this condition. In hospital they try to do operation to save the baby but due to hypertension is too high they cannot do the operation and also she has lose some blood and she need additional blood before going for that operation.”

Inter-Subjective Discourse with Medical Practitioners

The sub-category explained medical personnel as a source of accessing hypertension information. A participant stated that “as I said earlier, when I took my mum to the hospital, they will be telling us here are some of the causes, they will highlight the problem and possible solution to her.” Another narrated that

“as I told you earlier my father die due to hypertension and when we go to physiotherapist for exercise, some time the doctor consult their students in front of us, so I listen to them because I know It will be very useful to me because if my family or my neighbor might have this problem I can tell them how to prevent it”.

Also one participant explained that

“as I told you my mother is having the disease am the one that normally take her to hospital, even next week we shall be going there, today is Wednesday ba, next Wednesday I will take her there because we normally take her there every two weeks, the doctor normally tells me the symptoms and the sign of it, whenever I realize these symptoms in my mum I quickly take her to the hospital.”

Reading

The sub-category depicts narratives related to hypertension information access through reading. Respondent said “I was one time a science student I do read biology course, my future ambition is to become a doctor, a medical practitioner by God grace and by God will”

DISCUSSION, IMPLICATIONS AND CONCLUSIONS

The objective of the study is to explore knowledge and access to information on hypertension among the urban poor in Zaria using Barner Glaser and Anselm Strauss Grounded theory approach to derive a model of hypertension information for the urban poor in Zaria. The study adopted a qualitative research method, using case study research design as a specificexponential non-discriminative snowball sampling technique was used for this study, which made sample of 20 participants.

RQ1. What are the Knowledge of Hypertension among Urban Poor in Zaria?

Four (4) constructs explained this research question. These constructs are explained below:

The Participants have Knowledge on the Causes of Hypertension.

The participant showcases knowledge about causes of hypertension as emotional discomfort, stress, poverty, and unhealthy eating behavior. The participants portrayed emotional discomfort as a cause of hypertension. They believed that emotional discomfort results from thinking too much, worries, anger and bothering. They believe that if you are too perturbed by pressing issues that can result to hypertension. Other than the emotional discomfort the findings from the study reveals that the participant consider stress as a cause of hypertension, they explained that stress encountered at work, difficulties and too much of commitment can lead to hypertension. Moreover, participant perceived poverty as a cause of hypertension, they belief that hypertension can occur due to overwhelmed economic responsibilities of a family man. They belief poverty can make a man to think too much, faces agony and emotional pressure in life, which will result to hypertension. In addition, this study reports that unhealthy eating behavior reveals knowledge on causes of hypertension among the participant, they belief unhealthy eating like too much intake of salt, kola nut, sugar, and vegetable oil can cause hypertension.

Emotional discomfort, stress, poverty and unhealthy eating behavior are considered as indirect causes or factors that may increase risk of hypertension (Woolstone, 2016; Mayor 2016; Kurtzleben, 2012; Eitel, 2015). Findings identified that the participants positive knowledge on indirect causes of hypertension. This is because (Woolstone 2016) stated that emotional discomfort can temporarily boost blood pressure, fortunately, these spikes in pressure are usually too fleeting to threaten your health. But when emotional turmoil becomes a way of life, your blood pressure can take a dangerous, long term climb. The urban poor are also in line with the explanation of Mayor (2016) that the body produces a surge of hormones when you're in a stressful situation. These hormones temporarily increase your blood pressure by causing your heart to beat faster and your blood vessels to narrow. He further explained that there is no proof that stress by itself causes long term high blood pressure. However, short term stress related spikes in your blood pressure added up over time may put you at risk of developing long-term high blood pressure

The participants are also in line with the statement of Wilson, Kliewer, Plybon, and Sica, (2016) that people in low-socioeconomic-status environments are more susceptible to illnesses, such as hypertension and cardiovascular diseases. Similarly A.U (2013) reported that the prevalence of hypertension is increasing among poor section of the Africa society. Also a study conducted by Kurtzleben (2012) Showed that diabetes, high blood pressure, and heart attacks were slightly more likely to afflict those in poverty than those who are not. Unhealthy eating also reflects knowledge on causes of hypertension among urban poor in Zaria this is in line with explanation of Cleveland (2014) that when you eat too much salt, which contains sodium, your body holds extra water to "wash" the salt from your body. In

some people, this may cause blood pressure to rise. The added water puts stress on your heart and blood vessels. Also, Michaud (2015) stated that the caffeine in kola nut increases systolic and diastolic blood pressure by increasing the resistance in the peripheral veins. Furthermore, Pullen (2014) asserted that eating too much sugar can lead to weight gain over time, which puts you at risk of high blood pressure. In addition, Eitel (2015) stated that the American Heart Association recommends that people with heart disease eat a well-balanced diet low in sodium and saturated fats. Solid fats, such as butter and margarine, contribute a high level of saturated fat to your diet, so the AHA suggested switching to healthier alternatives. Liquid cooking oils can be used in place of solid fats for cooking and flavoring foods.

Although the exact cause of hypertension is unknown, there are several factors and conditions that may increase risk (WHO, 2013). The participants portrayed knowledge on factors and condition that may increase the risk of hypertension. But some of the participant held that staying under sun for too long and cockroaches are causes hypertension. However, (Parry, 2014; Macrae, 2014; Bakalar, 2014; broyd, 2013; fischer, 2014; Entin 2014) stated that a little time spent outdoors in the sunlight can lower blood pressure. While base on my knowledge there is no study that show link between hypertension and cockroaches. This has an implication because lack of knowledge on cause of hypertension will negatively affect its prevention.

The Participants have Knowledge about the Prevention of Hypertension.

The participants portray knowledge of prevention of hypertension as avoiding emotional distress, eating healthy, medical and avoid staying under sun ray for too long. The participants regard avoiding emotional distress as a way preventing hypertension. They believe emotional distress can be avoided by engaging in recreational activities, avoid thinking too much, exercising, avoiding loneliness and resting. The participants also portray eating healthy as a way of preventing hypertension, they believe that by reducing salt, sugar and kola nut intake one can prevent hypertension. Furthermore, taking medical step depict knowledge of urban poor in preventing hypertension, they belief that taking local herbs and visiting medical practitioner are the right steps in preventing hypertension. However, data reveals only one respondent has knowledge of visiting medical practitioner and having blood pressure check as a means of preventing hypertension.

The findings identified avoid emotional distress as knowledge of hypertension prevention among the participants. This is positive because Woolstone (2016) states that emotional control may decrease a person's risks for developing hypertension. The urban poor in Zaria also show positive knowledge about prevention of hypertension, compared to WHO (2013) recommendation of physical activities for at least 30 minutes a day, five time a week and following medical advices. Furthermore, participants are in line with the statement of Frisoli, Schmieder, Grodzicki and Messerli (2012) that in numerous epidemiologic, clinical, and experimental studies, dietary sodium intake has been linked to blood pressure, and a reduction in dietary salt intake has been documented to lower blood pressure.

The findings from this study reveal that the participants held that avoid staying under sun for too long can prevent hypertension. However, (Parry, 2014; Macrae, 2014; Bakalar, 2014; broyd, 2013; fischer, 2014; Entin 2014) asserted that while too much sun exposure may bring on skin cancer, researchers have found evidence getting some rays could protect against high blood pressure, however, sun bathing is not recommended as a way to treat high blood pressure. In addition, despite WHO (2013) recommendation that all adults should know their blood pressure level, however only one respondent poses knowledge of blood pressure check as a way of preventing hypertension, this has implication because hypertension symptoms are silent. The findings also reveal that urban poor take local herbs

to preventing hypertension, this also have implication, because the side effect of local herbs might not be known

The Participants are Knowledgeable about Symptoms of Hypertension.

Participant reveal knowledge on symptoms of hypertension as headache, body temperature, palpitation, unconscious, abnormal sleep, loss of appetite, and swollen of some part of the body. It is discovered in this study that the participants believe that hypertensive patient often experience symptoms. It is also found that the participant believe hypertensive patients are characterized with heart beating. They also have the belief that hypertension victim are characterized with fainting and dizziness.
However, WHO (2013) reports that there is a common misconception that people with hypertension always experience symptom, but the reality is that most hypertensive people have no symptoms at all. Meanwhile, WHL (2014) elucidated further that when the effects of hypertension start to damage one or more of the usual target organs such as brain, kidneys, heart, eyes or blood vessels. Then symptoms of the damaged organ manifest themselves. This is a late stage of *primary* hypertension, the large majority of cases (90%). Also when there occurs a disease that causes high blood pressure the symptoms of high blood pressure are those of the underlying disease. This is called *secondary* hypertension.
Despite the fact that “High blood pressure is called the “silent killer” because it often has no warning signs or symptoms” (Anderson, 2016). The participants do not know that hypertension symptoms rarely occur and this has negative implication on early diagnosis of hypertension.

The Participants Portray Knowledge About People Who are Likely to Have Hypertension**.**

Participants indicates knowledge about people that are likely to have hypertension as aged people, poor people, fat people, people with criminal mind, hypertension can affect any one, pregnant women, children, people experiencing emotional discomfort, and people with unhealthy eating behavior. They believe old age is a risk factor to hypertension. They are also of the opinion that fat people are likely to suffer from hypertension and its complications. Aside from aged people and fat people the participants believe hypertension can affect anybody, they belief that anybody can fall victim of hypertension and its complications. Moreover, the participants identify pregnant women as a group that is likely to fall victim of hypertension. In addition the participants indicate children, as a group that might likely suffer from hypertension. These beliefs exist largely among participants because they have come across different group of people suffering from hypertension.
The finding discovered that participant revealed positive knowledge on who is likely to have hypertension. This is because WHO (2013) stated that blood pressure typically increases with age, especially once one has passed middle age. The increase in blood pressure with age is mostly associated with structural changes in the arteries and especially with large artery stiffness. The participants are in line with the America Heart Association (2016) explanation that being overweight increases your chances of developing high blood pressure. A body mass index between 25 and 30 is considered overweight. A body mass index over 30 is considered obese. AHA (2016) explained further that the more you weigh the more blood flow you need to supply oxygen and nutrients to your tissues. As the volume of blood circulated through your blood vessels increases, so does the pressure inside your arteries. Also (National Institute of Heath, 2015; Keplan, 2016) asserted that anyone can develop high blood pressure; however, age, race or ethnicity, being overweight, gender, smoking, lifestyle habits, and a family history of high blood pressure can increase your risk for developing high blood pressure.

The participants are also in line with Zamorski and Green (2014) elucidated that pregnancy induced hypertension (PIH) is more common during a woman's first pregnancy and in women whose mothers or sisters had PIH. The risk of PIH is higher in women carrying multiple babies, in teenage mothers and in women older than 40 years of age. Other women at risk include those who had high blood pressure or kidney disease before they became pregnant. The cause of PIH isn't known. Also Falkner (2010) stated that hypertension is detectable in children and adolescents and, as in adults, is associated with a positive family history of hypertension, obesity, and life-style factors

How do urban poor in Zaria access information on hypertension?

One (1) constructs explained hypertension information access. This construct is explained below:

The Participants Access Hypertension Information Through Inter Subjective Discourse and Reading**.**

Participants access hypertension information through inter subjective discourse with informal relations, and medical practitioners and reading. The participants access hypertension information through inter subjective discourse with informal relations such as father, mother, aunty, cousin, grand parent, and family friends. Most respondents have one or two friends and family member whom are suffering from hypertension and they come to know about hypertension through them. The findings also reveal inter subjective discourse with medical practitioners as a mean through which Zaria urban poor access hypertension information. The urban poor in Zaria come to know about hypertension by taking hypertension victim to the hospital for treatment, going to the hospital to know about hypertension not willingly but conditional. Inter subjective discourse with medical practitioner arise from taking sick patient to the hospital.

Inter-subjectivity emphasizes that shared cognition and consensus is essential in shaping our ideas and relations Gillespie and Cornish (2010). In the same manner the responses show that the participants access hypertension information through inter subjective discourse with informal relations and inter subjective discourse with medical practitioners.

Discovering from the study that the participants access hypertension information through inter subjective discourse with informal relations has an implication. This is because informal relations are close associate and they are not formal source of hypertension information, therefore both appropriate and inappropriate information are accessed.

Furthermore, the study reveals that the participant who possess basic education access hypertension information through reading. The participants reveal that they have read about hypertension in their text books. And they stick to it because they find it easy to understand.

Reading is a means of language acquisition, communication, and of sharing information and ideas (Douglass, 2014). In the same manner the responses show that the participant access hypertension information through reading

Limitation of the Study

The exact population of the urban poor in Zaria is not known. The researcher visited Federal Bureau of Statistics for the statistic of total population of Zaria urban poor living below the average poverty line for developing countries, but all effort by the researcher to ascertain the total population of the study proves abortive. However the sample population for this study did not include Zaria urban poor who live above the average poverty line for developing countries ($2), two dollars a day (World Bank, 2015).

Conclusion

Scholars have made various attempts to address a person's knowledge of threat of a health problem; the uniqueness of this study is based on employing Grounded theory approach to derive a model of hypertension information for the urban poor in Zaria. Understanding the categories derived from this study has the potential of design an hypertension information program suitable for the urban poor in Zaria, Kaduna state.

The findings from this study has reveal emotional pressure, poverty, unhealthy lifestyle, sunlight and cockroaches as the causes of hypertension, however, sunlight and cockroaches reflects confliction between their knowledge and orthodox medical knowledge about the causes of hypertension, also the urban poor in Zaria do not know that hypertension symptoms rarely occurs, this shows that their knowledge about hypertension is deficient and this also contributes to late diagnosis of hypertension. Therefore, health policy makers such as ministry of health, world health organization (WHO), world hypertension league (WHL), Nigeria hypertension society (NHS), etc should consider above constructs when designing enlightenment and awareness programs on causes of hypertension in order to improve knowledge of hypertension among the urban poor in Zaria.

In respect to access to hypertension information, this study indicates that the urban poor in Zaria Kaduna state access hypertension information through inter-subjective discourse and reading, therefore, local decision makers and hypertension information provider should make hypertension information available in social spaces where inter-subjective discourse take place. Social spaces include mosque, churches, tea joint, cinema, motor pack, fitness centre, and online social media etc. This can be done by placing poster, stickers, and distribution of handbill, pamphlet in these social spaces.

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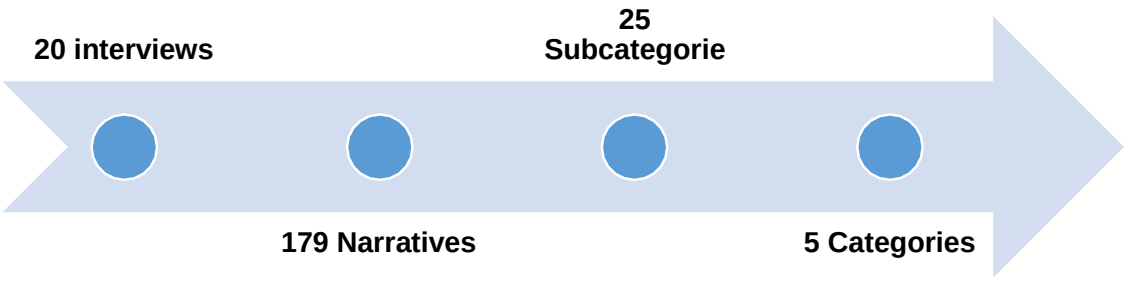
Data Analysis Step



DECISION SCIENCES INSTITUTE
Lean Manufacturing at The Brazilian Shipbuilding Industry

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ABSTRACT

Lean manufacturing has faced resistance in the Brazilian shipbuilding industry. This paper analyzes lean manufacturing implementation at "*Atlântico Sul" Shipyard (EAS)*, the largest Brazilian shipyard. Although the literature emphasizes waste reduction, human related issues were crucial for shipyard productivity improvement. Finally, lean manufacturing must be adjusted to specific industrial contexts.

KEYWORDS: Shipbuilding, Lean Manufacturing, Productivity. Case Study

INTRODUCTION

In 2004, PETROBRAS stimulated by oil discoveries in the Pre-Salt, decided to renew its ship fleet to transport oil and derivatives. Under the guidance of the Brazilian Federal Government, PETROBRAS has decided to place orders at local shipyards, aiming to reactivate the Brazilian Shipbuilding Industry (ICN). The Fleet Modernization Program (PROMEF) was created to renew the fleet of oil transportation and exploration vessels, since the that one was already quite old (average age above 25 years).

In the first phase of the program (PROMEF I), PETROBRAS has sought national shipbuilding decentralization away from the state of Rio de Janeiro, which had most of the national active shipyards. Thus, consortiums could take part on PETROBRAS-TRANSPETRO's bids with "virtual shipyards" (they had a project and financial commitments to build a new shipyard, but not the physical assets yet). The rationale behind this agreement would be to allow modern shipyards to be built in a time shorter than the delivery time of international shipyards (a few years delivery time due to a heated global demand for cargo ships and oil tankers).

The main winner of the PROMEF bids was the consortium led by "Camargo Correa" and "Queiroz Galvão", two of largest Brazilian EPC). This consortium also had a technology

partnership with SAMSUNG HEAVY INDUSTRIES from Korea, to transfer technology of ship production. To attend PROMEF demand, the consortium built in the industrial complex of SUAPE, Pernambuco, “Atlântico Sul” Shipyard (EAS), the largest shipbuilding in the southern hemisphere. EAS portfolio was composed of twenty-two Suezmax-type ships; a P-55 platform helmet; five Aframax-type ships, all placed by PETROBRAS-TRANSPETRO.
The physical structure of EAS was built from 2006 to 2010. In parallel with the construction of the physical facilities, the yard had to carry out an extensive program of labor qualification, beginning the processing of steel sheets to produce the first Ship in 2008. At the EAS installation, there was also an effort in the acquisition of state-of-the-art equipment, using advanced technologies such as welding robots as recommended by the literature (Liker & Lamb, 2000a).

Despite all the investment, theresults of the first ships at EAS were disastrous in terms of costs and delivery time. After several changes in the company's board, which consisted of re-runs of the representatives of the consortium companies, the shareholders decided for a radical change. An executive with great experience out of the shipbuilding industry (several industrial plants implanted in the automotive sector) was appointed. The new board quickly understood that the yard would not be competitive only by adding new technologies and equipment, and by providing traditional employee training. A radical change in the productive processes was needed to drastically reduce the waste in the yard. The new board decided, despite all the skepticism of the people associated with traditional shipbuilding, by adopting the lean manufacturing system.

LITERATURE REVIEW

Lean Manufacturing is a methodology coming from Japan that has made great contributions in several industrial sectors (Bhamu & Sangwam, 2013). This methodology is based on two pillars: reduction of waste and respect for people (Liker & Lamb, 2000b). There are seven main types of waste: (i) production above what is required, (ii) waiting, (iii) unnecessary transportation (iv) wrong or over-processing, (v) excess inventory, (vi) unnecessary movement, (vii) defects.
In addition to the traditional wastes focused on lean manufacturing, Liker & Lamb (2000b) add to the non-use of employee creativity. The focus on the human issue has its importance, given that the perspective of implementing lean manufacturing in the West has been predominantly technical focusing on waste reduction. The pillar of respect for people has been neglected, being considered something inherent of an Eastern culture and perhaps not completely applicable to Western countries.

The expected results of lean implementation in shipbuilding would be: improving the quality of the final product; reduction of manufacturing time; improvement of image vis-à-vis customers and suppliers; and improvements in the materials management system (Liker & Lamb, 2000a). In lean manufacturing, short feedback loops prevent propagation of errors and minimize waste. Restricting the use of large batches of stock prevents quality problems from being hidden and only manifested later when someone is going to use a non-working part (Liker & Lamb, 2000). This allows for a better quality of products and processes, as well as an improved production flow (Storch & Lim, 1999).

Despite the important quality gains, productivity is the focus of the lean methodology (Sanders et al., 2016). The reduction of the production lead time allows the improvement in customer service and increase of yard utilization, generating greater productivity. The reduction of this lead time results from the reduction of the time spent in activities that do not add value, and real

time problem identification and resolution. The elimination of activities that do not add value to the business, positively affects the morale and employees' sense of accomplishment. At the same time, lean production imposes discipline on employees to act on a set time, before the part moves forward in the system.

Despite the success in sectors such as the automotive industry, the application of the lean philosophy at the shipbuilding industry has been low, with a greater focus on employee safety improvement and damage protection (Phogat, 2013). Despite that, some lean methodology implementations have achieved significant results. A yard in Mississippi, U.S.A., implemented Lean Manufacturing in 2000 with a 54% reduction in manufacturing time, a reduction of rework by 80%, and a 29% increase in productivity. The Puget Sound shipyard in the U.S. also implemented a serial flow in its operations and obtained a 73% reduction in production lead time. Statistics also show that in the period from 1965 to 1995, the Japanese shipbuilding industry improved its productivity by 150%, mainly due to the development of lean principles and adoption of the Toyota production system (Phogat, 2013).

For lean implementation in the shipbuilding industry, it is suggested starting the program at the technical area as a long-term philosophy. Thus, moments of crisis where short-term solutions are sought, would not be good time for its deployment (Liker & Lamb, 2000b). Kaizen is seen in the literature as a key approach this implementation. It is a continuous improvement process involving employees at different levels in the plant hierarchy (Beifert et al., 2017). They propose suggestions for improvement on a regular basis, where the most efficient proposals are implemented. Kaizen workshops would then, be used for training and change implementation (Shah & Ward 2007). In this process, learning would be more by action than training, with mandatory participation during working hours. Also, the use of value stream pilots, metric establishment, and lean leader identification would demonstrate opportunities for major financial impacts.

The literature discusses barriers to lean manufacturing implementation. High costs and long lead times for deployment and restructuring, and reliance on a top-down approach are generally viewed as the main problems. Parveen and Rao (2009) indicate that high acquisition costs, high market volatility, and demand for customized products can outweigh the gains obtained in quality and productivity in the shipbuilding industry, which could discourage the lean implementation. Given the previous discussion, this work has the objective of presenting the case study of the implementation of lean production in the EAS yard, presenting its implications and unfolding.

METHODOLOGICAL PROCEDURES

This study is an applied and exploratory research. It is applied due to the practical use of available knowledge of lean manufacturing in an industrial organization; and exploratory because it provides some insights to a topic that has not been explored in the Brazilian shipbuilding industry. Due to the complexity of the shipbuilding sector, a greater flexibility was required at the field research, not allowing an exact and a priori definition of the paths to be followed. This paper converged to a predominantly qualitative approach, based on data collection, reduction, organization, analysis, interpretation, verification and validation (Miles & Hubermann, 1994).

In this study, we have used archival documents such as institutional shipyard documents, on site observations (which allowed the process mapping), and interviews as data sources. Based

on the interviewees' reports, observed data and secondary documents, we describe in detail facts and data, aggregating information to academic knowledge, highlighting the descriptive characteristic of qualitative research. Data analysis, in turn, was performed through comparisons and contrasts of theoretical and collected data, generating inferences resulting from the cases (Yin, 2009). In the empirical field, our interest was characterized by the understanding of meanings in the research process itself. Our focus was the understanding of the lean manufacturing implementation at EAS, thus confirming the qualitative characteristic of this work (Merriam, 1998).

To determine which members of the shipyards would be our respondents, we used the strategic importance criterion for change implementation of the yard production system. Thus, the shipyard CEO, the EAS directors (contracts, finance, supply, operations and planning), and the Corporate Production Manager were interviewed, totaling six in-depth interviews. Some stakeholders were also interviewed for participating directly in internal shipyard change processes (such as a contract manager for TRANSPETRO, an infrastructure analyst for the Merchant Marine Department - DMM and a representative of the classification society ABS – American Bureau of Shipbuilding) totaling three additional interviews. The interviews were transcribed and analyzed by more than one researcher. Excerpts related to the topics of waste reduction and respect for people were identified and categorized. Using a temporal point of view, we analyze the shipyard initial situation, the change actions and results, and the prospects of the lean system implementation.

RESULTS

This section will describe the shipyard status found by the new board and actions taken to implement the lean manufacturing system.

Shipyard Status before the Lean Implementation

The new board found a chaotic shipyard status. The delivery time and production costs for the first ships (especially due to the low productivity), surpass the PETROBRAS-TRANSPETRO contractual values. Although the quality of the final product was guaranteed, production costs were extremely high, especially due to losses on the production process and reworking. The first two ships cost twice as much as planned. From the third ship, production costs were gradually reduced, but accumulated losses were totaling more than one billion Reais (more than four hundred million dollars) at the time the new board of directors took over the shipyard. As a result, the enterprise lacked credibility (especially financial credibility), since few people believed that the yard could become a profitable business.

The new board represented a complete change of a traditional Brazilian Shipyard board. All people coming from the old shipbuilding industry were replaced (the CFO was the only member kept from the previous board, but he was coming from the shipbuilding industry). So the new management board was a disruption at the paradigms and resistances of the former Brazilian shipbuilding industry.

> The yard will not be able to live with it here. I need to eliminate the losses. Why do I paint three times? Why do you have 200% rework here? The problem is the cost of quality. If you lose a ship, you lose R $ 370 million. (EAS CEO).

The yard diagnosis by the new board was bad. There were no detailed production processes, or even process designs, but rather EAS actions were sought to comply with client regulations (PETROBRAS-TRANSPETRO), the financial agent requirements (Merchant Marine Fund - FMM), and the Classification Society evaluations (American Bureau of Shipbuilding). There was no clear shipyard culture. There were representatives of the partner companies (four presidents from the majority shareholders had took turns in the yard command of the yard assuming different agendas and keeping their own organizational culture). In addition to the natural difficulty related to the shipbuilding production learning curve, there was no clear production strategy. For instance, the first ships manufactured at EAS (Suezmax-type ships) had delivery times much larger than the established at the contract terms. To speed up those delivery times EAS had imported part of the hulls (called half-ships), instead of assembling them internally. However, this strategy, was discontinued after EAS manufacturing only two ships.

> Then look at the (learning) curve of the Suez; makes no sense ... and they never had a constructive strategy. They started making a whole ship, then came the half-ships from outside ... then we never made a ship like the other (EAS CEO).

The New Board Actions to organize the EAS

In this subsection we will discuss strategic actions taken by the new board, as well as the effective changes in the shipyard production system, to improve EAS results.

Strategic Decisions

The new board has brought to EAS a new focus on cost reduction and competitiveness. In this new perspective, production costs would have to be adjusted to the product sales value (Production Costs = Sales Price - Profit Margin), and not as occurred in the Brazilian shipbuilding mentality, where production costs were added to the profit margins and pushed into the negotiation of vessel sale prices.

> The naval industry is kind of prostituted, right? it is cost plus the profit margin, not this is the price and I must get into the cost. So, this equation is inverted in the industry and that must change ... otherwise we will not fulfill this business (EAS CEO).

EAS's previous experience with rig shells contracting (contracts were canceled after yard high preparation investment) showed that there was no strategically defined product line at the shipyard. The new board, based on the skills already developed at the shipyard, has decided to focus manufacturing of less technologically complex ships (oil tankers), which was the focus of PETROBRAS-TRANSPETRO contracts. After a while, that yard production line could be expanded to manufacture container ships (an already existent market that could be attended by EAS competences).

Another strategic decision by the new board, was the vertical integration of manufacturing and assembly activities, previously carried out by third parties. Productivity improvement has weighed on this decision. The yard had competence and resources (equipment, space, skilled labor, etc.) to do these activities. The use of many outsourced companies operating within the EAS facilities and, consequently, a low utilization of internal resources, only had damaged the yard productivity.

> So, when I look at the manufacturing part my only input here is steel, so I do not have a need for a chain. I do everything inside the house, the only thing I must buy (*besides equipment*) is accessory, integrated accessory (small parts, stairs, handrail, etc.) ...Conclusion is what I told you, I will not need any of them. Do everything internally. We used to have one thousand and five hundred providers here (EAS CEO).

Another factor for vertical integration in manufacturing and assembly was he local and national supply chain inadequacies. This action was supported by a supplier cost analysis, which corroborated to the elimination of most existing local and national suppliers. The idea of integrating a local or even national supply chain was also hampered by supplier corporate culture, who used to develop inadequate business practices, to the detriment of supply quality.

The use of local suppliers has been problematic since the beginning of yard operation. It was known that domestic suppliers of the naval industry were not cost or quality competitive against international suppliers (MDIC, 2003). Even so, to reduce the risks of supplies and to meet the national content index (CN), several contracts had been celebrated with those suppliers. However, before the new board arrived, 60% of contracts placed to Brazilian suppliers had been canceled due to quality/delivery problems.

Despite difficulties with the local supply basis, there was the understanding that, in the long term, vertical integration would not be the definitive yard answer. High internal integration would represent high capital intensive (equipment and facilities) business, which was not desirable from the shareholder standpoint. In this sense, some longer-term contracts with local suppliers have been carried out in the EAS. Some of these suppliers started working at the yard site to provide better customer service, either in client support, or operator training.

Lean Manufacturing Capabilities at EAS

In this section we will discuss the development of the four capabilities in EAS (Process Design, Kaizen, Improvement Sharing, and Training) related to lean manufacturing. Our emphasis will be placed on the first two capabilities. At the end of the section, we discuss the role of people in the yard changes.

Process Design

Given the EAS situation, the new board initially decided to map all processes, including the administrative ones, getting help from external consultants. The value mapping in EAS production was detailed. According to the interviewees, that step has taken at least six months. The yard was organized into eight mini factories: steel processing (blasting / preparation); sheet cutting; welding of profiles; block assembly; painting; assembly of accessories; (Figure 1).

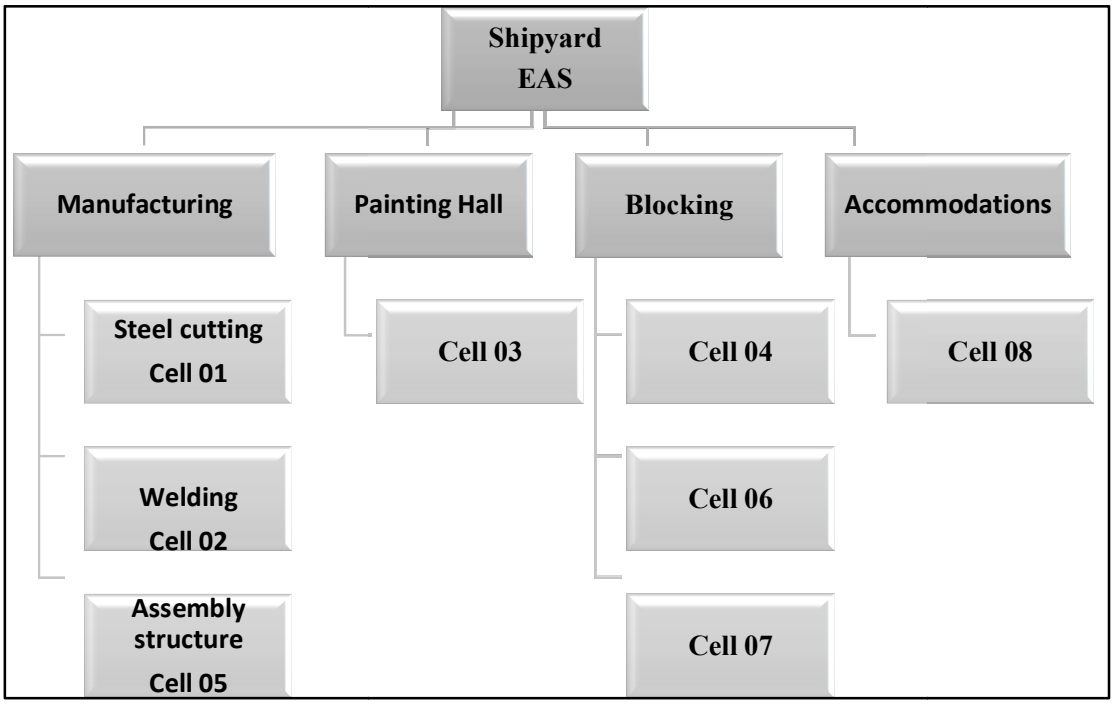

FIGURE 1 – MINI-FACTORIES AT EAS SHIPYARD

This new layout would allow each mini factory to focus on a specific part of the shipbuilding process. The mini-factory value streams were mapped, and an adequate number of people were allocated to each one, as well as, an adequate cycle time was defined. The mini-factory manager defines the schedule manager weekly. The supervisor takes this schedule, divides it by days, and delivers it to the leader. The leader divides those tasks into hours.

Each of these mini-factories has a cost center, reported directly to the EAS CEO. Any extrapolation of the mini factory's budget requires a negotiation process to analyze the possibility of resource transferring from another mini-factory that is on the loose. The mini factory cost control has helped the new board to control its key accounts and the yard cash flow control.

> Between 12 and 16 accounts represent 90% of my expenses. I have direct control over them, before I did not have. How did this work out here; economic accounting is POC. So, it's a margin projection, you know that when the margin does not happen you have to make the loss. (EAS CEO).

A block assembly management was created to record the block production history. That control would help not only to solve block related problems, but also future block related problems. The same control system was reproduced for each sheet and part produced at the shipyard. This would help to implement a PDCA for production continuous improvement, especially critical for reducing the yard total amount of men hours. In addition to changes in production control systems, there were changes in layout, significant reduction of physical space and equipment, showing that many of the original investments during the yard construction stage were oversized.

> If we were to do the yard today, I would pick up these bridges and throw it all away. It was going to be the opposite, the lines would be like this, I would not need this building (painting station) ... it's hard for them (shareholders) to hear it, all this money spent here I would not need it, I would need ¼ of what was built here to make a shipyard, to make eight ships a year (...) this yard is still going to be reduced to half of what it is today. This yard has an interesting feature; we make the block here, but the ship leaves on the other side; it is weird ... It still has lots to be worked on (EAS CEO).

Some traditional shipbuilding processes, such as painting has been redesigned to reduce costs (dry painting is much faster than the original water painting), to improve process quality, to expand partnership with key suppliers (subsidiaries of multinational ink suppliers), and to increase delivery flexibility. EAS managers have paid close attention to operations bottlenecks by planning for better use of expensive equipment (such as the fifteen hundred tons moving cranes). These simple ideas that increased the yard equipment utilization, like some others, were possible by a fresh look from people outside the shipbuilding industry.

> The staff had a table, put the plate there and cut it. After he cut, he had to take that material out to get another plate. That's a rule; then we raise the ruler and I have two tables. So, I cut into one table and I'm catering to the other one. While this one is being unloaded the other (table) is already cutting (the plate). So, I am utilizing the equipment capacity much more, (before) I have utilized at most 50% of the equipment. The “Golias” (crane) worked one each time; the other stood still. Nope, they will work simultaneously: one on this side and another on the other side (Corporate Production Manager).

In the new production system, the smallest unit of control was the team (composed of around 10 people) and managed by the team leader. Each team leader has a control framework that is the hour-hour. Then, at each hour closed, he needs to go to the board to see if he/she has met the team goal. If he/she did not meet the hourly goal, but still can meet the production within the working day, a countermeasure is triggered to recoup the production shortfall. For example, the leader may decide to release only a portion of the team at the scheduled lunch time to not stop production. If a question is out of the team leader's hand, such as overtime utilization he/she calls out the supervisor, who oversees eight teams, asking for authorization. If it is an issue where the supervisor has no autonomy to decide, the problem goes up to the mini factory manager. The mini factory manager has a once-a-day meeting called KPI (Key Performance Indicator), where performance figures are tracked in a frame.

All the decision staggering is supported by visual controls, indicating a production deficit (red color) or a production attainment (green color) in relation to the target (black color). There is no computerized production control system as in traditional project management. The logic of visual management is to simplify and facilitate control and even allow problems to surface as advocated by the lean manufacturing literature.

> The yard is big. So, I must be able to walk in the yard, any of us, and realize if the yard is good or if it is bad. Then, whenever I walk in the yard I only have one question to ask - is it good or bad? -... when I define what is good and what is bad, then I can add value to this

> business ... So, when I walk around the yard I already know which mini factory is up to date, which mini factory is late, where is the most critical point (Corporate Manager of Production).

Production lead times are tighter than the respective lead times for the customer. These goals are doggedly pursued, but in case you cannot solve a problem on time, there is still some slack to use. If necessary, the manager can request support from the “help chain”, via radio, telephone, etc. The “help chain” is formed by multifunctional members of sectors such as Quality, Manufacturing, Supplies, etc. The help chain is triggered when a mini factory finds that it will not be able to finish its job on time (usually triggered at 15% of the task completion time) due to several factors such as inability to meet a deadline, failure to approve an item, drawing issues, etc.

> At that moment there are seventy people from the mini factory II who are assisting the mini factory V that is delayed one day on its goal. I must to build (ship) with a million four hundred thousand HH. it's of no use (if only) factory II be good, I need the yard to be good, I need to deliver the ship there at the other end (EAS CEO).

Workshops KAIZEN

The Kaizen workshops were instrumental for deploying the EAS strategic goal of building the AFRAMAX vessels with one million four hundred thousand HH (number of hours lower than the one from the SUEZMAX series), in tactical and operational actions. In the workshops, teams start with a productivity number and analyze the bottlenecks and constraints preventing that achievement.

> Look, I have a machine here and my machine is 30% efficient and with 30% I'm not going to meet the demand I need. The efficiency of it needs to be at least 60%; that's a knot. So, that comes here on Wednesday and from there develops a Kaizen for improving from 30 to 60 (Corporate Production Manager).

The Kaizen workshop starts on Mondays with a theoretical presentation of what must be done, and which tools will be used. On Tuesdays, Wednesdays and Thursdays it is usually the work of data collection and implementation, and on Fridays the balance is made, celebrating the correct ones and correcting the errors. It could have more than one workshop per week at a mini-factory, implying that it may have up to eight simultaneous workshops. According to the Corporate Production Manager celebration is an important component of the kaizen workshop success: "Everything that went right we celebrate and everything that went wrong action plan of at most thirty days. This is the systematic ... It's wrong to give a lot. "

Kaizen has created a discipline to raise all kinds of process related problems that could affect the yard production. For each type of problem, a solution or countermeasure is designed. The solution consisted in acting on primary causes so, that the problem did not return. If there was no definitive problem, a countermeasure would be activated to momentarily resolve it. An example of a countermeasure is the use of kanban for inputs within the factory. As in certain situations, the exact consumption of certain inputs may not be known. Then, a kanban solves the lack of input problem, until the precise demand size could be determined.

At data collection time of this study, there have been over 120 Kaizen workshops deployed, with hundreds of thousands of ideas implemented, generating visible waste reduction and improvements at all levels in the yard. In those workshops all those directly involved with the change are present: from the operator of a machine to the leaders, supervisors and managers. Measurements are taken before and after the improvements, to see how effective the changes would be.

Improvement Sharing and Training

The improvement sharing competency was supported by information sharing at horizontal level. Employees were encouraged to develop the habit of searching information about a specific problem. According to the Production Corporate Manager, once a week there is an operational meeting of improvement group managers, who use to walk into the factory, and look for production information. Weekly improvement meetings show a cultural change in the yard, since people no longer accept error passively. In those meetings, there are people from all the areas: finance, personnel, manufacturing, planning, etc. There is also a regular board meeting to address business strategies, supported by daily follow-up meetings, to monitor the implementation of defined actions.

> Did you ever come to our meetings here on Wednesdays? It's a good altercation. So, we fight and must be separated. I'm reaching the level I want because when it starts like this it is cool. The production guy does not accept what engineering did wrong; the logistics guy does not accept what the guy from the warehouse made. It is a nourishing fight, in which everyone wants to improve (EAS CEO).

The training competency at EAS was developed using mainly through the on-the-job training provided by the immediate supervisor. There is a cascading training, where the board trains their managers, managers train their supervisors, and supervisors train their leaders, who ultimately train their team. The training was carried out in a continuous mode, focusing on employee autonomy to solve problems.

> Each moment of ours is a moment of training, this is a posture that we must have. So, I'm going to get to a painting that is red ... I call the people involved and - Why is it red? What was the action you took? - So, I try not to just charge at any cost, that's training, - Okay, but what can we do? The idea is that we do not give the fish; they must learn how to fish. So, we go there, it's Socratic Method; I will instigate them to arrive at this solution, this process takes a little longer than simply giving the answer, but it is forever (EAS CEO).

We can observe the goal is not only problem solving, but construction of operational autonomy. Employees are encouraged to think, and they end up developing their own problem-solving skills. The focus is to stimulate reflection and participation. Managers are not always able to solve problems, but they build commitment and empowerment at the operational levels. The human factor was crucial to the changes at EAS. Considering that actions such as leadership development and organizational culture change have had little prominence in the production literature, we will be highlighting those issues in the next section.

The Importance of Human Factors to the changes at EAS

The new board of directors sought to be as transparent as possible, at the change times, showing the yard situation, and discussing the importance of increasing productivity to avoid the enterprise closure. In this context, there was an emphasis on operational leadership. The production leader had two major missions at EAS: to keep a productive flow; and make improvements. There was a task assignment hierarchy, as well as, a resource request hierarchy composed of various levels (leader, supervisor, mini factory manager, director board). This hierarchy keeps control and allow the open discussion about resource needs to solve problems, fulminated the old culture of "slipping deadlines."

> People used to do like this: "It happened; now you cannot change!" Okay, what do we have to do to accomplish it? We need to put in more people? We need to put more resources? Put a crane? Bring another forklift? Do I have to make a different plate? We cannot say simply we cannot do it; this does not exist, there is no such option. It will happen and on the established date. This is the control, and then it triggers our whole process, which is the leader's hour-hour, which is the supervisor's daily control, the manufacturing manager's planning, the weekly board meeting that deals with our operations. Then, it unleashes the tools that we use to make this happen (Corporate Production Manager).

Good ideas are rewarded in ceremonies with everyone from the yard present. The best ideas from the mini factories, the seven best ideas and the best of all from the yard are awarded monthly. The significant number of ideas showed the success of the program. However, differently from lean manufacturing models such as the Toyota system, the spirit of competition between employees was encouraged.

> (Before) There was no sense of competition. So, this year I told the guys that we were going to organize some Olympics; I must start waking up those guys. So, what I saw here is convenient (behavior). At the beginning this was very difficult, because nobody understood what was happening, now everyone wants to break records: A winning culture (EAS CEO).

Focusing on intermediate leadership for implementing change and a serving attitude can be perceived throughout the organization. Leadership was identified, and the manager's role change from an activity prosecutor to an operational work facilitator (called positive leadership). The EAS CEO stated incisively: "Who has to serve is the boss. I that I must get there and see if it's okay and what I can help; that's the boss's role. So, until we reversed the pyramid here, it was a big fight. "

Control mechanisms and action plans were created not to punish those who made a mistake but to focus on the reaction plan for the problem solving. The commitment to excellence was instilled in Kaizen meetings. Errors have been part of the process, but never disseminated, and people must not accommodate to them.

> Nobody accepts a block, a plate, a piece that passed with defects, (he) does not accept. This is the role of each one here, and it took a year and so much to change this business. So, the staff arrives to say: "No, you have to; you are wrong”. In fact, that wrong/right is our way. (EAS CEO)

An interesting point at EAS changes was the valorization of the female participation in the labor force, which is predominately masculine in the Brazilian shipbuilding industry. There were a significant number of women in the technical areas of the shipyard such as Engineering, and Production Control Planning (PCP). Almost all employees that schedules and controls the factory floor are women. It was found at Kaizen meetings that the PCP and Engineering employees had little integration and, consequently there was a lot of rework. Multifunctional work cells coordinated by female employees were then created to redesign the process and define responsibilities.

Despite the lean pillar of respect for people, there was a strong reduction of jobs during the lean implementation at EAS. The number of employees has been reduced from 10,800 to 3,000 employees. As processes have improved, the overstaffing became apparent. Then, good and committed employees were gradually getting better and more productive. However, during that downsizing, there were openings for employees to have access to the entire board, to speak up, and to talk about what bothered them.

> Before ... their work was just to keep appearances; this does not last long with me. You can see that a lot of people who left were those people who tried to hide the truth from us and we do not accept it. This cultural change has leveraged the current spirit here. (EAS CEO).

Productivity improvements and results at EAS

The needed productivity for processing a ton of steel was 176 HH. With lean implementation it was necessary at most 127HH for the same work, with some reductions up to 90 HH. Due to the productivity improvement, it was estimated that it would reach between 80 and 90 HH in a few months, which would meet the expectations of the client PETROBRAS-TRANSPETRO. However, the planning of the new board was much more ambitious: it would reach in a short time the mark of 44 HH by processing a ton of steel and zero error, in building the new series of Suezmax-type vessels. This would be a competitive number even compared to the more productive international shipyards. Noticeable dramatic process improvements have which helped lessen the resistance to new changes.

> I used to make a flat block in eight days; today I make a flat block in four hours ... I used to make a sub-block that's one of our sub-assemblies around three days, and we're doing it in 35 minutes. So, those numbers are already measured with engineering control…when we designed and said we were going to make a block in four hours the staff said "will not do it". In fact, we did not it in four hours; we did in two (Corporate Production Manager) .

The increased productivity and process improvement have created a new paradox for the yard. With the amount of resources available at EAS, two ships could be built simultaneously on two production lines. However, the faster the ships are manufactured, the faster the portfolio orders would end. That is, if the shipyard would move fast in ship manufacturing, in two years it would no longer have orders to fulfill, which would be a problem if no new orders would have been placed.

Costs were reduced in the ship-to-ship production. The ninth ship (from the series of twelve SUEZMAX ships) was the first one without financial loss, and the tenth ship was the first

profitable one at EAS. No less important, in the view of the interviewees, there was a cultural change, especially work behaviors at tactical and operational levels.

> Today you can see that people are proud, beat in the chest to say that area is mine, in this area I am the boss. That was something that would not happen. Before, problems always used to escalate up and up; when there was an answer to the problem, the situation had already changed (Planning Director).

There is a general perception at EAS that top-down and bottom-up adaptations were made. The idea of autonomy with accountability has been bought by employees. People at the operational level are embracing their areas and solving most problems without having to turn to the boss. The cultural change has been described in an interesting way in the following dialogue:

> There was the stage when there was foolishness in the yard, and no one was punished or identified. Then, there was the phase where people with bad behaviors were identified, but not punished. And now, they have reached the stage when those who do nonsense are identified and punished for their mistakes. That matches the yard's CEOs turn for the last years (DMM Analyst).

EAS FUTURE PERSPECTIVES

The future perspective for EAS would become a fully “ship assembler" yard. In this sense, there is the understanding that ideally the production bottleneck would move to the dry dock. However, the remaining low order backlog does not encourage a significant increase in EAS production. In a fully “ship assembler" configuration, there would be a significant participation of systemists, who could occupy empty space at EAS site, delivering supplies directly to the EAS assembly line. The yard intends in the future not to buy only equipment or supplies but buying full services from suppliers. Thus, purchases would be based on utilization and not by acquiring inventory (that would be owned by suppliers).

> In the future I do not want to buy any welding machine, I want Supplier 1 and Supplier 2 to give me the best technology, the best wire, the best machine ... I do not want to buy EPI. I want to get on a machine and take EPI just like I buy Coca-Cola down there (at the vend-machine) ...I do not want to have inventory, I do not want to have suspended money. I want to pay just for what I use. (Corporate Production Manager)

There new board even foresees a future collaboration with the neighboring yard (PROMAR). A clear advantage of collaboration between these yards would be supply cost reduction for common parts, and even the deployment of common warehouses and sharing of service areas. This collaboration could also be supported by the complementarity of each shipyard's expertise. In that sense the demand of a yard for services that it does not do so well, would migrate to the neighboring shipyard and vice versa. Thus, PROMAR could be a potential future supplier of full blocks to EAS. The partnership between neighboring shipyards would be breaking the history of competition and non-collaboration between Brazilian shipyards. This new collaborative approach is assumed by the new board:

> Formally we have nothing (partnership with the neighbor yard) which is a shame for both of us. I have a very different position on this, the fact that they come here and see what we're doing does not mean they're going to do it, because if it was the case, everybody would make a car like Toyota. (Planning director)

CONCLUSIONS

P1Using the theoretical lens of lean manufacturing, we have analyzed significant improvements, especially productivity gains, at EAS, the largest Brazilian shipyard. We could verify in those changes not only the waste reduction pillar, but mainly the respect for people pillar, sometimes so neglected at the production and operations literature. All seven major wastes described in the literature were addresses by the EAS lean implementation. Leadership and commitment were the basis for a new organizational culture. Several strategic decisions, such as the elimination of most of outsourced functions, although going in the opposite direction to the one suggested by the literature (Liker & Lamb, 2000a), have helped waste reduction and productivity increase. Thus, like al best practices, lean manufacturing implementation must be adjusted to specific industrial contexts.

Contrary to the literature (Liker & Lamb, 200b), the lean system has been implemented at a time of crisis, leading to elimination of many jobs. On the other hand, the rapid results have strengthened a culture of excellence and commitment to productivity. Employee participation was so intense that it allowed the creation of a yard cultural identity, anchored at the lean production pillars. The four capabilities of the Toyota Production System have been gradually developed, processes and value chain ideas were designed, and waste reduction mechanisms were implemented. An improvement chain has been fed by information sharing, communication and continuous training.
We conclude that the major reason for lean implementation success at EAS was the human related pillar. This is in line with (Emblemsvag, 2014), which concludes that the human side, especially related to training and people empowerment, is important for lean deployment in the shipbuilding industry. The new board leadership has leveraged a massive employee participation and promoting a paradigm shift from and old-fashioned vision that some manufacturing best-practices may not be applicable to the shipbuilding industry. Thus, the production and operations literature should not overlook the importance of leadership at best-practices implementation. Finally, employee willingness to participate in something big was captured on the EAS CEO citation:

> What we are doing here is very basic but this was a motivation to make history, because of what we are going to do at this yard, we are going to make a different base for the whole (shipbuilding) industry to come and copy us (EAS CEO).

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DECISION SCIENCES INSTITUTE

Logo Symmetry for Brands that Promote Beauty as a Brand Promise: Theoretical Foundation and Content Analysis

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ABSTRACT

This study examined the use of symmetrical logo designs for products that promote beauty as a brand promise. We proposed that brands reflecting a 'beauty' component would have a greater proportion of logos that were symmetrical, compared to a sample of non-beauty brands. The results support this proposition.

KEYWORDS: Symmetry, logos, content analysis, brand promise, brands

INTRODUCTION

Logos are one of the graphic design elements of a brand and serve numerous important functions. Shimp (2007), for example, notes that logos serve as a 'shorthand way of identifying a brand." (p. 195). Watkins & Gonzenbach, (2013) state that logos help communicate the *personality* of the brand (or organization) to the target audience. Hynes (2009) reminds us that logos can act as a mark of quality and a way to increase a company's reputation. Finally, logos help differentiate the brand from competing alternatives (Janiszewski and Meyvis, 2001; MacInnis, Shapiro, and Manu, 1999; Park, Eisingerich, Pol, G. and Park, 2013).

As such, logos should be designed to ensure that they effectively communicate the appropriate message to the intended target audience. In this study, we restrict our analysis to the concept of symmetry, which Merriam-Webster defines as "the quality of something that has two sides or halves that are the same or very close in size, shape, and position" (http://www.merriam-webster.com/dictionary/symmetry). Research has shown that symmetry is associated with a perceptions of attractiveness and beauty (Enquist and Arak , 1994; Rhodes, Proffitt, Grady, & Sumich, 1998; Rhodes, Sumich, & Byatt, 1999; Berri, Simmons, Van Gilder, & O'Neill, 2011). Based on this evidence, we propose that logo symmetry would be particularly relevant in

industry sectors that promote beauty and attractiveness as a core brand promise. In particular, it is argued that logo symmetry would be particularly meaningful for brands that reflect elements of beauty as part of their selling proposition. In this study, we examine brand logos from the cosmetic and fashion industries.
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The rationale for selecting these industries is supported by their market characteristics. With regard to hari care, the FDA defines cosmetics as "intended to be applied to the human body for cleansing, *beautifying*, promoting *attractiveness*, or altering the appearance without affecting the body's structure or functions." Similarly, Phillips and McQuarrie (2009) note that advertising in the fashion industry “is conceived as a means for presenting an idealized image to which women are taught to aspire” which implies that beauty and attractiveness are central to the intended message (58). Flower and Carlson (2015) build on this by reminding that many of the fashion images in fashion advertising rely on the “ideals of fashion, beauty, and even sexuality (Ger and Belk 1996; Hung et al. 2007; Fowler 2012).” (136-37) As such, the cosmetic and fashion industries are appropriate for the current study.

We begin the study with a brief review of the concept of symmetry and its relationship to perceptions of attractiveness. As an exploratory analysis, we then propose that logo designs for beauty brands are more likely than non-beauty brands to utilize symmetrical logos. The method of analysis is then presented, followed by the results. We conclude with a discussion of the managerial implications and directions for further research in this area.

LITERATURE REVIEW

At the fundamental level, Henderson and Cote (1998) remind us that good logos are: (1) easily recognized, (2) convey the same meaning to members of the intended target audience, and (3) evoke positive feelings. These general guidelines are intended to assist brand managers with a useful template for developing an appropriate logo. This review focuses on the third guideline with an emphasis on the relationship between design symmetry and positive affect.

In this regard, the graphic design literature has long argued that symmetry elicits a positive affect relative to asymmetry (Dondis, 1973; Bevlin, 1989). More recently, it has been shown that the positive effect of symmetry may depend on what is being measured. Bajaj and Bond (2014) found that symmetrical logo designs were rated higher by respondents than asymmetrical designs in terms of ‘artistic quality’. Conversely, asymmetric designs were rated higher in terms of ‘energy’. The important implication to be taken from this research is that the decision to use either a symmetrical or asymmetrical design should be based on the objective at hand. In other words, symmetry is but one factor to be considered in the design of a logo.

Nonetheless, the overall evidence linking symmetrical designs to positive affects is relatively strong. Henderson and Cote (1998), for example, cite research demonstrating that symmetry “is the primary determinant of pattern ‘goodness,’ which produces positive affect”. (16) (Clement, 1964; Garner and Clement, 1963). A review of synonyms for ‘goodness’ include such terms as *decency*, *morality*, *integrity*, *virtuousness* while antonyms include such terms as *badness*, *evil*, and *immorality*. suggests that the notion of ‘goodness’ implies elements of ethical and socially desirable behavior. (http://www.merriam-webster.com/dictionary/goodness). It would appear, therefore, that logo designs that reflect symmetry are more likely to be viewed from the perspective of ‘goodness’, a positive affect.

In a related study, Enquist and Arak (1994) examined the influence of symmetry and found that it was positively related to perceptions of *attractiveness*. The notion of attractiveness can be considered a positive affect given its definition: 'the qualities in a person or thing that as a whole give pleasure to the senses' (http://www.merriam-webster.com/thesaurus/attractiveness).

Using attractiveness as the outcome variable, Enquist and Arak found that respondents perceived symmetrical patterns to be more attractive than asymmetrical ones. Furthermore, they posited that the preference for symmetrical designs may result from a universal need to recognize objects; as indidivuals learn to recognize objects, 'preferences can develop for particular forms that have no objective existance in nature'. (p. 21, Watson & Thornhill, 1994) This explanation is consistent with a suggestion by Henderson and Cote (1998) that good logos should be easily recognized.

Symmetrical designs have also been shown to be processed more efficiently as well (Reber, 2002; Reber, Schwarz, & Winkielman, 2004). The central argument is that symmetrical designs generate better processing fluency because symmetrical designs can be elaborated on more efficiently. Similarly, Garner (1974) argued that symmetrical designs are more easily processed because they have less information than asymmetrical ones.

Given the evidence on symmetry, it would seem particularly relevant for industries that emphasize attractiveness and beauty as part of their "brand promise" to use symmetrical logos. In this regard, a brand promise can be defined as the marketer's vision of what the brand must be and do for consumers (Kotler and Keller, 2009) and this is most commonly communicated to the intended audience through promotional activities. Given: (1) the cosmetic and fashion industries use of attractiveness and beauty as a brand promise and (2) the relationship between symmetry and perceived beauty, then (3) an analysis of the degree to which logo symmetry is evident in these industries appears warranted.

If the results reveal that beauty brands utilize symmetrical logo designs, it would imply that beauty brands are relying on scientific evidence to guide decision making. Conversely, should the logo designs show that beauty brands do not utilize symmetrical design to any greater or lesser extent than non-beauty brands, it would imply that companies in these industries are not responding to the scientific evidence. In either case, the results will reveal the efficiency of the market in adopting established evidence regarding the relationship between beauty and symmetry.

Based on this review, we present the following hypothesis:

H1: Logo designs for beauty brands will reflect greater symmetry than logo designs for non-beauty brands.

METHOD

The samples were obtained by reviewing online listings of fashion and hair care brands. A sample of leading U.S. charitable organizations was also utilized to serve as the comparison group. We selected charitable organizations because their core brand promise does not focus on elements of beauty. As such, charities represent a meaningful contrast to beauty brands. Based on guidelines by Henderson and Cote (1998) on logo design, two coders were trained to distinguish between symmetrical and asymmetrical designs. Any discrepancies were resolved through consultation with a third coder. Brands that did not utilize a logo were excluded from the analysis.

The test for differences between the groups, a cross-tabulation was developed and evaluated through the use of the Pearson chi-square statistic. Cross tabulation analysis (also known as contingency table analysis) is a common method for analyzing categorical data (nominal measurements). Qualtrics (2011) estimates that more than 90% of all industry analyses involve cross tabulations.

RESULTS

The data for the cross-tabulation is presented in Table 1. Each data cell contains information on the observed value (Obs Val), the expected value (Exp Val) and the individual X^2 values for each cell. Hair-care and fashion were combined into the category 'beauty brands'. Charitable organizations were categorized as 'non-beauty brands". For this data, the X^2 is 4.41, with 1 degree of freedom (p-value = .036), supporting the hypothesis that the sample of beauty brands will have a higher proportion of symmetrical logos relative to the sample of non-beauty brands.

Table 1: Data and Analysis of Cross Tabulations

	Symmetrical Design	**Asymmetrical Design**	**Total**
Beauty brands	Obs Val = 39 Exp Val = 33.86 X^2 =	Obs Val =18 Exp Value = 23.14 X^2 =	N=57
Non-Beauty brands	Obs Val = 21 Exp Value = 26.14 X^2 =	Obs Val = 23 Expected Value =17.86 X^2 =	N=44
Total	N=60	N=41	N=101
Decision	X^2 Statistic = 4.41 P<.05 (.036)	Decision: .036<.05 The groups differ in the proportions of symmetrical versus asymmetrical logos.	

DISCUSSION AND CONCLUSIONS

This exploratory study examined logo designs from a sample of brands characterized as reflecting 'beauty' as a brand promise and compared them with logo designs from a sample of brands that do no promote beauty as a brand promise. Based on the evidence presented in the literature, it was hypothesized that beauty brands would have a higher proportion of symmetrical logos relative to non-beauty brands. The results support the hypothesis, although it was also shown that not every beauty brand utilized a symmetrical logo.

While the results support the notion of relatively efficient transfer of research to practice, one might reasonably ask: if the evidence is strong, why haven't even more beauty brands used symmetrical logos? Studies have commented on this issue and provide some useful insights on what is commonly referred to as the 'research-practice gap' (Gill, 2018). Kauppinen-Räisänen and Grönroos (2015), for example, presented ideas on how to 'bridge the gap' between scholarly knowledge and business practice in services. Cascio (2007) notes that academics

use management science 'to create new knowledge' but practitioners 'are not always receptive to academic theory". Bogomolova, Szabo, & Kennedy (2017) studied the factors that influence price-promotion decisions and found that they were most often based on "intuition and untested assumptions" rather than evidence from the literature. These representative examples suggest that the evidence presented through scholarly research is sometimes, and perhaps often, not utilized by practitioners; i.e., there is an apparent gap between research and practice.

What factors hinder the adoption of research knowledge? Barends and colleagues (2017) addressed this issue and found that while most managers in their survey reported having positive attitudes towards scientific research, they also indicated that they lacked the time needed to review it and, even when they have the time, they have a limited understanding of it.

In this context, the apparent gap between scientific evidence and practice is somewhat understandable; scientific journals and other related forums typically use writing styles and norms that might not be readily understood by those not in the scholarly academy. As such, scientific articles it is sometime claimed that scientific articles are often read only by a small group of like-minded scholars. Here is how Donald Hambrick explained it during his presidential address at the Academy of Management Annual Meeting (1993):

> 'Each August, we come to talk with each other; during the rest of the year we read each other's papers in our journals and write our own papers so that we may, in turn, have an audience the following August—an incestuous, closed loop' (p. 492, as reported in Hamet and Maurer, 2017).

To help mitigate the gap between research and practice, scientific research is sometimes re-written to appeal to a wider audience. For example, Thompson, Hamilton, and Rust (2005) published an article in the *Journal of Marketing Research* that investigated the concept of 'feature fatigue'. Subsequently, the Harvard Business Review published a more practitioner-oriented version of the same research and by the same authors. In this way, it would appear that the market has developed a means for disseminating knowledge to a wider audience.

In other contexts, decision makers may understand the knowledge, but fail to act upon it. Pfeffer and Sutton (1999) refer to this phenomenon as the 'knowing-doing' gap. They attribute it to a basic human propensity: 'the willingness to let talk substitute for action'. (136) That is, when confronted with a problem, 'people act as if discussing it, formulating decisions, and hashing out plans for action are the same as actually fixing it.' (136). In their cross-sectional study of companies, Pfeffer and Sutton found that companies often do substitute talk for action. But, there is a remedy: the authors found that when Xerox was required to document quality improvements (and the managerial practices that led to the improvement), meaningful action occurred.

With respect to the current study, it appears that the knowing-doing gap is not very evident; that is, logos for beauty brands do tend to reflect the evidence in the literature. This was, of course, expected given the strength of the evidence and the fact that our understanding of the relationship between symmetry and positive perceptions has been known for over 50 years. (e.g., Clement, 1964). However, it would be interesting to know whether the logos were developed using the research evidence or if they were developed based on some other criteria. Additionally, it would be interesting to determine which came first? It may be that some brands developed symmetrical logos irrespective of the scientific evidence.

Finally, it is important to clarify the intent of this study. Overall, the investigation was only intended to document the use of symmetrical logo design by beauty brands and compare the proportions with a sample of logos from non-beauty brands. It did not examine the effectiveness of the logo design nor did it investigate the reasons that managers decided to use symmetry. As noted above, additional research is needed to better understand the rationale used by management to incorporate certain design characteristics into their logo. The results of this exploratory study, however, provide support for further investigations.

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DECISION SCIENCES INSTITUTE
Machine Learning Pairs Trading using Google Tensorflow

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ABSTRACT

Many financial trading strategies are statistically based. Wouldn't a machine learning system be a perfect fit, to run optimal mathematical trading strategies? The idea of machine learning financial trading is nothing new. This paper takes an approach using some of the latest machine learning techniques including Google's Neural Network, Tensorflow.

KEYWORDS: Machine Learning, Neural Networks, Pairs Trading

INTRODUCTION

Pairs trading looks at the relationship of financial instruments or commodities that are cointegrated, in our example cheese and milk futures, in which we traded one instrument based on the movements of the other. In the case of cheese and milk futures, when the prices of the two converged closer together, we sold the higher priced milk and bought the lower priced cheese. When the prices converged back to the mean, one or both positions would be profitable. If one understands the cointegration relationship, one can better predict price movements(Engle and Granger, 1987). In other words, we could watch the prices of milk and cheese futures, and predict, in some instances, price movements based on their cointegrated relationship.

Google Tensorflow was used to create a layer of perceptrons in a Neural Network to test for cointegration. We showed that Tensorflow can be used to pick out possible pairs of commodities which are good candidates for pairs trading. Essentially each perceptron tested whether or not it detected cointegration, and at what level. The next layer performed a trading test to see whether, a simple pairs trading strategy was profitable for that pair. The following is an example of milk and cheese future prices, which we detected as highly cointegrated by Tensorflow, then tested with a pairs trading strategy, and found to be profitable.

```
total buys:  4.0
total sells:  3.0
milk profit:  4.26
cheese profit:  -0.284
total profit:  3.976
Beginning cash:  1000.0
Final cash:  1313.03758907
```

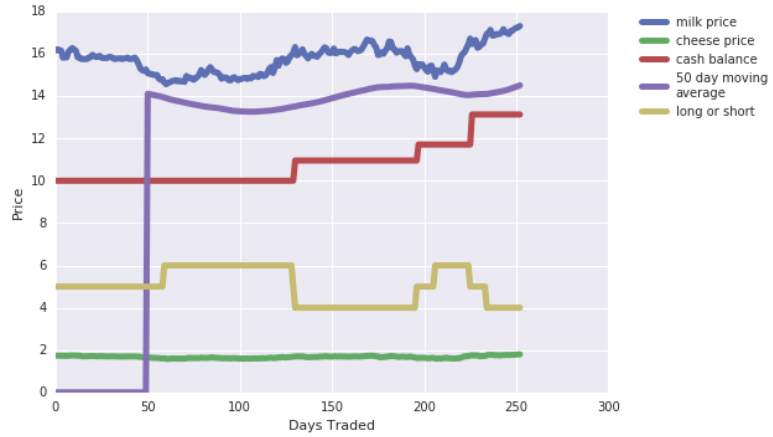

Fig. 1 Milk and Cheese Pairs Trading Simulation Results

Figure 1 shows the results of a trading simulation for milk and cheese future prices, run by Tensorflow. The returns for trading milk and cheese for one year was 31.3% percent. This is an extremely successful trading strategy, especially for commodities such as milk and cheese. The figure shows the price of milk and cheese over the last 12 months, and the results of our pairs trading algorithm. The blue and green lines represent the prices of milk and cheese. The purple line shows the moving average of the price difference between milk and cheese, which is used to generate buy and sell signals. The red line is our cash balance beginning at $1000.00, scaled down 1/10 and then overlaid on the graph. The yellow line is a buy or sell signal, also overlaid on the graph to show buys (line up) and sells (line down). When we saw the moving average line coming down, we bought milk and sold cheese expecting the price to move back up to the average. Conversely, when the line went up, we sold milk and bought cheese.

The period of 12 months was found to be optimal by Tensorflow based on its cointegration test of 12 months worth of milk and cheese prices. The first layer of perceptrons in Tensorflow used the Augmented Dickey-Fuller test (ADF) for cointegration (at a 95% confidence interval). Results of the statistical test allowed us to determine whether or not the pair was cointegrated.

PAIRS TRADING

Pairs trading is a strategy that simultaneously buys and sells a pair of financial instruments, or commodities, that are cointegrated. If the two instruments are highly cointegrated and their prices diverge from each other, then in time the prices will correct (Engle and Granger, 1987). In pairs trading, one observes deviations from the mean of the difference of the two prices in the pair, and places simultaneous buy and sell positions when they occur.

A common analogy for a cointegrated pair is a drunk man walking a dog(Murray, 1993). The drunk man performs a random walk and the dog follows. While the two may appear as two random walks, they always move together because of the leash. Similarly, if cheese and milk prices are cointegrated, one may expect prices that are far apart to converge back to a mean. If the prices are too close, they will diverge away to the mean. The mean gives us a baseline to determine trading opportunities.

In the example of milk and cheese, let's say the average price of a milk future is around $16.00 and the average price of a cheese future is $1.75. This makes an average difference of $14.25, a good baseline to make trading decisions. In this instance, we used a ceiling of 107% (or $15.25) and a floor of 93% (or $13.25). An array of possible floors and ceilings were tested, ie. 107%/93%, 105%/95%, and 103%/98%. A ceiling of 107% (or $15.25) and a floor of 93% were found to be optimal. If the average difference of milk and cheese went above $15.25, then we said that these cointegrated prices were too far apart, and we expected them to converge back to $14.25. If the average difference went below $13.25 we expected the prices to diverge back to $14.25. When we detected the prices to be too far apart, we took a short (selling) position in milk, and a long (buying) position in cheese, expecting that when the difference in price converged back to the mean, the price of milk would have gone down and cheese up. This strategy is market risk neutral, inasmuch as we don't care what the rest of the market is doing. We simply care about the current price difference between milk and cheese, the average price difference between milk and cheese, and the cointegrated value.

Even if both positions are not profitable it is likely that at least one position will be. This is where machine learning can help us. Testing for cointegration is statistical, and Tensorflow allows us to do the testing more efficiently and dynamically while performing trading simulations at the same time.

PROPOSED METHOD

To pairs trade, cointegrated pairs are needed, preferably, as highly cointegrated as possible. Using the previous analogy, we wanted to find a drunk/dog pair with a strongly elastic leash that we could dependably predict will continue to come back to the mean. This is where a Neural Net, such as Tensorflow can help. A tensor is simply an array of numbers. We created a neural network where the inputs and outputs to the perceptrons were all tensors. The perceptrons can be programmed to perform any task. In our case the perceptrons tested for cointegration. Additionally they can take any tensor as input, and they can easily scale as the input datasets become very large.

In our case, we created the first layer in our Tensorflow NN to calculate cointegration. Each perceptron will receive a pair of milk and cheese prices. Because all of the prices were cheese and milk futures, for testing purposes, we used a variety of time frames ranging from 1 month and 4 years. After each perceptron received its data (a tensor), and ran an ADF test. The ADF at a 95% confidence level told us, whether or not we can with a 95% confidence reject the null hypothesis that cointegration did not exist. For our purposes we considered this sufficient to move forward under the assumption that cointegration existed enough to test with a trading simulation.

The results from the perceptrons indicated that the longest time frame tested, in this case 48 months, did exhibit the highest cointegration. However, once we got to 12 months the cointegration yielded a very small change as we moved out to 48 months. In other words, 1 year's worth of

milk and cheese prices had a higher cointegration that any time frame shorter and very similar to any time frame longer. Therefore, for running trade simulation purposes, 1 year's worth of cheese and milk prices will yield returns, sufficient to prove out a pairs trading strategy.

The first layer of our NN perceptrons included cheese and milk prices as inputs. The output was then passed to the second layer which ran a pairs trading simulation test. Because most of the inputs were subsets of 1 year, running the trade simulation test for 1 year yielded the same performance results for any time frame shorter than 1 year. We intended to demonstrate that machine learning can give us the tools to find good pairs for pair trading, and to test to see how well they perform in trading strategies. We also showed that Tensorflow works well for this purpose.

The technologies used included: Google Tensorflow, Google Datalab to run Tensorflow and host jupyter notebooks used for testing. python 2.7.9 on Linux Ubuntu. The milk and cheese prices were supplied by websole.barchart.com via json api.

EXPERIMENT

We used Google Tensorflow, running on Google Datalab, to build a Neural Network. First, we retrieved cheese and milk futures prices from websole.barchart.com via their json api. The data was then cleaned and stored in nd arrays. The data pulled from websole.barchart.com was requested in increments to be tested for cointegration in our perceptrons in the NN. Initially we test for cointegration in cheese and milk for the time frames: 1, 2, 3, 4, 5, 6, 9, 12, 24, 36 and 48 months. As shown in the results section, the ADF critical score was -2.86 (between -5 to 5 is desired) as we approach 12 months. Beyond 12 months, the critical score remained close to -2.86 as the time period increases. 12 months was adequate to establish maximum cointegration for cheese and milk futures.

In a Tensorflow perceptron, the functionality is customized. In our environment we created perceptrons to check for cointegration at different time intervals, and then ran trading simulations to test for profitability using a classical pairs trading strategy. First, we created a session for the perceptron to run. The inputs were nd arrays of milk and cheese prices supplied for the given time frame. The output was an nd array with the ADF values for the critical values 1, 5 and 10%. An example perceptron output would be: [-3.44363, -2.8673966, -2.5698893]. This was interpreted as a 1% critical value of -3.44, a 5% critical value of -2.86, and a 10% critical value of -2.56. The example perceptron output suggested that the pair in question could be treated as cointegrated.

After the pairs were tested for cointegration, we proceeded with the trading simulation test. A future work would create a multi-layer NN with multiple types of pairs, with trading tests comprising the layers of the NN. For testing purposes, we simply performed a trading simulation test for 12 months' worth of cheese and milk prices.

TRADING SIMULATION

The trading simulation used real prices, and allowed us to test if a simple pairs trading strategy would be profitable over time. The strategy kept track of the moving average of the change between milk and cheese futures prices. As shown in Figure 1, the average price difference between cheese and milk is an estimated $14.25. The moving average of the difference, changes as the price changes and we keep track of this. Any time the price difference increases past 7% over the moving average,

or decreased 7% below the average we simultaneously bought and sold milk and cheese futures, expecting the price to correct, thereby making our positions profitable.

In Figure 1, the yellow line is not a price, but rather a signal that shows whether we are long or short milk. When the price of milk moved down initially, we entered a long position for milk, expecting the price to rise. The price did rise back to the moving average and we sold, creating a profit as shown in our cash balance. The price of milk continued to rise, until it is above 7% over the moving average. At that point we shorted milk, as shown by the yellow line. Once the price corrects, or return back to the moving average, we closed the short contract. We see our profit in the cash balance.

This cycle repeated again twice more, one long and one short position. In our 12 month simulation, this trading strategy produced a cash balance increase from $1000.00 to $1313, or a portfolio increase of 31.3%. Figure 2 shows simulation output for a single trade (not the entire simulation).

```
buying tight 0.93587128612
Long milk at:  14.65
Short cheeses at:  1.61
untighten 1.00409263636
cash before:  1000.0
Milk buy,sell prices,delta:  14.65 15.23 0.58
Cheese buy,sell prices,delta:  1.643 1.61 -0.033
new cash:  1039.59044369
```

Fig. 2 Example simulation trade performed by a perceptron

RESULTS

The trading simulation output shows the buy and sell positional movements as the simulation detects trading opportunities. In the trade output above you can see the simulation detects a "tight" scenario, or the price difference converging away from the moving average. We bought milk at $14.65, and sold cheese at $1.61. You can see, once the spread moved back to the average the positions are closed, resulting in a new cash balance of $1039.59, and a profit of $39.59 or 3.959% for the trade.

Figure 3 is a sample output from a perceptron performing a cointegration test on 12 months of cheese and milk futures prices. As part of the ADF test, it performed a regression on the pair, then tested the residuals for a unit root. At the end of the output, the ADF critical value of 5% is shown, indicating that we can with a 95% confidence interval, reject the null hypothesis that cointegration does not exist.

```
-----------------------Summary of Estimated Coefficients-----------------------
      Variable       Coef    Std Err      t-stat    p-value    CI 2.5%   CI 97.5%
--------------------------------------------------------------------------------
             x     0.0932     0.0022       42.02     0.0000     0.0889     0.0976
     intercept     0.2196     0.0359        6.12     0.0000     0.1492     0.2899
--------------------------------End of Summary--------------------------------

beta_hr:  0.0932451901286
(-1.3241444770264166,
 0.61805508213558213,
 0,
 495,
 {'1%': -3.4436298692815304,
  '10%': -2.5698893429241916,
  '5%': -2.8673965998934352},
```

Fig. 3 Cointegration test perceptron output

Below is shown the nd array output from Tensorflow. Each perceptron returns an nd array consisting of 1 5 and 10% critical values. The time frames tested are: 1, 2, 3, 4, 5, 6, 9, 12, 24, 36, 48 Months. The middle value, 4th from the bottom, is -2.87. This is the value for 12 months. As previously mentioned it takes about a years worth of prices to reach this value, and then it stays there from one to four years. Indicating, for cheese and milk, 12 months is enough time to observe the highest cointegration within the pair.

```
perceptron coints:  [-3.44363, -2.8673966, -2.5698893]
[array([-3.45656896, -2.87307858, -2.57291889], dtype=float32),
 array([-4.22323847, -3.18936896, -2.72983932], dtype=float32),
 array([-3.59663558, -2.9332974 , -2.60499096], dtype=float32),
 array([-3.53869534, -2.90864468, -2.59189677], dtype=float32),
```

Fig. 4 Cointegration test output for multiple time frames

CONCLUSION

The intent of this study was to test whether Tensorflow NN can be used to detect highly cointegrated pairs. The research tested that relationship with a classical pairs trading strategy to verify it's profitability. The pairs trading strategy tested yielded 31.1% returns. We showed that an NN layer of perceptrons performing ADF tests for cointegration can be effective and scalable. As the demand for testing more and more pairs grows, Tensorflow can easily create more perceptrons and more layers in the NN to handle more data. In this experiment, we limited ourselves to a classical pairs trading strategy to verify the usability of the cointegrated pair in a trading environment. However, using Tensorflow, one may easily use customized types of trading simulation tests. We conclude that machine learning techniques and mathematically based trading strategies work very well together.

FUTURE WORK

Pairs of financial instruments used for pairs trading can come from the stock and bond markets, commodities, FX currency pairs, and derivatives markets including: rates derivatives, credit derivatives, and other futures and options. It is conceivable that the data from an infinite array fo pairs

can be tested in a Tensorflow NN.

Additionally, there is room for expanding the types of tests possible on those pairs. One could add more customized pairs trading strategies, or other tests entirely. For example, for stocks market prices, one could add layers in the NN to derive information regarding the company's financial health information or media feeds.

CODE

The code can be viewed at github: `https://github.com/abrim24/fin5350/blob/master/chees_milk_cointegration.ipynb`

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DECISION SCIENCES INSTITUTE
Managing Service Operations with Quality-Conscious Consumers

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ABSTRACT

We investigate the optimal quality strategy and the service fee and capacity decisions of a service system with quality-conscious consumers. We find offering a high quality service by charging a higher price with a feasibly larger capacity is more profitable when informed consumers become more quality-conscious. With both informed and uninformed consumers, by using a threshold-based quality perception strategy, we find either the high or low quality strategy may be adopted and maintained the capacity serving the market at the threshold level. The results advance our understanding of the commonly observed queuing phenomenon in service industries with theoretical insights.

KEYWORDS: Quality strategy, Service design, Pricing, Capacity, M/M/1 Queue

INTRODUCTION

In all the branches of Din Tai Fung in Taiwan [Din Tai Fung has close to 150 branches around the world as of June 2018], a chain restaurant known for its xiaolongbao, long queues are always observed. Diners regularly queue for an hour or longer during peak hours for its signature steamed dumplings (Hwarng and Yuan, 2016). There are many possible reasons that consumers are willing to wait eagerly and patiently for certain popular products or services. One of the main reasons is quality. Indeed, consumers are becoming increasingly quality-conscious. However, long waiting time may inadvertently drive potential consumers away even though quality is the reason for forming long queues.

In the increasingly competitive and socially-networked market, consumers are becoming more conscious or demanding in product and service quality. Services of higher quality are usually

perceived to be of higher value. Thus, delivering high quality services arguably is the best sustainable strategy for success in today's competitive business environment. Although service providers have recognised the importance of service quality, providing high quality services can be costly. While Philip Crosby, known as a quality guru, asserted that "quality is free", an organisation has to invest heavily and "makes certain its products and services are delivered to the customer by a management system that does not condone rework, repair, waste or non-conformance of any sort." At Din Tai Fung Taiwan, in order to maintain the high quality standard, more than 50% of the revenue was invested in staff training, benefits and salaries, that are among the highest in the industry (Hwarng and Yuan, 2016). Therefore, to service providers, how to execute a sustainable strategy through its decisions in quality, price, and capacity is critically important.

In this paper, we investigate the appropriate quality strategy and its associated decisions in capacity and price for a service provider when facing quality-conscious consumers. We consider two categories of cases. First, the case with all informed consumers, e.g., the service quality is publicly known, is considered the benchmark case. Second, the case with both informed and uninformed consumers, we focus on a *threshold-based quality perception* used by uninformed consumers to form their opinions about quality of the service. The findings provide both theoretical as well as practical insights for service operations.

LITERATURE REVIEW

This paper builds on and advances two streams of literature, namely consumers' quality perception and purchase decision-making in service consumption, and the price and capacity decisions in service operations with delay sensitive and quality-conscious consumers.

A more extensive review of relevant literature is available upon request.

MODEL SETUP

Our model is motivated by Din Tai Fung's operations in the dinning and hospitality industry. A service provider offers a service of quality q to consumers in the market with a potential size Λ. Consumers are *quality-conscious*, where high quality services are always preferred. Generally, given all the other conditions fixed, the higher quality of the service is, the larger service value to consumers. The service provider first decides her quality strategy, and after that makes decisions on the service fee, denoted by p, and the service capacity which is measured by the service rate, μ. As quality is often a long-term operational strategy, the service fee and capacity decisions are dependent on the service quality strategy. Consumers can observe the service fee and capacity before making purchase decisions. However, service quality may be unknown to all or some consumers.

We assume the service is delivered through an M/M/1 queue system, where consumers have to join the queue to procure the service. We assume the queue is unobservable so that consumers have to take into account the expected waiting time when making purchase decisions. Consumers are *forward-looking* when making queue-joining decisions, in the sense that purchase decisions are made based on the comparison between the expected values from procuring the service and the reservation values before joining the queue.

We model consumers' value perception by the framework proposed by Zeithaml (1988). We use the superscript E to denote consumers' perception/expectation before joining the queue.

Given the service fee and capacity, based on the *percieved service quality*, q^E, an arriving consumer calculates the expected value based on his perception from purchasing the service, defined as below:

$$V^E = V(q^E) - p - CW(\lambda, \mu), \tag{1}$$

where $V(q)$ is the *service value* when the quality level is q, and $CW(\lambda, \mu)$ is the expected waiting cost when the arrival rate is λ, defined as

$$CW(\lambda, \mu) = \begin{cases} \frac{w}{\mu - \lambda}, & 0 \le \lambda < \mu, \\ +\infty, & \mu \le \lambda \le \Lambda, \end{cases}$$

where w is the waiting cost per unit time.

The service value depends on the *intrinsic value* of the service, denoted by v, and its quality. For analytical tractability, we assume the service value is the sum of the intrinsic value of the service and the quality of the service such that

$$V(q) = v + \alpha q, \tag{2}$$

where $\alpha \in [0, \bar{\alpha}]$ measures consumers' *quality-consciousness*, i.e., consumers always perceive a larger service value when the quality becomes higher. [Note that from consumers' perspective, the intrinsic value of the service and its quality may be interdependent, i.e., v depends on q. We refrain from such formulation for analytical tractability.] A consumer's reservation value is denoted by $V^r \ge 0$. The reservation value captures the consumption choices from other substitutable service options. Therefore, if $V^E \ge V^r$, an arriving consumer will join the queue to procure the service.

Denote the *effective arrival rate* as λ, which depends on the service capacity and service fee as well as consumers' perceived service quality, i.e., $\lambda = \lambda(\mu, p; q^E)$ such that

$$v + \alpha q^E - p - \frac{w}{\mu - \lambda} \ge V^r,\ \lambda \in [0, \Lambda],\ \lambda < \mu. \tag{3}$$

Note that the effective arrival rate depends on the perceived service quality. Therefore, how consumers perceive the service quality becomes critical, especially when they have different levels of information regarding the true service quality.

The service provider can always expand the service capacity to provide a faster service, or charge a lower service fee to attract more demand. To maintain the intrinsic service value and quality, expanding service capacity is at the cost of $C(\mu; q)$, which measures the *marginal capacity cost per unit time* and increases in μ when the service quality is q. We assume there are two service quality levels, q_H and q_L, with $q_H > q_L \ge 0$. If the service with quality q_H is offered, then we say that the service provider adopts the high quality strategy; otherwise, she adopts the low quality strategy. The capacity cost is linear in terms of the service rate μ for expositional simplicity such that $C(\mu; q_H) = \beta_H \mu$ with a high service quality, and $C(\mu; q_L) = \beta_L \mu$ when the service quality is low, where $\beta_H > \beta_L > 0$. The parameters β_H and β_L measure the *marginal capacity cost per unit capacity and time* when the service quality is high and low, respectively.

In the following analysis, we assume the following condition holds:

$$v \ge 2\sqrt{\beta_H w} + V^r. \tag{4}$$

The service provider knows consumers' quality-consciousness, and first decides the service quality strategy $i \in \{H, L\}$, and then chooses μ and p to maximize her expected profit rate taking

consumers' quality perception into account, as below

$$\max_{q_i\in\{q_H,q_L\},\mu>0,p\geq 0}\{\pi(\mu,p;q_i)\}=\max_{q_i\in\{q_H,q_L\}}\left\{\max_{\mu>0,p\geq 0}\left\{(p-\beta_i\mu)\lambda(\mu,p;q^E)\right\}\right\}. \tag{5}$$

As the effective arrival rate depends on consumers' quality perception, the above profit maximization problem suggests that service provider's quality strategy and operational decisions depend on consumers' perception about the service quality.

THE CASE WITH INFORMED CONSUMERS

When the service quality is common knowledge, all consumers know the exact quality of the service. Thus, consumers' peceived quality confirms with the actual service quality, i.e., $q^E=q$.

We use the superscript m to denote the optimal decisions and the effective arrival rate as well as the profit. The following result in terms of the optimal service fee and capacity decisions under the case with informed consumers holds. All the proofs are available from the authors upon request.

Proposition 1 *Given the quality strategy $i\in\{H,L\}$, the optimal service capacity and service fee are given as $\mu_i^m=\lambda_i^m+\sqrt{\frac{w}{\beta_i}}$ and $p_i^m=v+\alpha q_i-\sqrt{\beta_i w}-V^r$, respectively, and the optimal profit is $\pi_i^m=\left(v+\alpha q_i-2\sqrt{\beta_i w}-\beta_i\lambda_i^m-V^r\right)\lambda_i^m$, where $\lambda_i^m=\min(\lambda_i,\Lambda)$ is the effective arrival rate, and λ_i is given by*

$$\lambda_i=\frac{v+\alpha q_i-2\sqrt{\beta_i w}-V^r}{2\beta_i}. \tag{6}$$

The impact of consumers' quality-consciousness

In order to ensure the attractiveness of the high quality strategy for the service provider to adopt, we make the following assumption in terms of the *quality-cost ratio*,

$$\frac{q_L}{\beta_L}<\frac{q_H}{\beta_H}, \tag{7}$$

i.e., compared between the two quality strategies, the quality-cost ratio under the low quality strategy is smaller than that under the high quality strategy.

For ease of analysis, we assume the potential market size Λ is large enough such that $\Lambda>\max(\lambda_H,\lambda_L)$. The quality-cost efficiency assumption (7) for the two quality strategies implies the following result:

Corollary 1 *Suppose the potential market size Λ is large enough. There exist quality-consciousness levels $0<\alpha_1<\alpha_2<\alpha_3<\alpha_4$ such that*

- *if $\alpha\geq\alpha_1$, then $p_H^m\geq p_L^m$, i.e., the optimal price under the high quality strategy is higher than that under the low quality strategy;*
- *if $\alpha\geq\alpha_2$, then $\pi_H^m\geq\pi_L^m$, i.e., the optimal profit under the high quality strategy is higher than that under the low quality strategy;*
- *if $\alpha\geq\alpha_3$, then $\lambda_H^m\geq\lambda_L^m$, i.e., the optimal arrival rate under the high quality strategy is higher than that under the low quality strategy;*

- *if $\alpha \geq \alpha_4$, then $\mu_H^m \geq \mu_L^m$, i.e., the optimal capacity under the high quality strategy is higher than that under the low quality strategy.*

Corollary 1 indicates that consumers' quality-consciousness affects the operational performance of the service provider under the two quality strategies.

THE CASE WITH INFORMED AND UNINFORMED CONSUMERS

In this section, we consider the case with heterogeneous consumers where they have different information about the service quality. However, all consumers have the same level of quality-consciousness, which is known to the service provider. We assume the proportions of informed and uninformed consumers in the market are $\phi \in [0, 1]$ and $1 - \phi$, respectively, which are known to the service provider. Uninformed consumers know that some consumers are informed about the service quality; however, they do not know the exact composition of consumers in the market.

As widely observed in reality or laboratory experiments, consumers often infer the quality of a product or service by the sale quantity. Therefore, in this section, we consider uninformed consumers use the following *threshold-based perception strategy* to infer the service quality, where the threshold is charaterized by a demand rate λ_b:

- The *high-demand-high-quality* perception strategy, where

  > *If the effective arrival rate is larger than λ_b, then uninformed consumers will perceive a high service quality; otherwise, uninformed consumers will perceive a low service quality.*

We also investigate the case with the *high-demand-low-quality* perception strategy adopted by the low quality-conscious consumers in the long version of this paper, which is available upon request. By Proposition 1, we first consider two special scenarios where uninformed consumers' quality perception is opposite to the actual service quality. The first scenario is when the actual service quality is low, but uninformed consumers perceive it high. Denote the effective arrival rate as

$$\lambda_L^H = \frac{v + \alpha q_H - 2\sqrt{\beta_L w} - V^r}{2\beta_L} > \max(\lambda_H, \lambda_L). \tag{8}$$

The second scenario is when the actual service quality is high, but uninformed consumers perceive it low. Denote the effective arrival rate as

$$\lambda_H^L = \frac{v + \alpha q_L - 2\sqrt{\beta_H w} - V^r}{2\beta_H} < \min(\lambda_H, \lambda_L). \tag{9}$$

The case with high quality-conscious consumers

Depending on the magnitude of λ_b relative to λ_H, we consider two cases separately: (1) $\lambda_b \leq \lambda_H$, and (2) $\lambda_b > \lambda_H$. Given the quality choice $q_i \in \{q_H, q_L\}$, denote the optimal arrival rate in equilibrium as λ_i^e. The corresponding price, service rate, and the expected profit are denoted as p_i^e, μ_i^e, and π_i^e, respectively. Under the optimal quality choice, the optimal price, service rate, and the expected profit are denoted as p^*, μ^*, and π^*, respectively.

The case with a low demand threshold

In this section, we first focus on the case with $\alpha_b \geq \alpha_3$. Given the high-demand-high-quality perception strategy, for the case with a low demand rate threshold such that $\lambda_b \leq \lambda_H$, by Proposition 1, the following result holds:

Proposition 2 *For the case with $\alpha_b \geq \alpha_3$ and $\lambda_b \leq \lambda_H$, given $\alpha \geq \alpha_b$, the optimal quality strategy, the price and service rate decisions are given as follows:*

- *If $(1-\phi)\Lambda < \lambda_b$, then providing a high quality service is more profitable; the optimal price is $p^* = p_H$; the optimal service rate is $\mu^* = \mu_H$; the effective arrival rate in equilibrium is $\lambda^* = \lambda_H$; the optimal profit is $\pi^* = \pi_H$.*
- *If $(1-\phi)\Lambda \geq \lambda_b$, denote $\lambda_L^e = \min(\lambda_L^H, (1-\phi)\Lambda)$, $\mu_L^e = \lambda_L^e + \sqrt{\frac{w}{\beta_L}}$, $p_L^e = v + \alpha q_H - \sqrt{\beta_L w} - V^r$, $\pi_L^H = (v + \alpha q_H - \beta_L \lambda_L^e - 2\sqrt{\beta_L w} - V^r)\lambda_L^e$. Then, there exists a unique $\lambda_c < \lambda_H$ such that $(v + \alpha q_H - \beta_L \lambda_c - 2\sqrt{\beta_L w} - V^r)\lambda_c = \pi_H$ and*
  - *if $(1-\phi)\Lambda \geq \max(\lambda_c, \lambda_b)$, then providing a low quality service is more profitable; the optimal arrival rate in equilibrium is $\lambda^* = \lambda_L^e$; the optimal service rate is $\mu^* = \mu_L^e$; the optimal price is $p^* = p_L^e$; the optimal expected profit is $\pi^* = \pi_L^H$;*
  - *otherwise, providing a high quality service is more profitable; the optimal price is $p^* = p_H$; the optimal service rate is $\mu^* = \mu_H$; the optimal arrival rate in equilibrium is $\lambda^* = \lambda_H$; the optimal profit is $\pi^* = \pi_H$.*

We next consider the case with $\alpha_b < \alpha_3$ and $\lambda_b \leq \lambda_H$. If $\alpha \geq \alpha_3$, then the optimal quality strategy, the price and service rate decisions are given by Proposition 2. Therefore, we focus on the case with $\alpha \in [\alpha_b, \alpha_3]$, where the following result holds:

Corollary 2 *For the case with $\alpha_b < \alpha_3$ and $\lambda_b \leq \lambda_H$, if $\alpha \in [\alpha_b, \alpha_3]$, then the optimal quality strategy, the price and service rate decisions are given as follows:*

- *Under the high quality strategy, the optimal price is $p_H^e = p_H$; the optimal service rate is $\mu_H^e = \mu_H$; the effective arrival rate in equilibrium is $\lambda_H^e = \lambda_H$; and the optimal profit is $\pi_H^e = \pi_H$.*
- *Under the low quality strategy, there exists a unique $\lambda_{c2} < \lambda_L$ such that $(v + \alpha q_H - \beta_L \lambda_{c2} - 2\sqrt{\beta_L w} - V^r)\lambda_{c2} = \pi_L$. If $(1-\phi)\Lambda < \max(\lambda_b, \lambda_{c2})$, then the optimal price is $p_L^e = p_L$; the optimal service rate is $\mu_L^e = \mu_L$; the effective arrival rate in equilibrium is $\lambda_L^e = \lambda_L$; and the optimal profit is $\pi_L^e = \pi_L$. If $(1-\phi)\Lambda \geq \max(\lambda_b, \lambda_{c2})$, the arrival rate in equilibrium is $\lambda_L^e = \min(\lambda_L^H, (1-\phi)\Lambda)$; the optimal service rate is $\mu_L^e = \lambda_L^e + \sqrt{\frac{w}{\beta_L}}$; the optimal price is $p_L^e = v + \alpha q_H - \sqrt{\beta_L w} - V^r$; and the optimal profit is $\pi_L^e = (v + \alpha q_H - \beta \lambda_L^e - 2\sqrt{\beta_L w} - V^r)\lambda_L^e$.*
- *The optimal quality strategy can be determined by comparing π_H^e and π_L^e.*

By Corollary 2, if $\alpha < \alpha_3$ and uninformed consumers adopt the high-demand-high-quality perception strategy, it could be the case that the service provider always provides a high quality service especially when $(1-\phi)\Lambda < \max(\lambda_b, \lambda_{c2})$ and $\alpha \geq \alpha_2$ (see Corollary 1). A low quality service is always provided if $\alpha < \alpha_2$.

The case with a high demand threshold

Next, we consider the case with $\lambda_b > \lambda_H$. For expositional simplicity, we first denote the following price and service rate decisions as well as the corresponding effective arrival rates and expected

profits under either high quality or low quality strategies when the service provider determines the market coverage.

- Suppose the service is high, there are three cases in terms of market coverage:
  1. Only informed consumers are served and uninformed consumers perceive a low quality:
  $$\mu_H^e(1) = \lambda_H^e(1) + \sqrt{\frac{w}{\beta_H}},\ p_H^e(1) = v + \alpha q_H - \sqrt{\beta_H w} - V^r, \tag{10}$$
  where $\lambda_H^e(1) = \min(\lambda_H, \phi\Lambda)$ and $\pi_H^e(1) = (v + \alpha q_H - 2\sqrt{\beta_H w} - \beta_H \lambda_H^e(1) - V^r)\lambda_H^e(1)$.
  2. Both types of consumers are served and uninformed consumers perceive a low quality:
  $$\mu_H^e(2) = \lambda_H^e(2) + \sqrt{\frac{w}{\beta_H}},\ p_H^e(2) = v + \alpha q_L - \sqrt{\beta_H w} - V^r, \tag{11}$$
  where $\lambda_H^e(2) = \lambda_H^L$ and $\pi_H^e(2) = (v + \alpha q_L - 2\sqrt{\beta_H w} - \beta_H \lambda_H^e(2) - V^r)\lambda_H^e(2)$.
  3. The service provider maintains the arrival rate at λ_b to serve both types of consumers where uninformed consumers perceive a high quality:
  $$\mu_H^e(3) = \lambda_H^e(3) + \sqrt{\frac{w}{\beta_H}},\ p_H^e(3) = v + \alpha q_H - \sqrt{\beta_H w} - V^r, \tag{12}$$
  where $\lambda_H^e(3) = \lambda_b$ and $\pi_H^e(3) = (v + \alpha q_H - 2\sqrt{\beta_H w} - \beta_H \lambda_H^e(3) - V^r)\lambda_H^e(3)$.
- Suppose the service quality is low, there are two cases in terms of market coverage:
  1. Both types of consumers are served and uninformed consumers perceive a low quality:
  $$\mu_L^e(1) = \lambda_L^e(1) + \sqrt{\frac{w}{\beta_L}},\ p_L^e(1) = v + \alpha q_L - \sqrt{\beta_L w} - V^r, \tag{13}$$
  where $\lambda_L^e(1) = \lambda_L$ and $\pi_L^e(1) = (v + \alpha q_L - 2\sqrt{\beta_L w} - \beta_L \lambda_L^e(1) - V^r)\lambda_L^e(1)$.
  2. Only uninformed consumers are served and a high quality is perceived:
  $$\mu_L^e(2) = \lambda_L^e(2) + \sqrt{\frac{w}{\beta_L}},\ p_L^e(2) = v + \alpha q_H - \sqrt{\beta_L w} - V^r, \tag{14}$$
  where $\lambda_L^e(2) = \max(\lambda_b, \min((1-\phi)\Lambda, \lambda_L^H))$ and $\pi_L^e(2) = (v + \alpha q_H - 2\sqrt{\beta_L w} - \beta_L \lambda_L^e(2) - V^r)\lambda_L^e(2)$.

We consider the cases with $\alpha_b \geq \alpha_3$ and $\alpha_b < \alpha_3$ separately. Based on the above five cases of market coverage, the following result holds:

Proposition 3 *For the case with $\alpha_b \geq \alpha_3$ and $\lambda_b \geq \lambda_H$, given $\alpha \geq \alpha_b$, the optimal quality strategy, the price and service rate decisions are given as follows:*

- *There exists a unique threshold arrival rate $\lambda_c < \lambda_L$ such that $(v + \alpha q_H - 2\sqrt{\beta_H w} - \beta_H \lambda_c - V^r)\lambda_c = \pi_L$. If $\phi\Lambda > \lambda_c$ and $(1-\phi)\Lambda < \lambda_b$, then the optimal strategy is to provide a high quality service. While if $\phi\Lambda < \lambda_c$ and $(1-\phi)\Lambda \geq \lambda_b$, then the optimal strategy is to provide a low quality service.*

- *For other cases, the optimal quality strategy and the corresponding price and service rate decisions can be determined by comparing among* $\{\pi_H^e(1), \pi_H^e(2), \pi_H^e(3), \pi_L^e(1), \pi_L^e(2)\}$.

Next, we consider $\alpha_b < \alpha_3$. Given α, if $\alpha \geq \alpha_3$, then the optimal quality strategy, the optimal price and service rate decisions can be characterized by Proposition 3. Thus, we focus on the case with $\alpha \in [\alpha_b, \alpha_3)$. The following result holds:

Corollary 3 *For the case with* $\alpha_b < \alpha_3$ *and* $\lambda_b > \lambda_H$*, given* $\alpha \in [\alpha_b, \alpha_3]$*, the optimal quality strategy, the optimal price and service rate decisions are given as below:*

- *Under the high quality strategy, there exists a unique* $\lambda_{c1} < \lambda_H$ *such that* $(v + \alpha q_H - \beta_H \lambda_{c1} - 2\sqrt{\beta_H w} - V^r)\lambda_{c1} = (v + \alpha q_H - \beta_H \lambda_b - 2\sqrt{\beta_H w} - V^r)\lambda_b$*. If* $\phi\Lambda < \lambda_{c1}$*, the optimal price is* $p_H^e = p_H^e(3)$*; the optimal service rate is* $\mu_H^e = \mu_H^e(3)$*; the effective arrival rate in equilibrium is* $\lambda_H^e = \lambda_b$*; and the optimal profit is* $\pi_H^e = \pi_H^e(3)$*. If* $\phi\Lambda \geq \lambda_{c1}$*, the optimal price is* $p_H^e = p_H^e(1)$*; the optimal service rate is* $\mu_H^e = \mu_H^e(1)$*; the effective arrival rate in equilibrium is* $\lambda_H^e = \lambda_H^e(1)$*; and the optimal profit is* $\pi_H^e = \pi_H^e(1)$.

- *Under the low quality strategy, there exists a unique* $\lambda_{c2} < \lambda_L$ *such that* $(v + \alpha q_H - \beta_L \lambda_{c2} - 2\sqrt{\beta_L w} - V^r)\lambda_{c2} = \pi_L$*. If* $(1-\phi)\Lambda < \max(\lambda_b, \lambda_{c2})$*, then the optimal price is* $p_L^e = p_L$*; the optimal service rate is* $\mu^* = \mu_L$*; the effective arrival rate in equilibrium is* $\lambda_L^e = \lambda_L$*; and the optimal profit is* $\pi_L^e = \pi_L$*. If* $(1-\phi)\Lambda \geq \max(\lambda_b, \lambda_{c2})$*, the arrival rate in equilibrium is* $\lambda_L^e = \min(\lambda_L^H, (1-\phi)\Lambda)$*; the optimal service rate is* $\mu_L^e = \lambda_L^e + \sqrt{\frac{w}{\beta_L}}$*; the optimal price is* $p_L^e = v + \alpha q_H - \sqrt{\beta_L w} - V^r$*; and the optimal profit is* $\pi_L^e = (v + \alpha q_H - \beta_L \lambda_L^e - 2\sqrt{\beta_L w} - V^r)\lambda_L^e$.

- *The optimal quality strategy can be determined by comparing* π_H^e *and* π_L^e.

CONCLUDING REMARKS

In this study, we made some encouraging steps towards the better understanding of (1) the effect of consumers' level of quality-consciousness on the price and capacity decisions; and (2) how best to offer a service, namely, at what quality level, high or low, if consumers are informed or uninformed about the service quality?

Based on the benchmark case where consumers are quality-conscious and informed about the quality, the study shows that the more quality-conscious the consumers become, the higher quality of service should be provided to be more profitable. In reality, however, consumers are heterogeneous in their knowledge about the quality of service, i.e., some are informed about the service quality while the rest are uninformed, the results suggest that the service provider's quality strategy and its associated price and capacity decisions should depend heavily on the uninformed consumers' perception about the quality of service. We were able to shed some light in this regard by using a demand-based quality-perception strategy, and demonstrate the crucial role of the threshold demand rate. If the proportion of informed consumers is relatively low, it is advisable to offer services at a lower level of quality. If the proportion of informed consumers is relatively high, providing a higher level of service quality is desirable. At the threshold demand level, maintaining a relatively low level of service quality is sufficient.

For further studies, it would be interesting to consider competition among service providers in this context.

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Measuring Brand Charisma: An Exploratory Study of Luxury Brand Consumers

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ABSTRACT

The objective of this paper is to define the conceptual domain of the brand charisma construct and identify its foundational dimensions. All luxury brands have image, symbolism and prestige to some degree, but those with charisma build on these to generate extraordinary levels of buyer attachment and motivation. But how do luxury brands make claims of having a charismatic personality, and what are the charismatic characteristics they claim to have? Drawing upon charismatic leadership theory and qualitative data from luxury brand consumers, we shed light on the behavioral attributes of charismatic brands. Given the importance of building sustained brand-consumer relationships, a systematic understanding of brand charisma has the potential to create high impact for scholarship and practice. For luxury brand managers across the delivery channel, insights into the foundations of a charismatic brand personality can help in brand strategy and brand program decisions.

KEYWORDS: brand charisma, luxury consumers, exploratory, conceptual domain

INTRODUCTION

There is increasing evidence that a large and stable segment of customers seek to build relationships with brands (Fournier, 2008; Schau, Muñiz & Arnould, 2009). Research has established that consumers not only seek out brands for the instrumental and functional roles they serve, they also seek meaningful connections with brands and their corporate entities (Aaker, 2012). As a result, companies build brand equity through brand personalities that encourage consumer interactions and build relationships (Lloyd & Woodside, 2013). A brand personality refers to the overall persona created by a cluster of human-like characteristics attributed to a brand name (Azoulay & Kapferer, 2003). Brand personalities studied in the mainstream marketing literature include those based upon trust (Chaudhuri & Holbrook, 2001) and warmth (Aaker et al., 2010), with particular impact in specific market situations. Trusted brands, for example, are found to be impactful in service contexts given consumers' perceived risk, while warm brands are seen as relevant in non-profit contexts. In the context of relationships between luxury brands and their consumers, traditional views of brand personality are less relevant since luxury brand-consumer relationships transcend functional relationships (Keller, Parameswaran & Jacob, 2011). Given the role of emotional and transformative brand values in luxury branding, we propose brand charisma as a brand personality most likely to resonate with luxury brand consumers.

Although the importance of corporate brand personality to organizational success is acknowledged in the organizational behavior and communications literature (Czarniawska, 1997; Waeraas, 2010), where organizations are personified and attributed with human personality traits, we contend that brands are 'born' with neither charisma nor personality, and that there can be no such thing as brand charisma that is inherited "by virtue of natural endowment" (Hatch & Schultz, 2013). External perceptions thus determine whether brands have a similar status as charismatic individuals. Therefore, in order to acquire charismatic status, brands must display evidence of having charisma. But how do luxury brands make claims of having a charismatic personality, and what are the charismatic characteristics they claim to have?

Webster's dictionary offers one definition of charisma as "*a special magnetic charm or appeal*". Most of the research on charisma to date has focused on the area of leadership where charismatic leaders are viewed to create a sense of excitement among followers, build strong bonds, and ultimately possess the ability to exercise strong influence on the values and behaviors of followers (Fanelli & Misangyi, 2006; House, Spangler & Woycke, 1991). Although attempts have been made to generalize charisma to all human beings (Verčič & Verčič, 2011), little is known about the conceptual domain of brand charisma and how to measure it.

Grounded in existing literature on general charisma, charismatic leadership and consumer-brand relationships, we view strong brands in a similar way to strong leaders in society. Drawing upon this literature, and coupled with findings from an exploratory study of luxury brand consumers, the objective of this paper is to define the conceptual domain of the brand charisma construct and identify its foundational dimensions. All luxury brands have image, symbolism and prestige to some degree, but those with charisma build on these to generate extraordinary levels of buyer attachment and motivation. Charismatic brands are expected to lead to consumer admiration and advocacy, brand resonance, and ultimately result in increased willingness to engage with and consume the brand. Over time, they likely evolve to an iconic status. Our research has the potential to break new ground in academic brand research and specifically in the emerging area of luxury brand management. Given the importance of building sustained brand-consumer relationships, a systematic understanding of brand charisma has the potential to create high impact for scholarship and practice. For luxury brand managers across the delivery channel, insights into the foundations of a charismatic brand personality can help in brand strategy and brand program decisions.

The paper is organized as follows. Acknowledging that brands act as intentional agents (Kervyn, Fiske & Malone, 2012), we first review existing literature on charisma in general and charismatic leadership theory in particular to shed light on the charisma construct. In doing so, we acknowledge recent thinking that people relate to brands similarly to the way they relate to people around them (Hatch & Schultz, 2013; Verčič & Verčič, 2011), and we highlight the importance of understanding brand charisma for building sustained brand-consumer relationships. We then outline our research objectives specific to the conceptual domain and operationalization of brand charisma, and follow this with data collection procedures, sample selection and analytical methods. Finally, we discuss the results of our study, highlighting their exploratory nature. Areas for future research are also discussed, together with the study's limitations.

LITERATURE REVIEW

Brands as Intentional Agents

The idea that consumers' relationships with brands can be characterized in ways that resemble their relationships with people has gained considerable ground in the areas of branding and consumer behavior (Dion & Arnould, 2011; Fournier, 2008). Research on brand perception has shown that consumers not only care about a brand's features and benefits but also about a relationship aspect of brand perception (Fournier, 2008) and an emotional aspect (Shekhar, Dash & Purwar, 2013). Just as individuals have a host of different relationships with the people they interact with, they also have different types of relationships with the brands that have relevance to their lives. As individuals acquire more information through their interactions with others, their perceptions are based more on the relationship (Fiske, 1991). This suggests that over time, consumers will likely base their perception of charisma on their relationship with the brand.

Recent published work suggests that brands act as intentional agents (Kervyn, Fiske & Malone, 2012; MacInnis, 2012). The model of social perception called the Stereotype Content Model (SCM) maps out how people perceive social groups on two dimensions of social perception: warmth and competence, to guide their decisions about and interactions with other people and social groups. Just as people can be characterized in terms of warmth and competence (Fiske, Cuddy & Glick, 2007), so too can brands. Aaker et al. (2010) for example, found that brands that are both competent and warm positively impact purchase intentions. Perceptions of warmth and competence represent cognitive appraisals and result in emotions (feelings of admiration) which subsequently impact purchase behavior.

Brand building for certain extraordinarily successful brands may therefore include aspects of a social process best described as charismatic building. But what is charisma? We now shed light on this concept by first examining literature on the concept of charisma in general. This is followed by a review of charismatic leadership theory and existing instruments for measuring charisma.

The Concept of Charisma

Charisma comes from two Greek roots: (a) *charizesthai*, which means "to favour or to gratify: and (b) *charis*, meaning "gift". A natural starting point for understanding the concept of charisma is the work of Max Weber. Weber (1947) referred to charisma as a widely perceived appeal which transcends ordinary conceptions of reality, while Shils (1965) referred to the quality which is imputed to persons, actions, roles, institutions, symbols, and material objects because of their presumed connection with ultimate, fundamental, vital, or order-determining powers. These definitions imply that charismatics have a kind of aura. Smothers (1993) was the first to propose that brands, as well as people, can have charisma. He defined charisma as "the quality which is imputed to persons, actions, roles, institutions, symbols and material objects because of their presumed connection with ultimate, fundamental, vital, or order-determining powers" (Smothers, 1993, p.100). Following Weber (1947), Smothers (1993) argued that brand charisma is a social construction of the customers who give a brand its legitimacy. If we accept the notion that brands are like people, then it seems logical to identify the kinds of people that generate the highest levels of motivation. According to Smothers (1993), establishing that a brand has charisma amounts to demonstrating it is endowed with exceptional qualities by those it touches. In other words, determining if a brand has charisma means demonstrating it has exceptional qualities as believed by those who consume it (Hatch & Schultz, 2013).

Although Smothers (1993) follows Weber (1947) in assigning responsibility for the social construction of brand charisma to customers, his conceptual definition lacks specificity. We argue that greater clarity of the conceptual domain of brand charisma can be found in

charismatic leadership theory (CLT). In the psychology and management literature, individuals who foster the highest levels of loyalty and motivation among large groups are called charismatic leaders (Avolio, Walumbwa, & Weber, 2009). Charismatic Leadership Theory (CLT) generally takes a leader-driven approach where leader behaviors form the basis of followers' attributions (Conger & Kanungo, 1987; House & Howell, 1992). Drawing upon psychological theory to explain charisma, House (1977) was the first to propose that the basis of charisma is the emotional interaction that occurs between followers and their leaderAccording to House (1977), charismatic leaders display confidence in their own abilities and in their followers, set high expectations for themselves and their followers, and show confidence that these expectations can be achieved. Charismatic leaders are also role models for others, courageous (they challenge the status quo), self-confident, pro-social assertive (dominant and powerful), have moral conviction and are competent. Bass (1985) also describes charisma as the emotional component of leadership which is "used to describe leaders who by the power of their person have profound and extraordinary effects on their followers" (Bass, 1985 p. 35). Bass (1985) argues that charismatic leaders communicate symbolically, use imagery and are persuasive in communicating a vision that promises a better future. Later definitions of charisma suggest that charisma can have both behavioral and attributional components. Avolio, Bass and Jung (1999, p. 444) for example, define charisma as that which "provides followers with a clear sense of purpose that is energizing, is a role model for ethical conduct and builds identification with the leader and his or her articulated vision". Attributional characterizes the attributions of the leader made by followers as a result of how they perceive the leader. Behavioral components focus on the specific behaviors of the leader that followers can observe directly (Avolio, Bass and Jung, 1999).

Leaders with charisma also foster inspiration motivation, express their values by creating a value-laden vision of the future, and express confidence that followers can accomplish their collective objectives (Wilderom, van den Berg & Wiersma, 2012). Other studies suggest that charismatic leaders are guided by altruistic principles and higher cognitive moral development levels (Turner el al., 2002). The charismatic leadership framework of Shamir, House and Arthur (1993) posits that charismatic leaders use messages related to moral values on route to influencing a follower's self-concept, which denotes the totality of an individual's thoughts and feelings with reference to himself or herself as an object (Hong & Zinkhan, 1995). In a similar way, brands can use their vision and mission as a platform to implicate the self-concept of consumers. In this way, it is argued that leading brands can have exceptional effects on consumers, who are motivated by increased levels of self-esteem, self-worth, self-efficacy, identification with the brand and social identification. Just as charismatic leaders affect followers because of motivational mechanisms that are induced by leader behaviors (Shamir, House and Arthur, 1993), brands affect consumers that are induced by the behaviors of the brand.

It is clearly evident that 'charisma' does not represent a singular attribute. Grounded in an extensive study of charismatic leaders, Conger & Kanungo (1998) propose six characteristics to result in such attributions (see Table 1): being visionary, articulate, sensitive to the environments, sensitive to member needs, unconventional, and taking personal risks. The key behaviors in the House (1977) and Shamir, House & Arthur (1993) theories include articulating an appealing vision, emphasizing ideological aspects of the work, communicating high performance expectations, expressing confidence that subordinates can achieve them, showing self-confidence, modeling exemplary behavior, and emphasizing collective identity. Other researchers have further differentiated between the content of the vision and the use of an expressive style to communicate it (Kirkpatrick and Locke, 1996).

The emerging consensus today stresses the dyadic nature of the charismatic relationship (Weierter, 1997; Howell & Shamir, 2005) i.e. charismatic leadership is located in the relationship between the leader and the follower meaning that leaders and followers come together to form a dynamic relationship. This approach puts charismatic leadership in the relationships connecting individuals rather than the attributes of the leader or follower (Balkundi & Kilduff, 2006) i.e. followers will base their perceptions of charismatic leadership on their relationship with the leader (Campbell et al., 2008).

Our systematic review of CLT suggests that charisma is a sociological construct associated with a leader who generates extreme levels of loyalty and motivation among followers. A brand that is charismatic should therefore create a response in its audience or followers that is characterized by extremes of motivation and attachment beyond expectation. CLT tells us that charismatic leaders use communication and image-building strategies to appear powerful and confident (House, 1977). They engage in followers' self-concepts (Shamir, House & Arthur, 1993), they are risk-takers and are unconventional (Conger and Kanungo, 1998; House 1977). They know how to emotionally connect with followers and are good storytellers (Towler, 2003). A charismatic leader is also one who can influence, inspire and motivate their followers (Shamir, House & Arthur 1993; Waldman and Yammarino, 1999). They exude confidence, dominance, energy, a sense of purpose and vision, and the ability to articulate the goals and ideas for which followers are already prepared psychologically (Bass, 1985; Conger & Kanungo,1998; House, 1977). Charismatic leaders are also thought to possess outstanding rhetorical ability (Harvey, 2001).

Table 1: Observable characteristics of charismatic leaders. Adapted from Conger and Kanungo (1998)

Characteristic	**Meaning**
Vision	Inspirational, able to motivate, has vision, often brings up ideas about possibilities for the future, provides inspiring strategic and organizational goals, consistently generates new ideas for the future of the organization
Articulation	Exciting public speaker, skillful performer when presenting to a group
Environmental sensitivity	Readily recognizes constraints in the social, cultural, physical environments and within the organization, recognizes the skills and limitations of other members in the organization, recognizes new opportunities and seizes them to achieve goals
Behavior	Engages in unconventional behavior to achieve organizational goals, uses non-traditional means to achieve organizational goals, often exhibits very unique behavior that surprises other members of the organization
Personal risk	Engages in activities involving personal risk and self-sacrifice, takes high personal risk for the sake of the organization, often incurs high personal costs
Sensitivity to member needs	Shows sensitivity and expresses personal concern for the needs and feelings of members in the organization, influences others by developing mutual liking and respect

Existing instruments for measuring charisma

Despite the concept of charisma being popularized by Weber (1947), the number of scales constructed to measure the concept is sparse and most of these are specific to the context of

leadership. The most widely cited measure for charismatic leadership behavior uses the 20-item Conger-Kanungo charismatic leadership scale. In a series of empirical studies, the Conger-Kanungo measurement scale has undergone testing and validation (Conger & Kanungo, 1992, 1994; Conger et al., 1997). More recently, Verčič & Verčič (2011) have validated a 24-item scale measuring six human charismatic dimensions. Despite these instruments, there is no clarity on the conceptual domain of brand charisma and no instrument for its measurement. Moreover, both instruments are of limited use when measuring brand charisma. Some authors have examined if a human charisma scale can be adapted to measure brand charisma. For example, Lee, Workman & Jung (2015) used 17 of the 24 items from the human charisma scale cited by Verčič & Verčič (2011) to measure brand charisma. Factor analysis identified four dimensions: communicative, powerful and dominant, attractive and honest and reliable. However, the scale lacked content validity assessment, which is a fundamental first step in construct validation of a new measure.

Summary

Despite the obvious breadth of research examining charismatic leadership in the psychology and management literature, research on the concept of charisma and its relationship to brands has remained limited due in part to the lack of consensus regarding what brand charisma really is. The most useful definition of charisma seems to be in terms of attributions of charisma to a leader by followers (consumers) who identify strongly with the leader (the brand). The follower's attribution of charisma thus depends on the observed behavior of the leader. Brand charisma is therefore socially constructed and an observable behavioral process. Charisma is an attribution, and specific characteristics are causally responsible for this attribution. But in brand-consumer relationships, what are the behavioral components responsible for such attributions? Does brand charisma have a set of attributes similar to or different from the attributes identified in theories of charismatic leadership? Given the complexity of the phenomenon, measuring brand charisma is also fraught with problems of construct ambiguity and validity issues. This necessitates research on two major fronts: identifying the behavioral attributes of charismatic brands, and developing valid and reliable measures of such behavioral dimensions for use in future research. The focus of this research is on the former. In the remainder of this article, we present an exploratory study to shed light on the behavioral attributes of charismatic brands (the first objective) and posit a model of the elements or attributes of charisma in brand-consumer relationships for future empirical investigation.

RESEARCH APPROACH

Since the charisma construct has not been well delineated in literature examining consumer-brand relationships, but has been studied extensively in the field of leadership, the study did not follow a purely inductive (grounded theory) approach to data collection (Strauss & Corbin 1994). Rather, its design was largely exploratory to shed light on the domain of the construct within a brand- consumer context (Creswell, 2013). As noted earlier, brand charisma as a brand personality is most likely to resonate with luxury brand consumers because luxury brand-consumer relationships transcend functional relationships (Keller, Parameswaran & Jacob, 2011). To this end, focus-group sessions with 55 luxury brand consumers, were used as the data collection method (Miles & Huberman 1994). Qualitative research in the form of focus groups is a highly suitable research method for exploratory investigation, especially when little is known about a phenomenon. The concept of brand charisma fell into this category. Focus groups also act as a convenient method for interviewing a number of people in situations involving the exploration of complex issues requiring group interaction (Calder, 1977).

Five focus group sessions were conducted, each lasting 50 minutes. All participants were recruited from several postgraduate courses at a leading University in the United Arab Emirates (UAE) and were all identified as consumers of luxury products. The United Arab Emirates is one of the largest and most dynamic economies in the Gulf region with UAE residents' spending on luxury goods reaching more than $8 billion in 2017 (Maceda, 2018). Participants were predominantly female (65%) and ranged in age from 22 to 45.

At the beginning of each focus group session, participants were provided with an operational definition of charisma: “Charisma is the quality which is imputed to persons, actions, roles, institutions, symbols and material objects because of their presumed connection with ultimate, fundamental, vital, or order-determining powers”. Participants were then asked what makes a brand charismatic. In addition participants were asked to identify three charismatic brands (and the reasons why they are charismatic) and three brands that were not charismatic (and the reasons). These questions were designed to guide subsequent group discussion. Following the recommendations of Kidd & Parshall (2000), one of the researchers took on the role of moderator during these discussions. Data were collected via whiteboard summaries as well as written summaries from individuals within each focus group. The whiteboard summaries were digitally photographed. Each group varied between 9-12 individuals following the recommendations of Churchill and Iacobucci (2002) and Fern & Fern (2001). After the fourth focus group, participants were repeating information that had been gleaned from previous groups. The fifth group was thus treated as a final confirmation as no new information surfaced from this group.

The analysis followed the sequence of steps described in Miles & Huberman (1994, p. 10), who "define analysis as consisting of three concurrent flows of activity: data reduction, data display, and conclusion drawing/verification". In the first phase (data reduction), we broke the data down for each focus group into "thought units" (e.g., Gioia & Sims 1986), these thought units ranged from a phrase to several sentences. In the second phase (data display), all of the thought units were organized into emergent categories. Data reduction was undertaken for each of the 5 focus groups, using a list of basic codes devised prior to fieldwork. Subcodes were added to categorize information further within each of the main codes. However, not all codes were pre-specified. Additional insights frequently surfaced during data collection, and analysis, with additional codes emerging as a result. The codes were arranged in the form of 5 within-case displays which took the form of a matrix or a network according to which was most appropriate to the interview being analyzed (Miles & Huberman 1994). The within-case analysis generated insights into what makes a brand charismatic. The within-case displays were then reduced in order to create a conceptually ordered meta-matrix which assembled the descriptive data from each of the within-case displays in a standard format (Miles & Huberman 1994). This was the most inductive phase of the analysis. As much as possible, we allowed the categories to emerge from the data. We then assigned labels to each category in an attempt to capture the shared message of the thought units within it. Disagreements among the researchers regarding the categories (and their labels) were resolved by using a "blind" research assistant not familiar with the charismatic leadership and brand-consumer relationship literatures. This additional researcher was utilized to complete an independent content analysis. Independently derived findings were then compared and contrasted.

FINDINGS

The patterns we observed across all five focus groups and 55 respondents allowed us to draw inferences regarding behaviors that characterize brand charisma from the perspective of luxury brand consumers. These behaviors do not reside naturally in a brand, but in the way the brand is perceived. As noted earlier, we suggest that charisma is an attribution, thus charisma can be

attributed to any ‘persona’ that displays the relevant behavior. Our analysis of the whiteboard and individual summaries, suggests that brand charisma is not a single attribute but manifests itself in 9 different behaviors. Table 2 includes the names of each charismatic behavior, corresponding codes and illustrating examples provided by respondents. In the discussion that follows, we present findings that shed light on the conceptual domain of brand charisma and the behaviors that make luxury brands charismatic as perceived by luxury brand consumers. The number by each code represents the respondent that mentioned the corresponding codes.

Table 2. Meta-Matrix: Brand Charisma Behaviors as perceived by Luxury Brand Consumers

Charismatic Characteristic	Code and Description	Illustration (Examples)
1. Communication	- The brand is expressive with its communication (3, 7, 10, 14, 18, 25, 31, 38, 44, 48, 50, 51) - The brand is enthusiastic with its communications (3, 10, 25, 31, 38, 44, 53) - The brand continuously connects with its customers at an emotional level (2, 4, 8, 9, 14, 15, 25, 31) - The brand is optimistic with its communication (25, 31, 38, 44, 52, 53) - The brand is engaging with its communication (2, 3, 10, 25, 31, 38, 46, 48, 53)	"Cartier is so innovative in its communication" "Apple always has a story to tell. Behind each product, there is a history of what brought it to market. I feel inspired by those stories. It adds inherent value to the brand" "Chanel advertising always uses charismatic celebrities to communicate its message, those who are in the limelight like Natalie Portman after the Thor 2 success" "Fossil does not significantly differentiate itself in the way it expresses itself to consumers" "Fossil's communication doesn't inspire and excite. It is such a boring brand" "Michael Kors advertising involves relatable pictures which viewers can connect with" "I love the Louis Vuitton core values ads. They really connect with me at an emotional level" "Brand like Chanel, Hermés, Louis Vuitton and Gucci express themselves so beautifully and elegantly. They are so engaging"
2 Admiration and inspiration	- The brand is magical (7, 8, 14, 17, 22, 27, 35, 41) - The brand attracts great admiration (1, 2, 3, 6, 8, 9, 12, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 42, 48, 52, 55) - The brand easily grabs/attracts my attention (12, 14, 15, 16, 19, 48) - The brand has significant positive influence on other people (1, 4, 7, 10, 12, 15, 18, 24) - The brand is inspirational (1, 2, 8, 9, 12, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 42, 43, 52, 55) - The brand has my respect (2, 8, 9, 12, 13, 15, 16, 22, 28, 29, 31, 36, 40, 42, 43, 52, 55) - The brand is passionate (5, 29, 44, 53) - The brand has something special (10,12, 13, 23, 2, 30,46) - The brand is highly talked about by others (1, 2, 4, 6, 8, 9, 12, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 42, 43, 52, 55) - The brand is a role model (8, 9, 12, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 42, 49)	"Chanel is a charismatic brand because it is highly attractive and influences people in a positive way" "Audi is my favourite car brand, it promises for the future and inspires youth to become future successful businessmen" "Ferrari is such an inspirational brand. It is so magical and has a rare character which demands so much respect" "Emirates has a personality that you admire in a way; you don't feel the same way when you fly the other companies. It certainly has my respect!" "Aston Martin has a sense of heritage, and a certain sense of mystique and unattainability. It has something so special that no other luxury car has" "People gain so much respect and admiration from others when they own a Rolex" "Chanel influences people in such a positive way" "Mont Blanc has an image of being influential" "I am so envious of those people who can buy Chanel" "Louis Vuitton is such a passionate brand. Their stores stands out so much. It is a role model for all other luxury fashion brands" "The same brands I referred to earlier [Chanel, Hermés, Louis Vuitton and Gucci] are talked about by so many different people, many of whom will never be able to afford to buy them"
3. Honesty and reliability	- The brand is reliable (9, 15, 16, 22, 25, 31, 39) - The brand is a highly trusted one (4, 13, 19, 25, 31, 52) - The brand is honest (15, 16, 19, 25, 31, 51, 52, 55)	"Apple is popular, reliable and trustworthy and these traits are reflected in its personality" "Emirates is a trusted and reliable brand and renowned for its quality service" "Many luxury brands today recognize the importance of being honest and transparent when it comes to reporting. The Kering Group is a good

	- The brand is sincere (9, 11, 15, 19, 22, 26, 34, 36, 41)	example of this. The Chalhoub Group in the Middle East are also transparent in what they report about sustainability" "I feel that Chanel has so much sincerity in what it does. There is nothing pretentious about the brand. It really believes in what it is doing"
4. Attraction	- The brand is magnetically attractive (1, 3, 7, 10, 11, 13, 14, 21, 23, 46, 50, 51) - The brand is charming (1, 7, 8, 14, 15, 26, 33, 34, 36, 44, 45, 47, 50, 52, 53) - The brand is very appealing (2, 6, 8, 12, 28, 49, 50) - The brand is beautiful (2, 6, 7, 8, 11, 16, 22, 34) - The brand is elegant (2, 6, 7, 8, 11, 16, 34, 44, 47, 50, 52) - The brand is trendy (6, 7, 21, 27) - The brand is sophisticated (2, 8, 12, 26) - The brand has style (6, 7, 21, 27) - The brand stands out (1, 3, 7, 10, 11, 13, 14, 21, 23, 46, 49, 50, 51, 54) - The brand attracts but is not ostentatious (3, 7, 10, 11, 13, 14, 21, 23, 46, 47, 50) - The brand is classy (2, 8, 12, 26, 47)	"Charisa is like having a charm or an attractive character that people can relate to. Louis Vuitton is a good example" "Chanel is synonymous with beauty" "Omega is so attractive" "Patek Philippe is so sophisticated and stylish. The brand charms potential buyers" "The name of the Hermés brand speaks for itself and attracts people to it" "Hugo Boss is depicted as a brand for men who are extremely stylish, confident, appealing and have strong personalities: "Chanel is an incredibly seductive and attractive brand" "D&G is so appealing" "Chanel has so much charm and appeal" "Michael Kors doesn't charm me and the designs are boring" "The complete feeling of wearing Chanel is charismatic in itself" "The look, the feel of being in it and how people envy you when you drive a Jaguar; it's all about class, confidence and beauty" "Ralph Lauren offers specific quality products that showcase style and prestige" "Roberto Cavali has a different character to other brands. It is so classical and gives out so much aura" "Rolls Royce is such a classy brand" "You will always think about a Porsche driver in a specific way that they are unique and elegant in choice" "Chopard shows sophistication in status and speaks for itself. The fact that it attracts buyers of a certain type of social status makes it charismatic" "I see Tiffany & Co as a simple, elegant and classy brand and these things make the brand charismatic"
5. Visionary	- The brand has a vision for the future (1, 2, 8, 9, 12, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 42, 43, 52, 55) - The brand has lots of positive energy (2, 8, 9, 10, 12, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 42, 43, 47) - The brand consistently generates new ideas for the future (1, 2, 8, 9, 12, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 42, 43, 52, 53, 55) - The brand is dynamic (2, 8, 9, 10, 12, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 42, 43, 47) - The brand is outgoing (2, 8, 9, 10, 12, 13, 15, 16, 18, 22, 25, 28, 29, 31, 36, 40, 42, 43, 47, 49) - The brand is innovative (1, 2, 8, 9, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 43, 52, 53, 55) - The brand is exciting (2, 8, 9, 10, 12, 13, 15, 16, 22, 25, 28, 29, 31, 36, 40, 42, 43, 45, 47) - The brand is ambitious (2, 8, 9, 10, 12, 13, 15, 16, 18, 22, 25,	"Apple has a vision for the future and is innovative, which by default makes it unique and ambitious and risky" "L'Oréal is spontaneous and has so much energy. They keep launching new products every so frequently, getting celebrities to endorse their products, and improving their products. All of this keeps me on my toes, interested, and makes me want to purchase new products as they come out" "Apple's personality is so open. They always brings something new to the moment" "Apple is a great example of radical and incremental innovation" "Mango is not visionary because if follows change and does not innovate" "Tesla is such an exciting and dynamic brand. It is disrupting the car market and is so ambitious" "Take Chanel for example. It creates trends and shapes the future"

	28, 29, 31, 36, 40, 42, 43, 47, 49) - The brand is a creator of trends (17, 23, 46, 48)	
6. Powerful and dominant	- The brand is bold (2, 8, 12) - The brand is strong (2, 8, 12, 21, 27, 28, 35) - The brand is controlling (8, 12, 19, 21, 27, 28, 35) - The brand exuberates power (7, 12, 14, 21, 28, 28, 35) - The brand displays confidence (2, 6, 11, 17, 18) - The brand is a market leader (4, 19, 25, 35) - The brand is assertive (1, 2, 8, 12, 18) - The brand is a benchmark for all (4, 6, 7, 12, 22, 25, 38, 39) - The brand is influential (1, 2, 4, 8, 19, 25, 35) - The brand is not a follower (46) - The brand is fearless and daring (2, 8, 12, 27, 35, 36)	"Apple changes the lifestyles of consumers. Also, it is a role model or a benchmark which forces other companies to follow" "Aston Martin has charisma because it is bold and powerful" "Mont Blanc is strong and unique" "Humer significantly differentiates itself from all other competitors and does not follow market trends' "Fossil is a follower of market trends and does not create new ideas" "Fendi copies all other brands. For example the shape of the bags and colours" "Rolls Royce is so powerful; it the benchmark for the luxury car industry" "Brands such as Chanel Rolls Royce fear nobody. They are so daring"
7. Sensitive to the environment	- The brand models ethical standards (4, 6, 7, 12, 18, 22, 25, 28, 38, 39) - The brand considers what is moral/ethical (4, 6, 7, 9, 12, 18, 22, 25, 28, 38, 39, 41) - The brand goes beyond company self-interest (28, 35) - The brand raises awareness of important environmental issues and takes corresponding action (2, 3, 6, 7, 9, 10, 12, 18, 21, 22, 25, 28, 38, 39, 41, 46, 48, 52)	"de Grisogono follows a notable cause, breast cancer, it appeals to me because I can relate to its main purpose" "I know that brands such as Prada, Chanel, Hermés, L'Oréal and Louis Vuitton stand out in terms of their ethical and environmental performance" "If you take expensive fashion clothes, do they always come with a guarantee of ethical standards when it comes to producing them? I mean luxury fashion brands you always more for the clothing you but, but those people on the production lines and in the cotton fields, are they automatically paid more? I don't believe so, this behavior is not right. I often think that it is about higher profits for these brands" "I read a study a few months ago that says that climate change will have a big negative effect on raw materials used in luxury and this is going to have a pretty big impact on those communities that are farming these materials" "Luxury jewelry brands such as Chopard and Tiffany & Co now used stones that are ethically mined and they also recycle gold and silver and work with ecologically conscious mines. They are acknowledging the importance of sustainability through these actions"
8. Displays unconventional behaviour	- The brand engages in unconventional behavior to achieve its goals (9, 15, 16, 26, 27, 30, 34, 42) - The brand is outspoken (15, 16, 26, 27, 30, 34, 42) - The brand achieves its goals by non-traditional means (9, 15, 16, 26, 27, 30, 34, 42) - The brand is known for its provocative/controversial behavior (6, 9, 11, 13, 15, 16, 26, 27, 30, 34, 42, 45, 46) - The brand surprises customers (7, 15, 16, 26, 27, 30, 35, 48)	"A Charismatic brand is one that surprises you with things that you don't expect" "Apple's vision for innovation makes it risky and unconventional" "Desigual, the Spanish brand has charisma because its controversial ads capture a lot of attention. I like this behavior because it breaks from the norm" "Last year I bought a Tudor luxury watch. I know that these guys always push the envelope and use celebrities that are totally unconventional such as Lady Gaga, I love this approach" "I love Tom Ford because it is so provocative. It has a stunning, sexy sleek style" "Last year I came across an Yves Saint Laurent ad which was so controversial and provocative. The ad showed a model in fishnet stockings and a fur coat I think spreading her legs and wearing roller skate high-heels"

9. Associated with a strong leader (existing or former)	- The CEO/creative director insists on his/her own values and does not give them up easily (4, 6, 11, 13, 15, 19, 28) - The CEO/creative director has extraordinary leadership and communication skills (4, 6, 11, 13, 15, 23, 29, 30, 37) - The CEO/creative director is inspiring and energizing (4, 5, 6, 11, 13, 15, 19, 28)	"A charismatic brand is synonymous with great leadership. Steve Jobs is the perfect example. He always stood by his principles and own set of values" "Karl Lagerfeld is such an iconic person. He is such an inspirational designer for Chanel" "I was saddened to see Christopher bailey step down as the inspirational CEO of Burberry last year. He transformed Burberry into an iconic brand and was the first person to push the use of social media in the marketing and selling of luxury".

Behavior 1: Communication

Respondents in all five focus groups described the nature of the brand's communication as a vehicle to legitimize brand charisma. This behavior describes communications messages reflecting articulation, expressiveness, and formulated in an eloquent way. For example, respondent 7 in focus group 1 stated: "Brand like Chanel, Hermes, Louis Vuitton and Gucci express themselves so beautifully and elegantly. They are so engaging". Respondents made similar statements from focus groups 2, 3, 4 and 5. For example, respondent 15 from focus group 2 stated: "I love the Louis Vuitton core values ads. They really connect with me at an emotional level". These illustrations clearly show that charismatic brands demonstrate highly expressive communication, which is articulate in nature as well as elegant. The importance of being viewed as a highly expressive and articulate brand was further reinforced by the widespread use of storytelling as a communications tool. As stated by respondent 44 in focus group 4: "Apple always has a story to tell. Behind each product, there is a history of what brought it to market. I feel inspired by those stories. It adds inherent value to the brand".

Behavior 2: Admiration and inspiration

Brands that elicit great admiration, draw attention easily, and inspire were also described by respondents across the 5 focus groups. We labeled this behavior 'admiration and inspiration' to encompass a set of behaviors that include both inspiration to others and drawing attention and admiration. For example, respondent 8 in focus group 1 stated "Chanel is a charismatic brand because it is highly attractive and influences people in a positive way". Similarly, respondent 22 in focus group 3 stated: "Ferrari is such an inspirational brand. It is so magical and has a rare character which demands so much respect". These findings are consistent with existing research (Dion & Arnould, 2011) which contends that luxury retail draws on the principles of art and magic to assemble the charismatic persona of the creative director and to diffuse his/her aesthetic ideology to the brand. Moreover, luxury retail strategy enlists magical and aesthetic principles within and without the store to achieve these ends.

Behavior 3: Honesty and reliability

Brands that are honest and reliable were also identified by respondents. Respondents across all 5 focus groups made reference to qualities such as reliability, trustworthy, honesty, and sincerity. For example, respondent 19 in focus group 2 stated: "I feel that Chanel has so much sincerity in what it does. There is nothing pretentious about the brand. It really believes in what it is doing", while respondent 36 in focus group 4 stated: "Many luxury brands today recognize the importance of being honest and transparent when it comes to reporting. The Kerring Group

is a good example of this. The Chalhoub Group, as a major distributor and retailer of luxury in the Middle East are also transparent in what they report about sustainability".

Behavior 4: Attraction

The fourth charismatic behavior identified by respondents revolved around expressions of attractiveness. An attractive brand is one that is magnetically attractive, charming, appealing, beautiful, elegant, sophisticated and classy. For example, respondent 7 in focus group 1 stated "Charisma is like having a charm or an attractive character that people can relate to. Louis Vuitton is a good example", while respondent 34 from focus group 3 stated: "Chanel is synonymous with beauty". Respondents made similar comments from the other focus groups. For example, respondent 12 from focus group 2 stated: "Patek Philippe is so sophisticated and stylish. The brand charms potential buyers", while respondent 47 from focus group 5 stated: "I see Tiffany & Co as a simple, elegant and classy brand and these things make the brand charismatic".

Behavior 5: Visionary

Respondents in all five focus groups also described the importance of being visionary as a vehicle to legitimize brand charisma. This behavior reflects whether the brand has a vision for the future, has positive energy, focuses on unexploited and futuristic opportunities, and is dynamic, outgoing and ambitious in nature. For example, respondent 22 in focus group 3 stated: "Tesla is such an exciting and dynamic brand. It is disrupting the car market and is so ambitious", while respondent 48 in focus group 5 stated: "Take Chanel for example. It creates trends and shapes the future". These findings suggest that charismatic brands are perceived to be "visionary' in their outlook and behavior and stand out as model examples for other organizations. Being visionary clearly says something about the brands strength of character and the will to achieve this vision.

Behavior 6: Powerful and dominant

Respondents across all 5 focus groups made reference to qualities such as strong, controlling, confidence, assertive, influential, market leadership, a benchmark for all and audaciousness. We labelled this behavior 'powerful and dominant'. For example, respondent 4 in focus group 1 stated: "Apple changes the lifestyles of consumers. Also, it is a role model or a benchmark which forces other companies to follow", while respondent 28 in focus group 3 stated: "Aston Martin has charisma because it is bold and powerful". Similarly, respondent 36 in focus group 4 stated: "Brands such as Chanel Rolls Royce fear nobody. They are so daring".

Behavior 7: Sensitive to the environment

Respondents across several focus groups also described brand charisma in terms of sensitivity to the environment. This behavior characterizes the ability of the brand to adapt to environmental changes and revolves around whether the brand models ethical standards, goes beyond company self-interest and raises awareness and takes action on important environmental issues. For example, respondent 12 in focus group 2 stated: "If you take expensive fashion clothes, do they always come with a guarantee of ethical standards when it comes to producing them? I mean luxury fashion brands you always more for the clothing you but, but those people on the production lines and in the cotton fields, are they automatically paid more? I don't believe so, this behavior is not right. I often think that it is about higher profits for these brands", while respondent 21 in focus group 3 stated: "Luxury jewelry brands such as Chopard and Tiffany & Co now used stones that are ethically mined and they also

recycle gold and silver and work with ecologically conscious mines. They are acknowledging the importance of sustainability through these actions".

Behavior 8: Displays unconventional behavior

The eighth behavior to emerge from our data analyses was unconventional behavior. This behavior encompasses being outspoken, achieving goals by non-traditional means, and exhibiting provocative/controversial behavior. For example, respondent 26 in focus group 3 stated: "Desigual, the Spanish brand has charisma because its controversial ads capture a lot of attention. I like this behavior because it breaks from the norm", while respondent 15 in focus group 2 stated: "Last year I bought a Tudor luxury watch. I know that these guys always push the envelope and use celebrities that are totally unconventional such as Lady Gaga, I love this approach". Similarly, respondent 6 in focus group 1 stated: "Last year I came across an Yves Saint Laurent ad which was so controversial and provocative. The ad showed a model in fishnet stockings and a fur coat I think spreading her legs and wearing roller skate high-heels". These findings highlight the importance of doing things that other brands do not, and doing them in a way that is perceived as unique and different, and not following conventional methods of operation.

Behavior 9: Association with a strong leader/creative director

The final behavior to emerge from our data analyses described behaviors associated with strong leadership. For example, respondent 4 in focus group 1 stated: "A charismatic brand is synonymous with great leadership. Steve Jobs is the perfect example. He always stood by his principles and own set of values". Similarly, respondent 15 in focus group 2 stated: "I was saddened to see Christopher bailey step down as CEO of Burberry last year. He transformed Burberry into an iconic brand and was the first person to push the use of social media in the marketing and selling of luxury". Our findings are consistent with luxury research (Dion & Arnould, 2011) which contends that luxury draws on the principles of art and magic to assemble the charismatic persona of the CEO/creative director and to diffuse his/her aesthetic ideology to the brand.

DISCUSSION AND IMPLICATIONS

Acknowledging that little is known about the conceptual domain of brand charisma and the behaviors associated with its legitimization, the objective of the current study was to identify the behavioral attributes of charismatic luxury brands. Determining if a brand has charisma means demonstrating it has exceptional qualities as believed by those who consume and interact with the brand (Smothers, 1993). Although existing research on brand charisma assigns responsibility for the social construction of brand charisma to customers (Lee, Workman and Jung, 2015; Smothers, 1993), the charismatic behaviors that give a brand its legitimacy lack specificity. The results of the current study demonstrate the importance of nine core behaviors as perceived by luxury brand consumers and support a multidimensional conceptualization of the brand charisma construct. Drawing upon Conger and Kanungo's (1998) attribution theory, our findings show that brand charisma represents consumer perceptions of the brand in terms of whether it is expressive in its communication, admired and inspires, honest and reliable, attractive, visionary, powerful, sensitive to the environment, unconventional in its behavior, and lead by a strong inspirational leader. Although Lee, Workman and Jung (2015) claim to provide a valid and generalizable scale to measure brand charisma using items adapted from the human charisma scale of Verčič and Verčič (2011), concerns regarding the content validity of the scale exist. Our findings demonstrate a broader set of charismatic behaviors than the four

behaviors identified by Lee, Workman and Jung (2015). Moreover, these behaviors stretch well beyond the power and influence of charismatic corporate leaders/creative directors.

These nine behaviors form a constellation of components or dimensions of brand charisma. It is possible that different luxury brands can be seen as equally charismatic, yet their underlying charismatic structure has different behavioral configurations. We argue that the different behavioral attributes lend themselves to formative measurement using a first-order formative second-order reflective measurement model. First-order reflective measurement assumes that such core behaviors are reflective in nature i.e., the behavioral attributes are viewed as affected by the same underlying concept. However, we suggest that measuring brand charisma in this way is inappropriate. Brand charisma is formed from combining different behaviors, suggesting that the multi-dimensional and multifaceted nature of the construct can be specified as a summative index. Measuring brand charisma formatively means that the observation of one type of behavior does not imply the existence of other types of behaviors.

The insights generated in this study will be useful to practitioners in developing a better understanding of the behaviors that legitimize brand charisma. As noted earlier, charisma is an attribution, and specific characteristics are causally responsible for this attribution. Acknowledging that brand charisma is a key driver of healthy brand-customer relationships, our findings provide the managers with a bird's eye view of the behaviors responsible for such attributions.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

Given that the focus of this study was explicitly on obtaining insights rather than testing theory, depth of understanding rather than generalization was the prime concern (Miles and Huberman 1994). We acknowledge that are findings are exploratory in nature. However, without strong qualitative insights to understand the behaviors associated with brand charisma as perceived by consumers, marketers lack the foundation to better understand how consumers develop relationships with brands. Our research has several limitations. First, the study was conducted only in one context (luxury branding) and one country (United Arab Emirates). The findings of this study should be replicated in other contexts and countries. Second, although the current study advances theoretical understanding of the conceptual domain of brand charisma, it does not present and empirically validate an instrument to measure the construct. Given the increasing importance of emotional and transformative brand values in luxury branding, there is a need to develop a measurement instrument for managers to better gauge customer perceptions of brand charisma. Future research should therefore focus on the development of a valid and reliable measurement scale. The results of this exploratory study have identified an initial pool of potential items to measure brand charisma, which can be used in a future quantitative investigation of the brand charisma concept. Content and face validity checks are obvious next steps followed by rigorous psychometric analysis undertake using survey data from a sample of brand consumers. Future research should also examine how behavioral configurations differ across brands and how these configurations affect relationships between brands and their customers. Finally, we acknowledge that brand charisma is not a characteristic uniquely attributed for luxury brands. Future research should establish of the behavioral configurations identified in the current study have relevance to brands that have more mass appeal.

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DECISION SCIENCES INSTITUTE
Modeling Relief Distribution for Emergency Response

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ABSTRACT

We propose a bi-objective model to analyze the satisfaction for relief supplies at the minimal cost for a humanitarian operation. We use different modes of transportation for distribution and satisfaction scoring in terms of met and unmet demand. We also consider constraints on transportation supply due to the disaster. The model is applied to the data on relief distribution missions after May 2015 earthquake in Nepal.

KEYWORDS: Humanitarian logistics, relief distribution, decision making, transport capacity

INTRODUCTION

Relief supply after the disaster is extremely challenging due to the dynamically changing disaster situation and the demand for relief supplies. This situation has been witnessed mostly in large-scale disasters. Demand can change due to the identification of new disaster places or the changes obtained through the reassessment of the disaster area. Similarly, the relief supplies may arrive but the distribution of those supplies may be constrained due to the limited capacity or inaccessibility of the disaster locations. That means there are concurrent changes in supply capacity and demand situations. Alternate transportation might also have to be considered for urgent supplies in order to meet the relief demand in some inaccessible areas. Even if there may be no direct and immediate costs accounted for relief supplies through these modes, there would still be some costs due to the allocation of these resources.

The research considers two objectives: one, to meet the expected demand, and; two, to reduce the direct cost of immediate operation by considering the information on available transport options (mode and route) and the demand in different locations. The main contribution of the paper is the consideration of the two objectives by considering alternative distribution methods and maximizing satisfaction through the reduction of unmet demand. The model provides the opportunity to provide a better distribution option for relief supplies.

LITERATURE REVIEW

Comprehensive reviews of optimization models in humanitarian logistics are given in Canhuye

et al (2012) and Özdamar et al (2015). Some essential features that should be considered for the satisfaction of victims through deprivation costs are given in Holguin-Veras et al (2012, 2013). The notion of deprivation cost is analyzed in more detail by Gutjahr and Fischer (2018), who show that the deprivation cost increases exponentially to a higher level when the response materials are not sent to the victims on time. The authors mention that the smaller the time range of distribution frequency, the smaller would be the deprivation time. However, this also depends on the type of relief supplies. For food supplies, the deprivation would be much higher compared to that for the non-food items for the same distribution frequency.

Most previous literature (Özdamar et al., 2004 and Yi and Özdamar, 2007, Özdamar, 2011, Rottkemper et al., 2012) in relief planning propose single-objective dynamic models considering serviceability. Serviceability in these studies is considered mainly in terms of minimizing the time and maximizing the supply reach.

Özdamar et al. (2004) and Yi and Özdamar et al. (2007) maximize the serviceability minimizing unmet demand. Both of these studies focus on vehicle routing and scheduling. Özdamar (2011) focuses on the air transportation of the resources and propose a model for dynamic scheduling of the helicopters. The aim is to minimize the total mission time which is the sum of the flight time and loading and unloading time.

Facilities location models have also been developed by different authors. Vahdani et al. (2018) Boonmee et al (2017), Baskaya et al. (2017) and Khayal et al. (2015) have proposed different location and allocation models by considering different aspects of relief distribution. Balcik et al (2010), on the other hand also mention the need for a coordinated distribution of emergency logistics.

Rottkemper et al., (2012) considers a part of uncertain demands that may appear in the resource planning. The model considers the land-based distribution of the resources and minimizes the sum of the transportation, holding and the penalty cost of unsatisfied demands.

Several multi-objective models have also been proposed. Tzeng et al. (2007) discuss the multi-objective model with three objectives of cost, response time and distribution fairness. The cost objective includes setup and operational costs of transfer depots and distribution of relief resources. The response time objective includes the travel time between the resources collection points, transfer depots and demand centers. The distribution fairness objective includes the maximization of satisfaction in distribution fairness by considering a weighted score for the satisfaction value for each relief supply item in different planning periods. The multi-objective model proposed by Gralla, Goentzel, and Fine (2014) has similar objectives.

Nikoo et al. (2018) propose a transportation network design model with three objectives as well: minimizing the length of the network for distribution, minimization of the total time required for distribution, and the minimization of the number of routes. Their objective function is focused mainly on network design. The authors also consider some kind of prioritization of the objectives by giving more weightage to the goal of reaching to the victims. The objectives are analyzed as single objectives and with weights assigned to different functions.

Cao et al. (2018) also consider a multiobjective model for relief distribution. The authors consider the maximization of the perception of satisfaction on relief supplies, minimization of the satisfaction deviation at any two distribution centers, and the minimization of the perceptual satisfaction by considering the relief response period. In essence, the model considers satisfaction in different aspects in order to develop a relief supply model.

The review shows that the current research in response planning overlooks the capacity limitations in response phase and availability of the limited numbers of helicopters availability. We present a response planning model which considers resource distribution with mixed transportation modes (land and air) to maximize utilization of the available number of helicopters. We also consider satisfaction level of the victims so that it can be maximized for the distribution of resources in far-flung areas as well by considering satisfied and unsatisfied

demand. Therefore, the proposed model is different compared to what has been presented so far in the literature. We consider the actual disaster situation in Nepal's earthquake and propose a network structure which could maximize supply reach to the disaster regions with available transportation capacity. The model is solved through simultaneous (joint optimization) of both objectives.

MODEL AND SOLUTION METHODOLOGY

In order to develop the model, we consider the distribution of, $\boldsymbol{K}$ set of commodities, $\boldsymbol{K_1} = \{\boldsymbol{1}, \ldots, \boldsymbol{k_1}\}$ referring to food commodities and $\boldsymbol{K_2} = \{\boldsymbol{k_1} + \boldsymbol{1}, \ldots, \boldsymbol{k_1} + \boldsymbol{k_2}\}$, referring to non-food commodities. We consider the planning horizon with $\boldsymbol{\mathcal{T}}$ number of short distribution periods *t.* We consider $\boldsymbol{\mathcal{C}}$ as collection points and $\boldsymbol{\mathcal{D}}$ as demand area (or a region) and $\boldsymbol{A_d}$ as demand points in $\boldsymbol{\mathcal{D}}$. Then supplies collected at a location in a period can be considered as S^{kt}_c. We consider vehicle types $\boldsymbol{\mathcal{V}}$ that may consider a set of helicopter $\boldsymbol{L_d}$trucks types, and vehicles $\boldsymbol{\mathcal{V}_{ad}}$ that are able to access a particular demand location in the disaster area $\boldsymbol{\mathcal{D}}$. Food demand is represented per period as D^{kt}_{ad} and non-food demand is represented only for the beginning of response time, as D^{0k}_{ad}. We assume the maximum number of trucks rented varies over the time, N^{0t}_{cv} and N^{t}_{dv}. Helicopters of different types available are H^{t}_{v}.

Table 1: Notations used in modeling

Symbol	Description
Parameters:	
$\boldsymbol{D_{ad}^{kt}}$	Periodic demand for food commodity *k* at ADP *a* of DB *d* in period *t*
$\boldsymbol{D_{ad}^{0k}}$	One time demand for non-food commodity *k* at ADP *a* of DB *d*
$\boldsymbol{S_c^{kt}}$	Commodity *k* collected at CP *c* in period *t*
$\boldsymbol{V_c^0}$	Inventory holding capacity at CP *c*
$\boldsymbol{V_d^1}$	Inventory holding capacity at DP
$\boldsymbol{V_{ad}^2}$	Inventory holding capacity at ADP *a* of DB *d*
$\boldsymbol{Q_v}$	The capacity of the vehicle of type *v*
$\boldsymbol{N_{cv}^{0t}}$	Maximum number of trucks of type *v* that can be rented at CP *c* in period *t*
$\boldsymbol{N_{dv}^{t}}$	Maximum number of trucks of type *v* that can be rented at DB *d* in period *t*
$\boldsymbol{H_v^t}$	Number of available helicopters of type *v* in period *t*
$\boldsymbol{HT_v}$	Maximum number of trips possible from a helicopter of type *v* within the length of a time period
$\boldsymbol{T_{cdv}^{0t}}$	Cost of transportation from CP *c* to DP *d* in period *t* using a truck of type *v*
$\boldsymbol{T_{dav}^{t}}$	Cost of transportation from DB *d* to its ADP *a* in period *t* using vehicle of type *v*
$\boldsymbol{F}$	The fixed cost of allocating a helicopter to a DB
$\boldsymbol{H^0}$	Unit inventory holding cost at CPs
$\boldsymbol{H^1}$	Unit inventory holding cost at DBs
$\boldsymbol{H^2}$	Unit inventory holding cost at ADPs
Variables:	
$\boldsymbol{g_{dav}^{kt}}$	Amount of commodity *k* distributed from DB *d* to its ADP *a* using vehicles of type *v* in period *t*
$\boldsymbol{\delta_{ad}^{kt}}$	Net demand for commodity *k* at ADP *a* of DB *d* in period *t*

	$= D_{ad}^{kt}$ for $k \in \mathcal{K}_1$
	$D_{ad}^{0k} - \sum_{n\in\mathcal{T}, n<t} \sum_{v\in\mathcal{V}} g_{dav}^{kn}$ for $k \in \mathcal{K}_2$
h_c^{0kt}	Inventory of commodity *k* at CP *c* in period *t*
h_d^{1kt}	Inventory of commodity *k* at DB *d* in period *t*
h_{ad}^{2kt}	Inventory of food commodity *k* at ADP *a* of DB *d* in period *t*
u_{ad}^{kt}	Unsatisfied demand for food commodity *k* at ADP *a* of DB *d* in period *t*
u_{ad}^{0k}	Unsatisfied demand for non-food commodity *k* at ADP *a* of DB *d* by the end of the time periods $= D_{ad}^{0k} - \sum_{t\in\mathcal{T}} \sum_{v\in\mathcal{V}} g_{dav}^{kt}$
s_{ad}^{kt}	Satisfaction score for food commodity *k* at ADP *a* of DB *d* in period *t* $= (D_{ad}^{kt} - u_{ad}^{kt})/D_{ad}^{kt}$
s_{ad}^{0k}	Satisfaction score for non-food commodity *k* at ADP *a* of DB *d* by the end of the time periods $= (D_{ad}^{0k} - u_{ad}^{0k})/D_{ad}^{0k}$

x^t_{cdv} is the number of trucks of type-*v* (having capacity Q_v) traveling from C to D in period *t*. A set of truck types that can access a D, *is* $\mathcal{L}_d$. r^{kt}_{cdv} represents the amount of commodity-*k* carried by x^t_{cdv} with the number of trips as y^t_{dav}. Similar to DBs, ADPs are also required to be serviced by specific types of vehicle. Therefore, we identify a set of vehicle types, which includes both the truck types and the helicopter types that can reach to ADP-*a* of DB-*d* represented by $\mathcal{V}_{ad}$. The number of trips of vehicles of type-*v* from DB-*d* to ADP-*a* in period *t* represented by y^t_{dav}; and its value is equal to 0 for all those vehicle types that are not in $\mathcal{V}_{ad}$. The number of helicopters trips z^t_{dv} is restricted by H^t_v trips that it can make. Each helicopter of type-*v* can make a maximum of HT_v trips. Therefore, y^t_{dav} for helicopters depends on the maximum number of trips possible by z^t_{dv}.

We assume that satisfaction is measured with a score based on the proportion of demand satisfied. The satisfaction score $s_{ad}^{kt} = (D_{ad}^{kt} - u_{ad}^{kt})/D_{ad}^{kt}$ for food commodity as no delays are allowed. For non-food commodity, s_{ad}^{0k} depends on the unsatisfied demand of the commodity at the ADP by the end of the distribution periods represented by u_{ad}^{0k}.

The relief distribution model is formulated as follows:

$$f_1 = \min \sum_{t\in\mathcal{T}} \sum_{c\in\mathcal{C}} \sum_{d\in\mathcal{D}} \sum_{v\in\mathcal{L}} T_{cdv}^{0t} x_{cdv}^t + \sum_{t\in\mathcal{T}} \sum_{d\in\mathcal{D}} \sum_{a\in\mathcal{A}_d} \sum_{v\in\mathcal{V}} T_{dav}^t y_{dav}^t + \sum_{t\in\mathcal{T}} \sum_{d\in\mathcal{D}} \sum_{v\in\mathcal{H}} F z_{dv}^t + \sum_{t\in\mathcal{T}} \sum_{k\in\mathcal{K}} \sum_{c\in\mathcal{C}} H^0 h_c^{0kt} + \sum_{t\in\mathcal{T}} \sum_{k\in\mathcal{K}} \sum_{d\in\mathcal{D}} H^1 h_d^{1kt} + \sum_{t\in\mathcal{T}} \sum_{k\in\mathcal{K}_1} \sum_{d\in\mathcal{D}} \sum_{\epsilon\mathcal{A}_d} H^2 h_{ad}^{2kt} \quad (1)$$

$$f_2 = \max \sum_{t\in\mathcal{T}} \sum_{d\in\mathcal{D}} \sum_{a\in\mathcal{A}_d} \sum_{k\in\mathcal{K}_1} s_{ad}^{kt} + \sum_{d\in\mathcal{D}} \sum_{a\in\mathcal{A}_d} \sum_{k\in\mathcal{K}_2} s_{ad}^{0k} \quad (2)$$

subject to

$$\sum_{d\in\mathcal{D}} x_{cdv}^{t} \le N_{cv}^{0t} \qquad \forall c\in\mathcal{C}, v\in\mathcal{L}, t\in\mathcal{T} \qquad (3)$$

$$\sum_{a\in\mathcal{A}_d} y_{dav}^{t} \le N_{dv}^{t} \qquad \forall d\in\mathcal{D}, v\in\mathcal{L}, t\in\mathcal{T} \qquad (4)$$

$$\sum_{d\in\mathcal{D}} z_{dv}^{t} \le H_{v}^{t} \qquad \forall v\in\mathcal{H}, t\in\mathcal{T} \qquad (5)$$

$$\sum_{a\in\mathcal{A}_d} y_{dav}^{t} \le HT_{v} z_{dv}^{t} \qquad \forall d\in\mathcal{D}, v\in\mathcal{H}, t\in\mathcal{T} \qquad (6)$$

$$\sum_{k\in\mathcal{K}} r_{cdv}^{kt} \le Q_{v} x_{cdv}^{t} \qquad \forall c\in\mathcal{C}, d\in\mathcal{D}, v\in\mathcal{L}, t\in\mathcal{T} \qquad (7)$$

$$\sum_{k\in\mathcal{K}} g_{dav}^{kt} \le Q_{v} y_{dav}^{t} \qquad \forall d\in\mathcal{D}, a\in\mathcal{A}_d, v\in\mathcal{V}, t\in\mathcal{T} \qquad (8)$$

$$h_{c}^{0kt} = h_{c}^{0kt-1} + S_{c}^{kt} - \sum_{d\in\mathcal{D}}\sum_{v\in\mathcal{L}} r_{cdv}^{kt} \qquad \forall c\in\mathcal{C}, k\in\mathcal{K}, t\in\mathcal{T} \qquad (9)$$

$$h_{d}^{1kt} = h_{d}^{1kt-1} + \sum_{c\in\mathcal{C}}\sum_{v\in\mathcal{L}} r_{cdv}^{kt} - \sum_{a\in\mathcal{A}_d}\sum_{v\in\mathcal{V}} g_{dav}^{kt} \qquad \forall d\in\mathcal{D}, k\in\mathcal{K}, t\in\mathcal{T} \qquad (10)$$

$$h_{ad}^{2kt-1} + \sum_{v\in\mathcal{V}} g_{dav}^{kt} - h_{ad}^{2kt} + u_{ad}^{kt} = \delta_{ad}^{kt} \qquad \forall d\in\mathcal{D}, a\in\mathcal{A}_d, k\in\mathcal{K}_1, t\in\mathcal{T} \qquad (11)$$

$$h_{ad}^{2kt} \le \left| h_{ad}^{2kt-1} + \sum_{v\in\mathcal{V}} g_{dav}^{kt} - \delta_{ad}^{kt} \right| \qquad \forall d\in\mathcal{D}, a\in\mathcal{A}_d, k\in\mathcal{K}_1, t\in\mathcal{T} \qquad (12)$$

$$u_{ad}^{kt} \le \left| \delta_{ad}^{kt} - h_{ad}^{2kt-1} + \sum_{v\in\mathcal{V}} g_{dav}^{kt} \right| \qquad \forall d\in\mathcal{D}, a\in\mathcal{A}_d, k\in\mathcal{K}_1, t\in\mathcal{T} \qquad (13)$$

$$\sum_{v\in\mathcal{V}} g_{dav}^{kt} \le \delta_{ad}^{kt} \qquad \forall d\in\mathcal{D}, a\in\mathcal{A}_d, k\in\mathcal{K}_2, t\in\mathcal{T} \qquad (14)$$

$$\sum_{k\in\mathcal{K}} h_{c}^{0kt} \le V_{c}^{0} \qquad \forall c\in\mathcal{C}, t\in\mathcal{T} \qquad (15)$$

$$\sum_{k\in\mathcal{K}} h_{d}^{1kt} \le V_{d}^{1} \qquad \forall d\in\mathcal{D}, t\in\mathcal{T} \qquad (16)$$

$$\sum_{k \in \mathcal{K}_1} h_{ad}^{2kt} \leq V_{ad}^2 \qquad \forall d \in \mathcal{D}, a \in \mathcal{A}_d, t \in \mathcal{T} \qquad (17)$$

$$x_{cdv}^t = 0 \qquad \forall c \in \mathcal{C}, d \in \mathcal{D}, v \in \mathcal{L} \backslash \mathcal{L}_d \; t \in \mathcal{T} \qquad (18)$$

$$y_{dav}^t = 0 \qquad \forall d \in \mathcal{D}, a \in \mathcal{A}_m, v \in \mathcal{V} \backslash \mathcal{V}_{ad}, t \in \mathcal{T} \qquad (19)$$

Objective (1) minimizes the total cost of transportation. Objective (2) maximizes the satisfaction scores. Constraints (3) and (4) are the restrictions on the maximum number of available trucks for rent. Constraint (5) allocates the available helicopters. Constraint (6) ensures that the possible number of helicopter trips is maintained. Constraints (7) and (8) are the capacity limitations of the vehicles. Constraints (9) and (10) are the balance equations at the CP and DB, respectively in period *t*. Constraint (11) is the balance equation at ADP for food commodity. Constraint (11) together with constraints (12) and (13) determines the unsatisfied and excess amount of food supplies at each of the ADP in each period. Constraint (14) confirms that the distribution of non-food supplies to ADPs do not exceed their net demand. Constraints (15) to (17) are inventory storage capacity limitations at CPs, DBs, and ADPs, respectively. Constraints (18) and (19) ensure that the distribution of supplies takes place using vehicle types reachable to the destinations.

In order to solve the model, compromise programming method has been used. In this method, distance metrics are used to find the best possible options. Let f_1^* **and** f_2^* represent the optimal value of objectives and l_∞represent the distance metric. Then in this case, we have

$$\textbf{min} \quad l_\infty \qquad (20)$$

subject to

$$\frac{f_1 - f_1^*}{f_1^- - f_1^*} \leq l_\infty \qquad (21)$$

$$\frac{f_2^* - f_2}{f_2^* - f_2^-} \leq l_\infty \qquad (22)$$

Eqs. (3) to (19)

APPLICATION CASE

We use the actual network distribution for the case of Nepal Earthquake 2015. The network consists of a CP located at the capital city Kathmandu and 14 Demand areas and 744 demand points. Some of the demand points are only accessible through helicopters. Table 1 shows the total number of ADPs in each DB and the number of ADPs that are reachable only by air after the disaster.

Table 2: Total and number of ADPs that must be reached by air

DBs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of demand points	18	55	62	44	42	89	59	67	18	49	79	52	54	56
Number of demand points only accessible by air	9	10	0	0	0	9	0	14	0	5	10	6	2	3

We consider one package of food- commodity and one package of the non-food commodity with a four day period for a planning horizon for distribution planning. Although food items are needed to be supplied after the first supply period, the demand for non-food items is satisfied

when they are supplied once. We assume that all demand is satisfied at the end of the planning horizon. Table 3 shows the periodic supply capacity at the supply point. It is assumed that 0.5kg per person per day for the food item and 4.5 kg per household for non-food items.

Table 3: Supply capacity at the CP for the planning period

Time period	1	2	3	4
Food item supply capacity (kg)	10950	10950	10950	14123
Non-food item supply capacity (kg)	4972	4972	4972	5611

In the model, four types of trucks and three types of helicopters are considered. Table 4 shows the capacities of each type of these transportation modes. Each helicopter is assumed to make two trips a day (due to distance coverage, loading, unloading, and distribution).

Table 4: Vehicle types and capacities

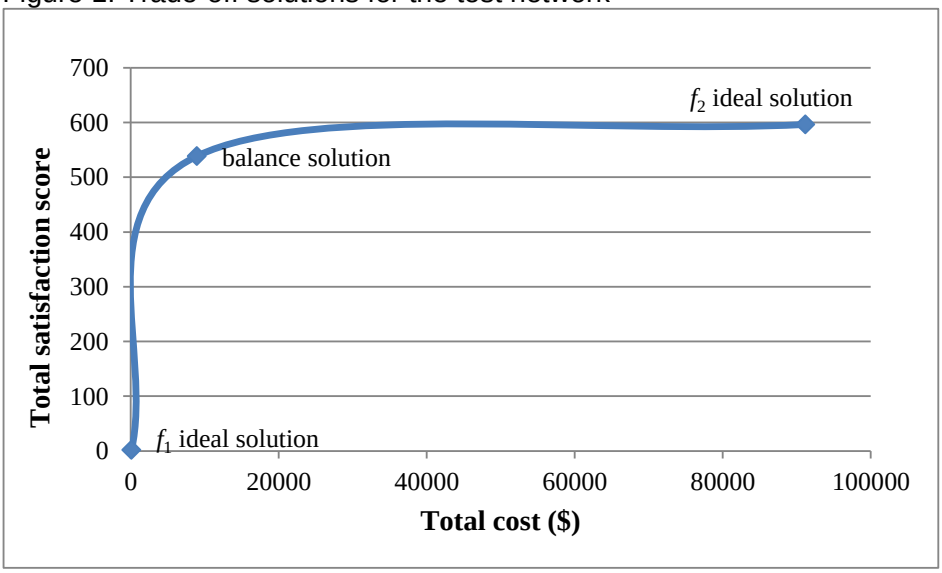
Vehicle types	V1	V2	V3	V4	V5	V6	V7
Capacity (kg)	500	1070	1500	3000	1000	1700	3000

Costs for trucks are based on fuel cost per km, but the cost of the helicopter is based on the cost of allocation only. It is assumed that the helicopters are provided with no immediate cost. Other parametric cost values are generated based on the authors work in Nepal.

RESULTS AND DISCUSSIONS

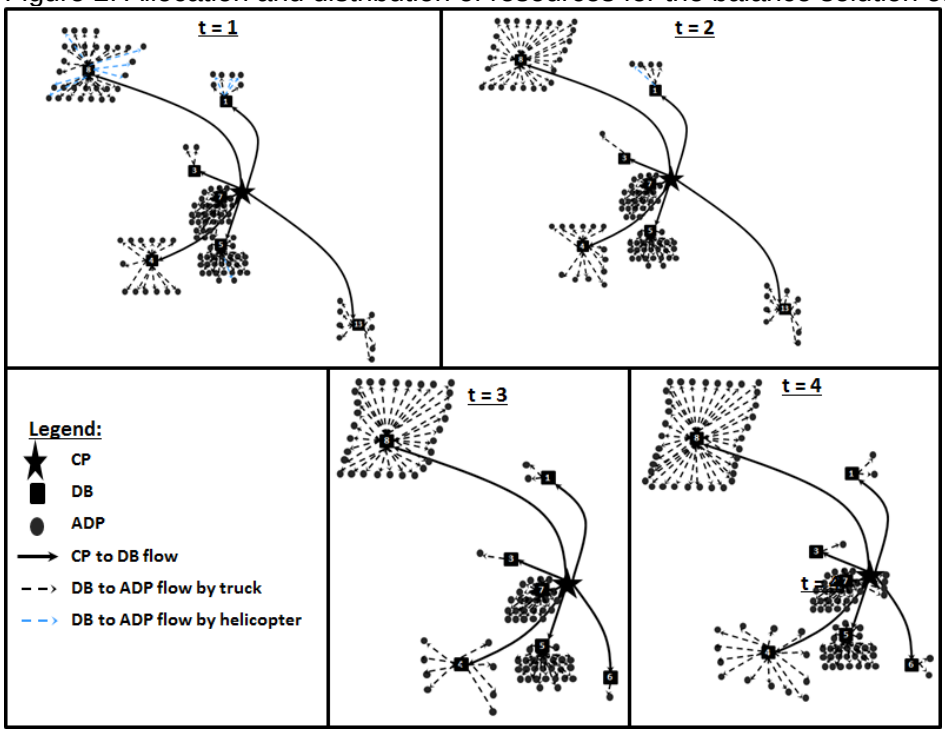
Figure 1 shows that for cost optimality, the solution is very small, about 100 because it tends to use maximum helicopter due to lower cost for the relief agencies and supplies to the nearby locations. The balanced solution associates a cost of about $9000 and maintains a satisfaction score of about 540. The satisfaction score here is close to the optimal value based on the solution methodology. Deliveries for a balanced solution are mainly done through the trucks.

Figure 1: Trade-off solutions for the test network



In terms of commodity distribution, Figure 2 shows the allocation and distribution of resources in the network for the four periods. It shows helicopters are used more for the initial periods and then it gets reduced as the truck supply starts arriving at the location. It also means that the demand of distant locations is met through the helicopters in the beginning periods.

Figure 2: Allocation and distribution of resources for the balance solution of the test network



CONCLUSION AND FURTHER RESEARCH

We present a bi-objective model for assessing relief supplies in an earthquake disaster setting. The model considers several demand points, fewer distribution centers, and one central supply point. We find that when there is a change in demand and supply, it has impacts on demand satisfaction. Increase in demand or decrease in supply creates more dissatisfaction but the reverse situation is not necessarily true due to supply capacity constraints. However, given the constant demand and unlimited transport capacity, the cost and satisfaction levels increase with an increase in supply capacity. The results show that if cost is the only consideration, then supplies are dispatched to the nearest location first irrespective of more acute demand problems in other areas. This can be avoided by considering multiple supply points in the future research. The focus should also be to consider temporary distribution points between the supply points and the demand points so that inter-allocations among such temporary locations can be promoted to mitigate the problem of demand and supply dynamism. Such temporary locations can also reduce the cost of transportation and increase satisfaction levels.

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DECISION SCIENCES INSTITUTE

Modular Interconnected Process, Fluid Partnering, and Innovation Speed: Loose Coupling Perspective

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ABSTRACT

We examine the antecedents of innovation speed in the context of loosely coupled systems as encompassed in modular interconnected processes and fluid partnering in enhancing innovation speed. Specifically, we evaluate the importance of coordinating mechanisms – standard process and content interface, and structured data connectivity in developing modular interconnected process. We also examine whether or not a fluid partnership and information quality enhance innovation speed. The results indicate that standardized process and content interfaces are positively associated with modular interconnected processes. Modular interconnected processes positively influence ability to reconfigure supply chain partners. Fluid partnership enhanced information quality, which, influences innovation speed.

KEYWORDS: Modular interconnected process, innovation speed, information quality

INTRODUCTION

Rapid changes in dynamic business environment (Teece, 2012) and shortening of a product lifecycle (Chien, Chen & Peng, 2010; van Iwaarden & van der Wiele, 2012; Bakker et al., 2014) require organizations to introduce innovative products and services at a periodic interval to keep up with the evolving demands of customers. At the heart of innovation speed literature lies the question as to how can a firm offer series of innovative products or services relatively quickly so that it can continuously reinvigorate the sources of revenue.

Our contention is organizational design can be a source for innovation if the organization is designed to act like a loosely coupled system. In this study, we address following research questions: how can we design organizations to act like a loosely coupled system? How the various elements of a loosely coupled system interact with each other? How does a loosely coupled organizational design affect innovation speed?

THEORETICAL BACKGROUND AND HYPOTHESES

Loosely Coupled System

Loosely coupled system is where coupled subsystems are responsive to one another, but each subsystem also "preserves its own identify and some evidence of its physical and logical separateness" (Weick, 1976; p. 3). Loose coupling could occur among individuals, among organizations, among subunits, between organization and its environment, between activities, etc. (Orton & Weick, 1990).

The extent of an integration of a system determines the degree of its coupling. In the case of manufacturing a vehicle, if all the components of a vehicle were manufactured in-house, as in the case of Ford - Model T, then the system would be characterized as a tightly coupled system. On a contrary, a disintegration of systems into modules, outsourcing of components, and components compliance with design standards will result in a loosely coupled system. Orton and
Weick (1990) argued that a system needs to have dialectical characteristics of *distinctiveness* and *responsiveness* to be a loosely coupled system. The *distinctiveness* of components is achieved when various suppliers conducts their tasks independently, making a system loosely connected. The *responsiveness* of a system is achieved when suppliers conform to design and output standards while conducting their tasks. Responsiveness refers to the coupling of a system as there is some degree of linkage among various components at interfaces so that output of processes conducted by each partner is compatible at the interfaces.

Modular Interconnected Process and Standardized Process and Content Interfaces

Modular interconnected process refers to "the breaking up of complex processes into subprocesses (activities) that are performed by different organizations independently and simultaneously with clearly specified interlinked outputs" (Gosain et al., 2004; p. 16). Modular interconnected process assumes the two important aspects of a loosely coupled system- responsiveness and distinctiveness.

We argue that standardized process and content interface and structured data connectivity are coordinating mechanisms that could take over the role of manager to coordinate various business units (Sanchez & Mahoney, 1996). In the power plant industry, for example, one of the components required for the construction of the power plant is pipe hangers. Primarily, two parties are involved in making pipe hangers – an engineering firm that draws designs of pipes and a supplier firm responsible for fabricating the design. In a research study, Arbulu and Tommelein (2002) found that the absence of an industry-wide standard of a

pipe design resulted in operational inefficiencies and the lack of coordination among partners. Lack of standardized industry-wide design meant that the standardized design was built only after a supplier was chosen and consulted, increasing the time-to-market (Arbulu & Tommelein, 2002). The presence of standardized process and content interface was important for two parties to perform their respective tasks immediately. Based on the discussion, we present our first hypothesis:

H1: Standard process and content interface is positively associated with modular interconnected process.

Structured Data Connectivity and Modular Interconnected Process

Structured data connectivity refers to the exchange of electronic data and content with another enterprise in a specific format (Gosain et al., 2004). Similar to standardized process and content interface, the prime importance of data connectivity lies in its ability to act as a coordinating mechanism for autonomous modules (Zuiderwijk & Janssen, 2013). While standardized process and content interfaces relate to the distinctiveness aspect of a loosely coupled system; structured data connectivity relates to the responsiveness aspect. Structured data connectivity allows value chain partners to communicate easily and effectively in real time using electronic format. The purpose of structured data connectivity is to provide guidelines to codify and exchange data in an electronic format so that it could be shared with suppliers in a real time. Partners, then, could decipher the coded data seamlessly, without ambiguity, improving their responsiveness (Gosain et al., 2004).

H2: Structured data connectivity is positively associated with modular interconnected process

Modular Interconnected Process and Fluid Partnering

Fluid partnering refers to the ability to effectively and efficiently reconfigure supply chain network (Duysters & De Man, 2003). We argue that fluid partnering reflects modularity in relationship between organizations where managers have flexibility to replace ineffective/inefficient partners with the one who possesses the capability to meet the changing demand in the business environment (Gosain et al., 2004). The competitive pressure (Aghion et al., 2005; Gilbert, 2006) and changing customers tastes (Jaworski & Kholi, 1993; Erdil et al., 2004) could force a business to innovate a component(s) of a product. If an existing partner does not have the capability to supply a new component, then the replacement of that partner becomes inevitable. The ability to seamlessly switch partners is critical for business organizations to preserve its competitive edge (Stevenson & Spring, 2007).

Modularity in a process implies an ability of the process to disconnect easily form old processes as well as connect easily with new processes. Thus, we hypothesize:

H3: Modular interconnected process is positively associated with fluid partnering

Modular Interconnected Process and Information Quality

Information quality refers to relevancy, value-addition, timeliness, and completeness of information (Li and Lin, 2006). The presence of better quality of information in the collaborative relationships involving information sharing, problem solving, and joint decision making has a positive influence on supply chain performance (Wiengarten et al., 2010). Modularity enhances information quality through two mechanisms-environmental sensing and local adaptation.

One of the advantages of a loosely coupled system that reinforces the distinctiveness aspect of such system is its ability for a local adaptation. A supplier adapting to its local environmental contingency avoids the entire system from having to go through a change, which

also increases the chance of adaptability and survivability (Sanchez & Mahoney, 1996). Customarily, it is a learning inertia that prevents innovation from occurring (Liao, Fei, & Liu, 2007). One of the causes of learning inertia is organizational size. Larger organizations could be bureaucratic in nature, which could also be more rigid in the face of a dynamic business environment (Ruef, 1997). On a contrary, smaller organizations are nimble in terms of decisions making ability and are likely to adapt to environmental changes more easily. One of the benefits of modularity and local adaptation is similar to what small organizations have that result in their nimbleness – lesser bureaucratization. In a modular interconnected process, each module adapts to its local constraints, resulting from its local environment. Local adaptation also enables each module to have a lesser number of decision-makers, hence lesser bureaucratization. This could result in a lesser conflict of interests (Carlile, 2004), increased creativity (Hirst et al. 2011; Thompson, 1965), and a free flow of information. Based on the discussion, we hypothesize that

H4: Modular interconnected process is positively associated with information quality

Fluid Partnering and Information Quality

Fluid partnering helps to enhance information quality in two ways – selection and attrition process of suppliers will, over time, enhances the information quality; heuristics – trial and error learning, will enhance the quality of information in the long-run.

Given the changing demands of customers in a dynamic business environment, the alteration of a component of a products or services could be inevitable. This could result in a search for a new partner with a skill to fulfill the new demand. Of course, replacement of partners could have a negative implication on the efficiency of a project completion. But, Schwab and Miner (2011) argue that if partners replacements occur frequently, then the costs involved in the replacement of a partner declines and the organization becomes more effective and efficient at replacing partners. The idea resembles the learning curve in partner selection (Li & Rowley, 2002).

Fluid partnering also helps to create weak ties among partners. The partners with weak ties have varying ability to bring novel ideas and creativity (Granovetter, 1973), which will help to foster innovation speed. Based on the discussion, we hypothesize:

H5: Fluid partnering is positively associated with information quality H6: Fluid partnering is positively associated with innovation speed

Information Quality and Innovation

Quality information has four aspects – it should be relevant, valuable, timely, and complete. Relevant information is useful information. Irrelevant information is a burden to a firm. Cognitive limitation of individuals or even organizations hinders them from grasping excessive information. When inundated with information, organizational actors could find it difficult to interpret, comprehend, and benefit from the excessive information (Cohen & Levinthal, 1990; Bawden, Holtham & Courtney, 1999). Irrelevant information could be a noise and increase the rate of error (Edmunds & Morris, 2000). It is only when a firm has a complementary knowledge base, they can absorb new information and learn from it (Lane & Lubatkin, 1998). The exchange of relevant and concise information could reduce the information overload (Butcher, 1995), distraction (Klapp, 1986), and protect organizational actors from processing unnecessary information (March & Simon, 1958).

Another element of information quality is the exchange of information in a timely manner. Because product/service lifecycles are shortening (Chien, Chen & Peng, 2010; van Iwaarden & van der Wiele, 2012; Bakker et al., 2014), firms need to rely on the real-time information to address pressing issues in business environments.

H7: Information quality is positively associated with innovation speed

METHODS

The sample was drawn from the target population of the U.S. service organizations. Zoomerang was used for the data collection. Zoomerang consists of two million registered users and provides a platform to conduct online surveys. It provides an option to filter prospective respondents based on 500 attributes. In the previous studies, researchers have used Zoomerang for the data collection (Ojha et al., 2014; Cudney & Elrod, 2011). The characteristics of the sample are presented in table 1. The sample is evenly distributed across different organizational size based on the number of employees and sales revenue.

Table 1: Sample characteristics

Sales		**Respondents**	
<$1 million (m)	83	Vice President/Asst. Vice President	19
$1 million - $ 10 million	79	CFO/Treasurer/Controller	13
$10 million - $100 million	55	Director/Asst. Director/ Department Head	41
$100 million - $ 1 billion	17	Manager/Asst. Manager	144
> 1 billion	30	Small business owner	21
Total sample	**264**	Doctor/Physician	26
		Total Sample	264

Industry		**Number of employees**	
Automotive	6	19–20	82
Biotech	2	20–49	28
Telecommunication services	9	50–99	17
Agriculture, forestry, fishing and hunting	3	100–149	24
Construction	18	150–499	28
Wholesale trade	13	500–999	20
Retail trade	45	1000–4999	22
Transportation and warehousing	23	5000–9999	18
Finance, banking and insurance	50	10,000–14999	2
Healthcare and social assistance	70	15,000–25,000	5
Arts, entertainment and recreation	14	25000+	18
Information	4	**Total sample**	**264**
Total sample	**264**		

Measures

The measures used in the study are established in the prior studies. To adopt the measures in the context of our study, we modified the measures. The scales that were used to measure variables are presented in Appendix A.

We used Gosain et al., (2004) source to measure Standardized Process and Content Interface (SPCI). A 3-items on a 7-point Likert scale was used to measure SPCI. Three items on a 7-point Likert scale were used to measure Structured Data Connectivity (SDC). Modular Interconnected Process (MIP) was measured using three items on a 7- point Likert scale. Fluid Partnering (FP) was measured using three items on a 5-point Likert scale. We used four items

on a 7-point Likert scale to measure Information Quality (IQ). Three items were used to measure innovation speed. We included three control variables in the study, which are number of employees, sales revenue and industry types. Number of employees was a proxy for a company size, sales was a proxy for resource available, and industry type controlled the effect of differences in industry structure.

RESULTS

Structural equation modeling (SEM) was used to test the hypothesized nomological structure and the direct relationship between variables. The psychometric properties of scale were identified by evaluating reliability and validity of constructs. Confirmatory factor analysis was conducted to examine the discriminant and convergent validity of constructs. Two-step technique was used to examine measurement model and structural model (Anderson & Gerbing, 1988). The two-step technique ensures that the hypotheses testing is conducted after researchers assess the model fit of a measurement model, internal consistency, and convergent and discriminant validity.

Convergent, Discriminant Validity, and Composite Reliability

Table 2 presents validity and reliability of the constructs used in the study. The value of average variance extracted (AVE) for all constructs are above 0.50 threshold, providing support for convergent validity (Fornell & Larcker, 1981). Moreover, the square root of AVE of each construct is greater than its correlation with other variables in the model (Fornell & Larcker, 1981), providing support for discriminant validity.

Table 2. Validity and reliability of the constructs

	CR	AVE	MSVASV	IS	SDCI	MIP	SDC	FP	IQ
IS	0.938	0.835	0.1530.064	0.914					
SPCI	0.876	0.706	0.0270.012	-0.072	0.840				
MIP	0.886	0.723	0.4080.123	0.236	0.136	0.850			
SDC	0.783	0.546	0.0340.020	-0.029	0.164	-0.185	0.739		
FP	0.930	0.815	0.3280.118	0.391	0.051	0.314	-0.074	0.903	
IQ	0.890	0.673	0.4080.177	0.328	0.079	0.639	-0.181	0.573	0.820

Note. CR = Composite reliability; AVE = Average variance extracted; MSV = Maximum shared variance; ASV = Average shared squared variance; IS = Innovation speed; SDCI = standardization of process and content interfaces; MIP = Modular interconnected process; SDC = Structured data connectivity; FP = Fluid partnering; IQ = Information quality

We conducted the confirmatory factor analysis (CFA) using the measurement model where latent variables used in the study were freely correlated. All items measuring its latent variable were statistically significant.

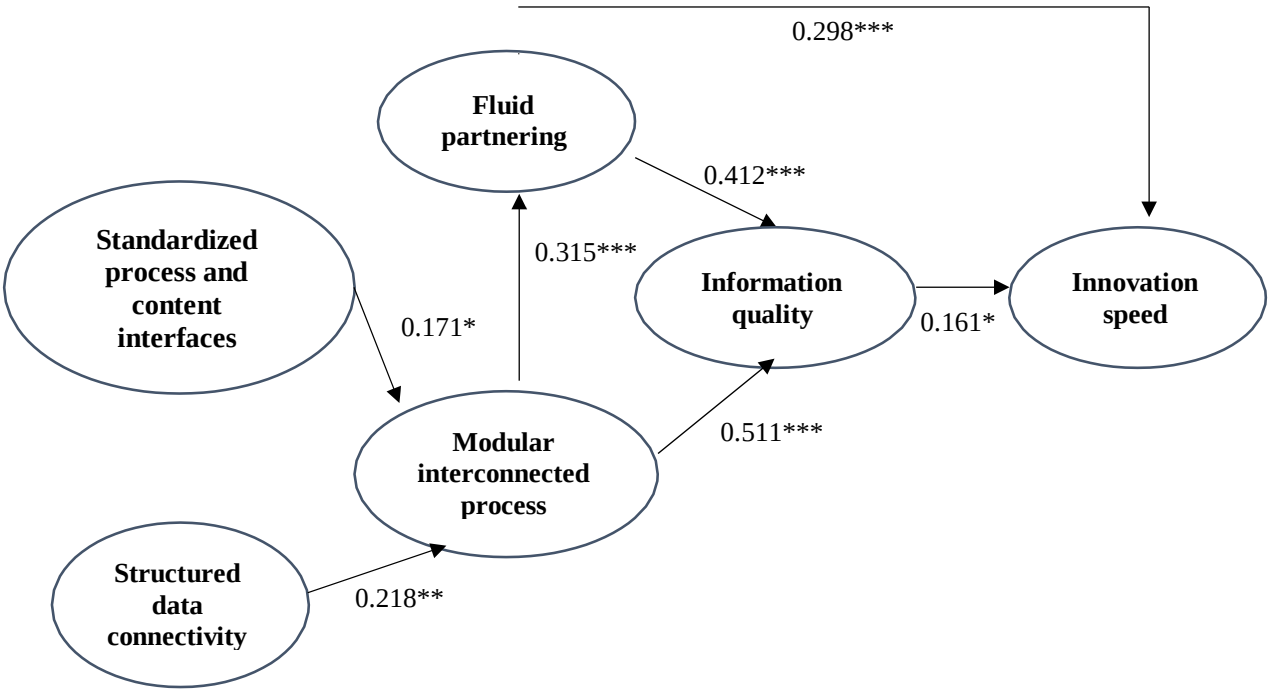
Evaluation of Nomological Structure

We evaluated the fit indices of both the measurement model ($\chi 2$ [df] = 317.771[137], p = 0.000; CFI = 0.949; RMSEA = 0.071) and the causal model ($\chi 2$ [df] = 323.103[144], p = 0.000; CFI = 0.949; RMSEA = 0.069), which were quite satisfactory. The fit indices provided support for the nomological structure of the research model (Kline, 1998). With regards to control variables, results indicated that none of the control variables were statistically significant.

Test of Hypotheses

Figure 1 provides the research model along with path loadings. Hypothesis 1, which stated that standardized process and content interface was positively associated with modular interconnected process was supported (β = 0.171, p = 0.012). Hypothesis 2 stated that structured data connectivity was positively associated with modular interconnected process. This hypothesis was supported (β = 0.218, p = 0.003). The positive association between modular interconnected process and fluid partnering, as stated in hypothesis 3, was supported as well (β = 0.315, p = 0.000). Hypothesis 4, which tested the positive association between modular interconnected process and information quality was supported (β = 0.511, p = 0.000). Hypothesis 5, which stated fluid partnering was positively associated with information quality was supported (β = 0.412, p = 0.000). Hypothesis 6 stated that there was a positive association between fluid partnering and innovation speed, which was supported (β = 0.298, p = 0.000). Lastly, hypothesis 7, which stated that fluid partnering was positively associated with innovation speed was also supported (β = 0.161, p = 0.036).

Figure 1. Research model with path loadings ***$p \leq 0.001$; **$p \leq 0.01$.



DISCUSSIONS AND CONCLUSION

Primarily, the results of the study reinforce the concepts presented in a loosely coupled system (Weick, 1976). Drawing the equivalence between a loosely coupled system and a modular interconnected system, we implemented the various benefits of the loosely coupled system to develop arguments for our hypotheses. We include both distinctiveness and responsiveness aspects of a loosely coupled system in the research model as modularity and coordination mechanisms respectively. This permits us to perform the dialectical interpretation of the modular interconnected process, which Orton and Weick (1990) believe to be inseparable characteristics

of loosely coupled system.

There are various dependencies both within and between organizations: task-task dependencies, task-resource dependencies, and resource-resource dependencies. Crowston (1997) proposes various coordinating mechanisms to overcome problem encountered in each of these dependencies. Pertinent to our study is the

The findings of this study also contribute to dynamic capability (Eisenhardt & Martin, 2000; Teece, Pisano & Shuen, 1997). O'Reilly & Tushman (2008) present that change in the business environment is inevitable and one of the ways to address environmental change is through developing the dynamic capability. Our research thus reinforces the three underlying dimensions of dynamic capability – adaptation, integration, and reconfiguration – for competitive advantage. The adaptation of skills among modular partners is achieved through generation of constant standards and rules at the interfaces. The ability to easily reconfigure the partnering (fluid partnering) allows the integration of only the most competent suppliers in the modularity. Competent suppliers could introduce relevant and valuable ideas essential for innovation. The outcome of which is observed in the organization's ability to ramp up their innovative activities.

One of the limitations of this study is its failure to explicate the types of innovation a firm is conducting. As evidenced by research findings, different types of innovations require distinct types of organizational structures. While an organic organizational structure is apt for radical idea generation, a mechanistic organizational structure favors incremental innovation (Nord & Tucker, 1987; Sheremeta, 2000). It is intuitive to assume that MIP itself is an organic, as the decision-making authorities are separated and interaction between subunits is restrained. But from a module's standpoint, the identification of organizational design that is apt for the structure of a module – interactions of functional departments and decision- making authorities within a module – is something we propose for future researchers to examine.

Appendix A. Operationalization of constructs

Standardization of Process and Content Interfaces (SPCI; Gosain et al., 2004): 7 points Likert- scale

- Extent to which your business process interfaces with your supply chain partners are similar across all partners, in terms of rules and procedures.
- *Very similar for all partners, moderately similar across partners, extremely specific for each partner*
- Extent to which the business process interfaces with your supply chain partners are similar across all partners, in terms of data formats.
- *Very similar for all partners, moderately similar across partners, extremely specific for each partner*
- Extent to which information exchanged (e.g., sales reporting, service information, service availability, inventory information, etc.) with your supply chain partners needs to be converted/translated to be interpreted by your business unit.
- *Does not need to be converted/translated, needs to be converted/translated moderately, needs to be converted/translated extensively*

Structured Data Connectivity (SDC; Gosain et al., 2004): 7-point Likert scale

- What is the extent to which you can exchange data in electronic formats with your supply chain partners and other potential supply chain partners?
- *Mostly electronic, Equally electronic and non-electronic, Mostly non-electronic*
- What is the extent to which you can exchange data in real time with your supply chain partners and other potential supply chain partners?

- *Extensive real-time exchange, Equally Real time and batched exchanges, Mostly batched delayed exchanges*
- What is the extent to which data exchange with your supply chain partners is structured (rather than free format exchange such as e-mail text)?
- *Data can be highly structured, Moderate support for structured data, No support for structured data*

Modular Interconnected Processes (MIP; Gosain et al., 2004): 7-point Likert scale (*Strongly disagree, Neutral, Strongly agree*)
- The processes conducted in conjunction with your supply chain partners are divided into clearly understood activities to be performed by you and each of your supply chain partners.
- The output/job requirements of your supply chain partners from your business unit and your requirements from your supply chain partners are precisely specified and understood.
- The activities performed by your company and your supply chain partners are performed simultaneously to a large extent.

Fluid Partnering (FP; Rosenzwieg & Roth, 2007): (5-point Likert scale; strongly disagree, neutral, strongly agree)
- You are adept at reconfiguring network of supply chain partners in very short time.
- You have the ability to quickly coordinate activities across a dynamic pool of supply chain partners.
- You have the ability to effectively maintain a shifting network of supply chain partners.

Information quality (IQ; Gosain et al., 2004): 7-point Likert scale
- How would you rate the information exchanged with your supply chain partners in terms of its relevancy to your business needs?
- *Not relevant, Moderately relevant, Very relevant*
- How would you rate the information exchanged with your supply chain partners in terms of its value-added to your business needs?
- *Of no value, Moderately valuable, Very valuable*
- How would you rate the information exchanged with your supply chain partners in terms of its timeliness?
- *Always late, Sometimes on time, Very timely*
- How would you rate the information exchanged with your supply chain partners in terms of its completeness?
- *Incomplete, Moderately incomplete, Very complete*

Innovation speed (IS):
- How does your business unit's ability to develop new services at a high rate compare with your competitors?
- How does your business unit's ability to develop new features in your existing services at a high rate, compare with your competitors?
- How does your business unit's ability to develop new service delivery technology, at a high rate, compare with your competitors?

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DECISION SCIENCES INSTITUTE

New Elevated Ratio Estimator of the Population Mean Using the Known Median of Study Variable

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ABSTRACT

The purpose of the study is to explore a new estimator for estimating precise population mean. We suggest a sublime population mean ratio type estimator and analyze its properties for several samples. We calculate the efficiency of the proposed estimator for both analytical as well as empirical perspectives. The study attempts to prove that the suggested estimator is improved over other competing estimators.

KEYWORDS: Ratio estimator, Median, Study variable, Auxiliary variable, Percentage relative efficiency (PRE).

INTRODUCTION

Population mean estimation is a very common problem in sampling surveys. Aim of the researcher is to search the most efficient population mean estimator. Auxiliary information enhances the efficiencies of the estimators and there is a sufficient amount of information available in the literature of theory of sampling. One of the brummagem of the auxiliary variable is that it is collected on additional cost of the survey. The recent references include Yadav and Kadilar (2013), Yadav and Mishra (2015), Yadav et al. (2016) and Abid et al. (2016). The alternative of the secondary variable is to use the known parameters of study variable for exalted estimation of the population mean. We have used population median as a variable for improved estimation of population mean for selected data set. The information on population median is easily available as it does not require information on every unit of the population but it requires information in some intervals. The very good examples have been presented by Subramani (2016) information on population median of study variable is readily available.

LITERATURE REVIEW

In the literature, many authors and researchers have suggested various improved estimators for population mean utilizing known auxiliary information. Following is a summary of the competing estimators of population is presented in Table 1.

Table 1: Summary of Literature Review of Existing Estimators		
YEAR	REFERENCES	JOURNAL
2017	Soponviwatkul and Lawson	Gazi University Journal of Science
2016	Yadav, Mishra, Shukla and Chaudhary	International Journal of Agricultural and Statistical Sciences
2016	Subramani	Statistics in Transition New Series
2016	Yadav, Gupta, Mishra and Shukla	American Journal of Operational Research
2015	Ekpenyong and Enang	Hacettepe Journal of Mathematics and Statistics
2015	Yadav and Mishra	Statistika
2013	Subramani	Journal of Modern Applied Statistical Methods
2013	Yadav and Kadilar	Applied Mathematics and Computation

PROPOSED ESTIMATOR

As discussed in section 1, known information on population median of study variable which is many times readily available can be utilized for enhancing the population mean estimation. We propose the following estimator by getting motivated by Nangsue (2009) and Subramani (2016) as,

$$t_p = \bar{y}\left(\frac{M}{m}\right)^b \tag{1}$$

Where b is the regression coefficient of the line Y on M, given by $b = \frac{s_{ym}}{s_m^2}$.

The bias of t_p up to the approximation of order one can be obtained as,

$$Bias(t_p) = \bar{Y}\left[(B+B^2)\frac{1-f}{n}\frac{C_m^2}{2} - B\frac{\bar{M}-M}{M} - B\frac{1-f}{n}(C_{ym} + \frac{\mu_{12}}{S_m^2 M} - \frac{\mu_{21}}{S_{ym}M})\right] \tag{2}$$

The MSE of t_p up to the approximation of order one is expressed as,

$$MSE(t_p) = \frac{1-f}{n}\bar{Y}^2[C_y^2 + B^2C_m^2 - 2BC_{ym}] \tag{3}$$

EFFICIENCY COMPARISON

Under this segment, Table 2 shows the theoretical improvement of the proposed estimator over other competing estimators along with the assumptions for which it performs better than the other competitive estimators.

Table 2: Theoretical efficiency of suggested estimator over competing estimators of population mean

S.No.	Estimator	Condition under which suggested estimator have more efficiency compare to the competing one
1.	Sample Mean estimator	$[\upsilon_1 + r] > 2$
2.	Watson (1937) estimator	$\lambda C_y^2(1-\rho_{yx}^2) + r > 1$
3.	Cochran (1940) estimator	$\lambda[C_y^2 + C_x^2 - 2C_{yx}] + r > 1$
4.	Bahl and Tuteja (1991) estimator	$\lambda[C_y^2 + 4C_x^2 - 4C_{yx}] + r > 1$
5.	Kadilar and Cingi (2003) estimator	$\lambda[C_y^2 + 4C_x^2 - 4C_{yx}] + r > 1$
6.	Srivastava (1967) estimator	$\lambda C_y^2(1-\rho_{yx}^2) + r > 1$
7.	Reddy (1974) estimator	$\lambda C_y^2(1-\rho_{yx}^2) + r > 1$
8.	Gupta and Shabbir (2008) estimator	$r - \nu_1 > 0$
9.	Singh and Solanki (2012) estimator	$r - \nu_2 > 0$
10.	Solanki et al. (2012) estimator	$\lambda C_y^2(1-\rho_{yx}^2) + r > 1$
11.	Ekpenyong and Enang (2015) estimator	$r - q > 0$
12.	Kadilar (2016) estimator	$\lambda C_y^2(1-\rho_{yx}^2) + r > 1$
13.	Nangsue (2009)	$\lambda C_y^2(1-\rho_{yx}^2) + r > 1$
14.	Subramani (2016) estimator	$\lambda[C_y^2 + R_{13}^2 C_m^2 - 2R_{13} C_{ym}] + r > 1$
15.	Soponviwatkul and Lawson (2017)	$\lambda C_y^2(1-\rho_{yx}^2) + r > 1$

NUMERICAL STUDY

For the verification of the theoretical educts, we have taken into consideration the population given by Subramani (2016). Table 3 represents the different parameters of the population under consideration, and for this population, MSEs of various competing estimators and suggested estimator have been calculated. The PREs of the suggested estimator have also been calculated over the competing estimators.

Table 3: Parameters of the population under consideration

Parameter	Value
N	20
n	5
${}^{N}C_{n}$	15504
$\overline{Y}$	41.5
$\overline{M}$	40.0552
M	40.5
$\overline{X}$	441.95
R_{13}	1.0247
C_y^2	0.008338
C_x^2	0.007845
C_m^2	0.006606
C_{ym}	0.005394
C_{yx}	0.005275
ρ_{yx}	0.6522
ρ_{ym}	0.81543

RESULTS AND DISCUSSION

Table 4 shows several estimators for estimating population mean with their MSE that ranges from 2.15 to 1.09. However, the MSE of suggested estimator is 1.0073, which is lower than all competing estimators of population mean. Thus, our research for an efficient estimator of population mean demonstrates that precise estimation is possible without a large survey and eventually costs of surveys and analysis of large data can be minimized.

CONCLUSION

The study presented an enhanced estimator of the population mean and explained the biases and MSEs. The conditions under which the suggested estimator is a better predictor of mean than the competing estimators are discussed and justified through the numerical examples. The results show that the suggested estimator has lower MSE than every competing estimator of population mean. The worth notable thing is that the aim of searching the most efficient estimator have been achieved without increasing the cost of the extensive survey. We expect that academicians and professional will use the proposed estimator to estimate the mean of the population. We also expect that the researchers will further explore similar estimators to simply the predictions. The study will useful for future researchers for producing application research work using the proposed mean estimator in various areas of businesses. Furthermore, professional can use the estimator in developing software for predictive modeling.

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DECISION SCIENCES INSTITUTE
On Sharing Preferences in Social Networks

ABSTRACT

In this paper, we study sharing in online social networks through the lens of resource-allocation. Specifically, we study whether people with large networks share as much as people with small networks. Our work shows three influencing factors in content-sharing inequality: individual sharing tendencies, sharing tendencies of one's friends, and content relevance. We then show that, content shared by an individual is determined by the number of his/her friends who are frequent sharers; thus, network composition plays a role in content-sharing.

KEYWORDS: Content-sharing inequality, Theil inequality, Online social networks, and Pareto distribution.

INTRODUCTION

Sharing is an intrinsic part of human nature, manifested in everyday experiences of tangible entities (e.g. food, wealth) and intangible entities (emotions, ideas, advice). While the sharing of tangible entities such as wealth and possessions conforms to the social norms of reciprocity and status consistency (McPherson, Smith-Lovin &Cook, 2001), the concept of sharing emotions or ideas is far less studied. Social Networking Sites (SNSs) have emerged as a significant platform in modern social discourse by facilitating sharing between users in myriad ways (e.g. likes, shares, posts, tags, followers, pins and tweets, to name a few). However, individual sharing patterns differ; some share frequently, while others merely lurk (Nonnecke & Preece, 2000). Individuals also tend to exhibit homophily (Meeker, 1971) and networks have been shown to follow the rich-get-richer pattern (Albert & Barabasi, 2002), where individuals who are new to the network are more likely to form friendships with individuals who have larger networks, than with individuals who have smaller networks. In this paper, we study the volume of content-sharing and its relationship with network size, i.e. we seek to answer the question: do people with large networks share more, less or as much as people with small networks?

To answer this question, we looked at self-reported findings of sharing tendencies of Facebook users. We borrow on the framework in (Murimi, 2016) and grouped users into one of four categories of sharers: frequent (posting at least once a day), moderate (posting at least once a week), sparse (posting at least once a month) and non-sharers (users who do not post). Users were additionally asked to provide network sizes (small or large), and the perceived sharing tendencies of friends on their network. Our results showed that users with large networks shared less than users with small networks. While the inverse relationship between network size and sharing tendencies may appear as contrary to intuition, we posit that this provides further evidence of the theory of weak ties (Granovetter, 1973). Since large networks are comprised primarily of weak ties, users are not inclined to share as much information as they would with a smaller network of friends. We call this phenomenon of inverse correlation between network size and content-sharing as the inequality of content-sharing, and analyze the various parameters affecting this inequality with the help of the Theil inequality index.

The Theil index of inequality was first proposed by the econometrician Henri Theil as a tool to measure the inequality of income distribution (Conceicao & Ferrera, 2000). Since then, numerous studies to quantify the inequality of income distribution have used the Theil index to capture effects such as public-school finances (Evans, Murry & Schwab, 1977), health outcomes (Navarro et al, 2006) and racial segregation (Reardon & Firebaugh, 2000). This paper presents the first application of the Theil index to a content-sharing inequality in SNSs, and while content-

sharing and income distribution appear to be disjoint aspects of the human experience, they both exhibit a fundamental inequality in distribution –a larger portion of the wealth is generated by fewer individuals. Our findings show a similar inequality exists in content-sharing as well. Users with small networks share more content than those with large networks. We extend the heretofore limited scope of the Theil index into the realm of content-sharing in SNSs, and do so with another frequently used aspect of the unequal income-distribution literature: the Pareto distribution. The Pareto distribution, which is frequently used to model the 80/20 rule of income distribution, belongs to the family of heavy-tail distributions such as the power-law distribution and the Zipfian distribution. These heavy-tail distributions have been used to measure inequality in areas such as income, graph structure of the World Wide Web, stock returns and sizes of files, human settlements and particles (Reed & Jorgensen, 2004; Stutzmann, 2006; Zukernam, Neam& Addie, 2003; Addie, Neame & Zukerman, 2002).

LITERATURE REVIEW

The centrality of content-sharing to the social network experience has enabled a variety of studies on the nature of the content and the content-sharers themselves. In (Burke, Marlow & Lento, 2009), the authors show that newcomer sharing is directly proportional to the activity level of the newcomer's contacts. Sharing is also focused – people offer varying amounts of attention to various contacts in their networks (Backstrom et al, 2011). The authors studied this balance of attention as a function of network sizes and tie strength. Sharing content on a SNS also has the effect of reaching a wider than anticipated audience (Bernstein et al, 2013) and is not limited to the more familiar scenarios of viral online content (Berger & Milkman, 2012). In (Sleeper et al, 2013), the authors found that users frequently self-censored their posts to manage their online reputation. The content of the post and the intended audience also influenced sharing (Zhao, Lampe & Ellison, 2016). Sharing as a function of social learning and network effects was studied in (Qiu, Tang & Whinston, 2015). The need to present different information to different online audiences was studied through the mechanism of faceted identities in (Farnham & Churchill, 2011). The relationship between personality traits and online behavior was explored in (Gosling et al, 2011), where the authors found that an individual's personality online is an extension of their offline personality. The underlying elements behind sharing of goals and motivations, manifested as cooperative behavior and social cognition, was studied in (Dominey & Warneken, 2011). The role of content-sharing in enabling information discovery was studied in (Stutzmann, 2006). Sharing was identified as functional building block of social media alongside presence, identity, relationships, conversations, groups and reputation (Kietzmann et al, 2011). Voluntary, informal knowledge-sharing (VIKS) was studied in (Lee et al, 2004). The authors defined VIKS as serendipitous, spontaneous and extemporaneous sharing of information. VIKS interactions were noted as opportunities for learning and teaching, and social engagement. Knowledge sharing was also studied in (Leonardi et al, 2014), where the author analyzed the nature of communication between employees of a financial services organization over a new enterprise social networking site. This work studied the concept of communication visibility, where users can make inferences about their co-workers' knowledge based on the content of messages. This inference was enabled through network translucence (who knows whom) and message translucence (who knows what). A similar framework is observed on most social networking sites, where user's friends are visible to others and their activities on the network (posts, shares and likes) are visible to subsets of their contacts on the network. Settings enable users to narrow the scope of the message translucence and even network translucence – users possess the abilities to limit the number of friends who can see their network activities (Granovetter, 1973; Stutzmann 2006; Mitzenmacher 2004).

From a theoretical perspective, the inequality of content-sharing is related to the theory of weak ties (Granovetter 1973), homophily (Meeker 1971) and network structure (Albert & Barabasi, 2002). Our model of inequality in content-sharing is derived from local and global factors influencing the sharing: sharing tendencies of an individual's contacts, relevance of a post and the sharing tendency of the individual. Furthermore, our approach also applies to the model of interpersonal exchange developed in (Meeker 1971), where interpersonal exchanges is described according a framework of six elements: reciprocity, rationality, altruism, group gain, status consistency, and competition. Recent research has shown that an individual's standing in a SNS is impacted by the composition of the contacts in her network, volume of content shared (Murimi 2016) and the nature of shared content (Hajargasht & Griffiths, 2015). Finally, our measure of inequality in content-sharing in social networks is related to other metrics of inequality studied in offline social networks such as social capital (Cattell 2001) and information diffusion (Kempe, Kleinberg & Tardos, 2005). The focus of our work is to quantify the inequality of content-sharing in terms of the Theil index and to analyze the sensitivity of this index to factors such as network size and sharing tendencies of both the individual and his/her contacts.

CONTRIBUTIONS

Our main contribution is to show that sharing of content in social networks is inequitable, i.e., while one would expect that individuals with large networks would share more than individuals with smaller networks, our research shows that content-sharing follows an inverse relationship with network size. We study this inequality of content-sharing using the Theil index. We model the inequality of content-sharing using a Pareto distribution. Specifically, we study the following model: The number of posts on an individual's feed arises from the sharing tendencies of friends in his/her network. We model the number of posts that an individual makes as a function of three parameters: (a) the individuals' own sharing tendency, which can lie in any of the four categories mentioned above, (b) the number of posts that appear in his/her Newsfeed, which in turn is a function of the sharing tendencies of his/her friends on the network, and finally, (c) the relevance of the posts in one's News feed.

We consider the simple model, where the sharing tendency of an individual is fixed, i.e. if an individual is a frequent sharer, she/he remains so for the duration of network use. We also exclude other News feed items such as content recommendations and advertisements from non-individuals (such as business and other organizations) in our analysis of content-sharing. This enables us to focus on the reciprocity of content sharing between individuals. Consider a network where n_r percent of individuals have small networks and n_l percent of individuals have large networks, and $n_r \gg n_l$. The number of posts made by these individuals is Pareto distributed, i.e. n_r percent of individuals share s_r percent of posts and n_l percent of individuals share s_l percent of the posts, and $s_r \ll s_l$.

The shape parameter of the Pareto distribution has important implication is the calculation of the Theil index. We show that when the composition of the network is split evenly among small and large networks, the slope of the Theil index increases with the shape parameter. In other words, the inequality of content-sharing persists, since the individuals with small networks are expected to post less than the individuals with large networks. In this setting, we show that if the number of individuals with small networks is same as that of individuals with large networks, then the shape parameters of the Pareto distributions modeling the sharing tendencies of individuals on small networks (α) and on large networks (β) dominate the sharing patterns. Specifically, we show that as the difference between the values of the shape parameters tends to zero, i.e., $\alpha \rightarrow \beta$, with an increase in the number of posts from individuals with large networks, there is a corresponding decrease in the number of posts from individuals with small networks. Our hypothesis for this behavior is the underlying Pareto distribution, which assumes an inverse

Table 1: Findings of Inequality in Content-Sharing			
Network Size		Sharing Tendency	
$\boldsymbol{n_{regular}}$	78%	$\boldsymbol{s_{regular}}$	81%
$\boldsymbol{n_{large}}$	21%	$\boldsymbol{s_{large}}$	18%

relationship between network size and sharing. An increase in the shared content from individuals with large networks signals the availability of less content on the news feed from individuals with smaller networks. However, as $\alpha \gg \beta$, an increase in the number of individuals with small networks or an increase in the value of α increases the number of posts on an individual's feed. This is in line with the Pareto distribution, since individuals with small networks share more than individuals with large networks. Additionally, we investigate extreme inequality of sharing in scenarios where a few individuals are responsible for all the content shared on the networks. Even in this situation of extreme inequality of content-sharing, we show that as the number of individuals with small networks increases, the inequality of content-sharing can be reduced (since individuals with small networks post more than individuals with large networks). Another method to reduce the extreme inequality is to increase the value of the sharing parameter α. As α increases, the sharing tendency of users increases, thus reducing the inequality. Finally, we show that in a network where both individuals with small networks and large networks have similar sharing tendencies($\alpha \to \beta$), the network takes on a more homogenous form. This contributes to the inequality of content-sharing since individuals with small networks would post as much as individuals with large networks and thus increase the value of the Theil index.

METHOD

A sample size of 118 students was used to obtain the data in this study. In addition to the definition of the four categories of sharers (frequent, moderate, sparse, and non-sharers) introduced above, the following terms will be introduced and defined in the context of SNSs for our study. We define content as any kind of activity performed by a user. Thus, status updates, shares, likes (and related emotion-conveyors), comments, page creation and following activities are considered as shareable content, since it has the potential of showing up on the News feed of friends in the individual's network. The average network size of our survey participants was found to be 651 friends. Thus, we categorized networks as belonging to one of two categories: small networks (1-650 friends) and large networks (greater than 650 friends). Based on the definition of the various kinds of sharers and network size categories, students were asked to answer the following questions: (a) perception of their own sharing tendency (b) preferred sharing tendency (c) percentage of friends on their network whom they would associate with a sharing tendency – for example: 40% of friends are frequent sharers, 10% of friends are non-sharers, etc. and (d) user's own network size.

Table 1 shows the inequality of content-sharing as a function of network size. Individuals with small networks (n_r) comprise 78% of the network and report sharing 81% of the content (s_r), while individuals with large networks (n_l) comprise 21% of the network and share only 18% of the content. Thus, we see that individuals with small networks share more than individuals with large networks. This inequality of content-sharing is the basis of the work in this paper, where we study the various factors influencing the inequality of content-sharing in networks. In the next section, we study the impact of three factors (a) network composition (b) sharing tendency of the self and (c) relevance of content on the content-sharing inequality.

MODEL

We use the Pareto distribution to model the sharing tendency f of an individual. The Pareto distribution is defined by a shape parameter and a scale parameter. The shape of the Pareto curve representing the inequality is influenced by the value of the shape parameter. We use the shape parameter to determine the minimum number of posts made by an individual. We denote the Pareto distribution of sharing inequality in small networks with the scale and shape parameters as x_m and α respectively. For the case of large networks, we denote the Pareto distribution with the scale and shape parameters as x_n and β respectively. We model the mean number of posts by an individual with the Pareto distribution (x_m, α), where α is proportional to the sharing tendency of the individual (s), the relevance of the posts on the feed, and the composition of the network (n).

$$\boldsymbol{\alpha \propto rns} \quad (1)$$

The composition of the network, n, is described in terms of the frequency of the posts made by users in distinct categories. The number of posts on a user's feed in terms of n_m (number of moderate sharers), n_f (number of frequent sharers) and n_s (number of sparse sharers) is given as,

$$n = (n_m)/7 + (n_f) + (n_s)/30 \quad (2)$$

We exclude the contributions of non-sharers in our calculations of the number of posts in (2), since their activity in invisible on one's News feed. Thus, the CDF of the Pareto-distributed sharing tendency is given as:

$$F(x) = \begin{cases} (x_m/x)^{\alpha}, & x \geq x_m \\ 1 & , \ x < x_m \end{cases} \quad (3)$$

Our analysis can be readily extended to the case of the Poisson Pareto Burst Process (PPBP) which has been shown in (Zukerman, Neams & Addie, 2003; Addie, Neame & Zukerman, 2002) to closely model the bursts of Internet traffic.

Theil Index

The Theil index has been used extensively (Conceicao & Ferreira, 2000) in income inequality literature to characterize the complex dynamics of inequality among rich and poor countries. Here, we use the Theil index, T_I, to characterize the inequality of content-sharing between content-rich and content-poor groups of SNS users. The value of the Theil index, as a function of the network sizes (n_r, n_l) and sharing tendencies (s_r, s_l) is derived as (Granovetter, 2006):

$$T_I = s_r \log(s_r/n_r) + s_l \log(s_l/n_l) \quad (4)$$

We model s_r and s_l as Pareto-distributed sharing tendencies as a function of the network sizes n_r and n_l respectively. Thus,

$$\boldsymbol{s_r = \alpha x_m^{\alpha}/n_r^{\alpha+1}} \quad (5)$$

$$\boldsymbol{s_l = \beta x_n^{\beta}/n_l^{\beta+1}} \quad (6)$$

Case 1: Zero Inequality

Here, we study the conditions under which the Theil index of inequality in content-sharing is zero when there is an equality in network composition, i.e. $n_r = n_l$. Within this constraint, we study two

Figure 1: Relationship between minimum number of posts in small $\mathbf{x_m}$ and large networks $\mathbf{x_n}$ for zero inequality in content-sharing.

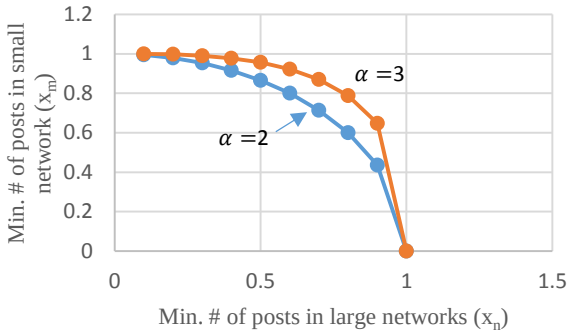
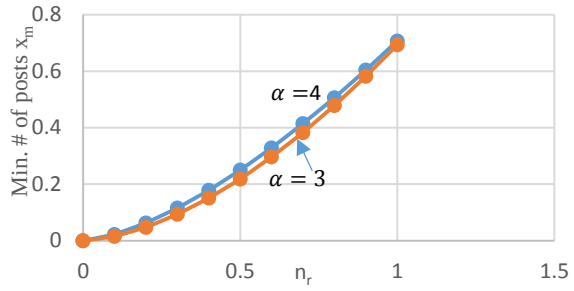


Figure 2. Relationship between network composition $\mathbf{n_r}$ and minimum number of posts $\mathbf{x_m}$



cases (a) the sharing tendencies of both small and large networks is similar, i.e. $\alpha \rightarrow \beta$, and (b) the sharing tendency of the small networks is much less than the large networks, i.e. $\alpha \ll \beta$. Substituting (6) in (5), we find that when $\alpha \rightarrow \beta$, for T_I to be equal to zero,

$$x_m = (1 - x_n^{\alpha})^{1/\alpha} \tag{7}$$

This relationship between minimum number of posts in small and large networks is depicted in Figure 1. In Figure 1, we see that, for the inequality of content-sharing to be zero, as the number of posts from friends with large networks increases, there is a decrease in the number of posts from friends with small networks. We suggest that this behavior is due to the underlying Pareto distribution, which assumes an inverse relationship between network size and sharing. An increase in the shared content from individuals with large networks signals the availability of less content on the news feed from individuals with smaller networks.

Next, we investigate the condition when $\alpha \ll \beta$ for $T_I = 0$.

$$x_m = 10\text{^}[(\log \beta + \beta \log x_n)/(\beta + 2)] \tag{8}$$

Figure 2 shows the impact of network composition on the minimum number of posts. As the percentage of people with small-sized networks (n_r) increases, the minimum number of posts seen on one's news feed increases. This is intuitive since people with small networks share more than people with large networks. The shape parameter of the Pareto distribution, α, also impacts

Figure 3. Impact of Sharing Tendency on the Minimum Number of Posts

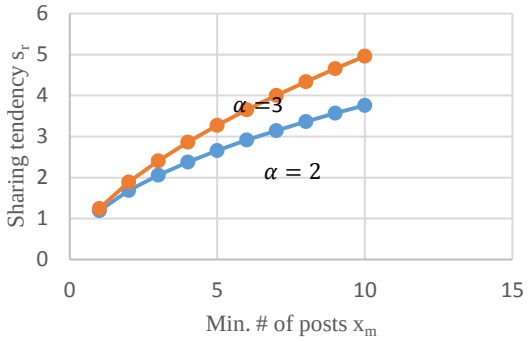
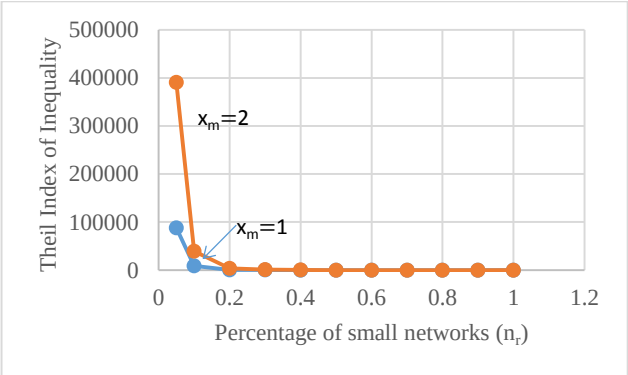


Figure 4. Extreme Sharing Tendencies

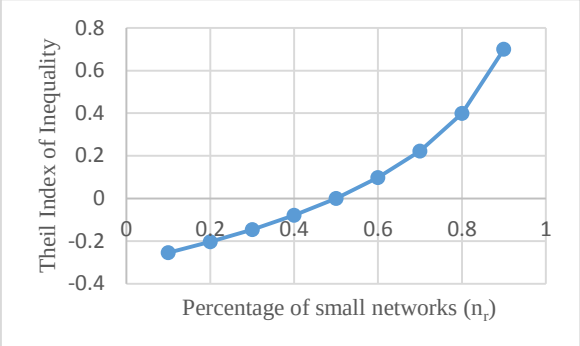


the minimum number of posts. As the value of α increases, the minimum number of posts increases. Figure 3 shows the sharing tendency of an individual as a function of the minimum number of posts by friends in the network. As the minimum number of posts increases, there is a greater probability that at least some of them will be deemed 'shareable', and this causes an increase in the sharing tendency of the individual. Similarly, a decrease in the number of people with large networks points to a corresponding increase in the number of people with small networks.

Case 2: Extreme Sharing Tendencies

In this case, we analyze extreme sharing tendencies, i.e., what happens if $\boldsymbol{n_{regular}} \ll \boldsymbol{n_{large}}$ and $\boldsymbol{n_{regular}} \gg \boldsymbol{n_{large}}$? (i.e.1 person does 99% of the sharing and the other 99% do 1% of sharing? Figure 4 shows the conditions under which extreme inequality exists, i.e. a few individuals share majority of the content. Here, we investigate the scenario where friends with small networks comprise less than 2% of the individual's network. The value of the Theil index of inequality in this case is extremely high, and points to the fact that in such networks, content-sharing by individuals with smaller networks should be much less than content-sharing from friends with large networks. Also, as the minimum number of posts from small networks (x_m) increases, the inequality increases since the large networks are sharing less, and their reticence is helping to drive up the inequality of content-sharing.

Figure 5. Impact of Equal Sharing Tendencies



Case 3: Homogeneous Sharing Tendencies

What happens when irrespective of network size, people share the same, i.e., $s_{regular} = s_{large}$?

$$T_I = -0.3 - 0.5\left(\log n_{regular} + \log n_{large}\right) \quad (9)$$

In Figure 5, we see that when the sharing tendencies of large networks and small networks are the same, the Theil index of inequality in content-sharing increases. This trend is as expected, since content-sharing is expected to be directly proportional to network size. Yet, the inversely proportional relationship between the two is the driving factor between the inequality of content-sharing. This is amplified when the sharing tendencies are equal – as the percentage of friends with small networks increases, it implies a corresponding decrease in the percentage of friends with large networks and creates a scenario where people with small networks share more than people with larger networks.

CONCLUSIONS

The main contribution of this paper is to model sharing in social networks, and to show that the inequality of content-sharing can be realistically modeled using the Pareto distribution. The Theil index of inequality in content-sharing was used to demonstrate various scenarios of inequality by performing a sensitivity analysis to the parameters that affect content-sharing. The patterns of content-sharing in social networks initiates an intriguing new area of study that raises many questions. Among these are:

1. In this paper, we have assumed that sharing tendencies are fixed. Thus, a frequent sharer or sparse sharer does not change sharing patterns. However, in practice, sharing patterns are a function of various global (news events), regional (local events such as city-wide events) and individual circumstances (life events). We considered an extremely simple news feed; ads, trending news and sponsored content had no influence on the posts. The study of these diverse scenarios will require the development of new models.
2. Our work is based on categorizing users into two broad categories: small networks and large networks. However, even with large networks, individuals do not engage with all or most of the friends on the network. In a SNS, network size management can be accomplished in several ways: unfriending, hiding/unfollowing, creating separate sets of friends for communication or just communicating with only a specific subset of friends regularly on the network. Our work has not considered the implications of users who have large networks, but communicate only with a subset of the friends on the large network. How can the network be modeled to reflect such a structure? Does the network then resemble a homogeneous composition of individuals with small networks?

3. We focus on the inequality of content-sharing. However, there might be SNSs where content-sharing might be equitable. A study of the sharing patterns and network structures within these SNSs would be insightful in learning more about computer-mediated communication in SNSs.
4. Our model also discounts the role of non-sharers (individuals who do not share) on a social network. There are many reasons why individuals do not share: they would like the benefit of observing the News feed from their friends, but do not want to engage with any of the content due to the nature of the online exchange, or perhaps individuals are more interested in snooping on the network and are content with being mere observers of their friends' lives on the network. Alternately, we may not be able to view an individual's posts (and thereby deem them as a non-sharer) because of the non-sharer's privacy settings. The non-sharer may have blocked an individual from viewing their posts using privacy settings. Thus, while the non-sharer is sharing, none of the shared content is visible to the blocked friend. How does a non-sharer contribute to the content-sharing inequality on the network? These and other related questions are central to the formation of social identity in SNSs and merit further research to uncover how people decide whether to share or not to share.

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Online Versus Traditional Teaching: A Discussion of Students' Perspectives

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ABSTRACT

This study presents students perceptions about the online and traditional components of ten Decision Science courses offered in a hybrid fashion in a small mid-western Jesuit Business School. Our goal is to have a better understanding about the learning value and effectiveness of online teaching compared to traditional teaching.

KEYWORDS: Online, education

INTRODUCTION

With the growing demand for education from non-traditional students many universities are turning to hybrid and online courses. As more and more top universities continue to embrace online education such a delivery mechanism is gaining credibility and popularity while reducing cost and increasing accessibility and flexibility. Hybrid courses are blended courses which are offered partially in class and partially online using course delivery platforms such as Blackboard. Online and hybrid model can increase the access of education which can otherwise be bound by time and geographical constraints. Online classes are also appealing to students who want to do things independently in their own time and pace (Lorenzetti, 2005). However the flexibility that online classes provide may take away the face to face disciplined interaction that certain students require to do well. Hybrid courses may be able to provide the best of both worlds. That is the fundamental reason to conduct more and more studies comparing learning outcomes from online and traditional classes and report such outcomes along with lessons learnt. Such research work may help other instructors across disciplines that are looking for more knowledge to succeed in their online teaching endeavors which is growing more and more in the current times particularly for higher education in Business.

The majority of studies comparing student performance in online versus traditional classes show no significant difference (Russell, 1999; Fredda, 2000; Dutton et al., 2001, Lorenzetti, 2005) which is also a motivation for higher education institutions to promote more and more online classes. Larson and Sung (2009) suggested that there are no differences in learning perceptions between the online and face to face delivery models and hybrid classes do well when it comes to learning effectiveness and student and faculty satisfaction. Most research on online education suggests that online education is as effective and in some cases more

effective than traditional classroom education. Comparing student perceptions about their learning in face to face and online classes is needed to determine whether and how students can develop and grow as Business professionals with the desirable skills that help them succeed in the real world work environment.

RESEARCH QUESTION

Despite extensive research comparing student perceptions and learning outcomes from online and traditional education there is continued need for more research in discipline context. With growing interest and demand in online education we are interested in finding out whether the perceived value and effectiveness of online teaching is equivalent to that of traditional teaching. We are investigating this specifically for Decision Science courses but believe that the findings could be applicable to Business education as well as higher education in general. The main purpose of our study is to describe students' perspectives in hybrid Decision Science courses.

RESEARCH METHODOLOGY

Data for this study was collected over a period of three years through a survey of college students enrolled in ten hybrid Decision Science courses. These ten different courses were taught by three Decision Science faculty members. Four out of the ten courses were senior level undergraduate courses while the remaining six courses were graduate courses. All of these courses were previously taught in traditional manner in a class room setting. The faculty members modified these courses to be taught and delivered in hybrid fashion. One third to two third of the classes were taught online and the remaining classes were taught face to face. The ten Decision Science courses from which we collected our data are as follows:

1. BUS 3150 Quantitative Methods for Decision-Making
2. BUS 3160 Control of Operations Management and Quality
3. BUS 3170 Management of Information Systems
4. BUS 4940 International Studies in Business
5. MBA 5200 Decision Analysis
6. MBA 5260 Information Systems and Technology
7. MBA 5320 e-Business Strategies
8. MBA 5370 Project Management
9. MBA 5940 International Studies in Business
10. EMBA 6200 Global Supply Chain Management

All the students participated in the survey which was a required assignment for each of these classes. The survey questionnaire included a set of questions that reputable universities use to collect data related to online teaching. There were a total of 24 questions in the survey. Out of the 24 questions, 19 were based on a 4 point Likert scale ranging from strongly disagree to strongly agree and 5 questions were open ended that helped us to collect suggestions and comments from the students which could help us to improve the courses. The 19 questions included questions from three categories – student, course readings and feedback, and course design and delivery. All the course materials for the online portions of the hybrid classes were provided to the students using Blackboard course management platform. The course material posted in Blackboard course site included: lesson content, assignment, quizzes, and discussion boards (specifically for the online classes). The students reflected on their experiences in the online and the face to face classes through their survey responses. The students' responses were analyzed and presented in the next section.

RESULTS

The students perceptions in the courses were somewhat varied with the delivery format which might be of interest to administrators as well as educators as they attempt to address the challenges of increasing demand for flexible online courses.

The student related aspects for the online and the face to face classes were overall almost similar with the average for the face to face classes being 0.925 whereas the online classes average being 0.918. As we can see from table 1, within the student category the students claimed that the amount of time / effort that they put for the face to face classes were higher than the online classes (0.970 vs 0.924). Students also claimed that the lectures, activities, and assignments reflected course objectives almost equally for online and face to face classes (0.985 vs 0.971). The students rated both types of classes as equally challenging (0.931 vs 0.930). The perceived understanding of concepts and principles in face to face classes were higher than the online classes (0.925 vs 0.892). Students confidence levels in applying the course principles in new situations was slightly more in face to face classes (0.888 vs 0.869). Technology used was helpful for learning in online classes more than face to face classes (0.916 vs 0.889). Students comfort level with their learning was equivalent for the two types of classes (0.910 vs 0.905). Students were almost equally likely to recommend the online classes as well as the face to face classes (0.925 vs 0.916). Overall based on these results from student specific questions related to the courses it seems like the online and face to face classes are close to being equivalent with some differences within the underlying measures. This finding is encouraging and provides some insight about how students compare between the two delivery mechanisms and how educators can improve their courses taking these student perceptions into account.

Table 1: Student

Category	Criteria	On-Ground	On-Line
Student	The amount of time/effort I put into this course was as expected (hours per week)	**0.970**	**0.924**
	Course lectures, activities, and assignments reflected course objectives	**0.971**	**0.985**
	The course was intellectually challenging	**0.931**	**0.930**
	I gained good understanding of concepts and principles	**0.925**	**0.892**
	I feel confident I can apply the principles in new situations	**0.888**	**0.869**
	Technology used was helpful for learning	**0.889**	**0.916**
	I was comfortable with my learning	**0.910**	**0.905**
	I will recommend this course to others	**0.916**	**0.925**

The course readings and feedback aspects of the face to face classes were also comparable to those of the online classes with the average for the face to face classes being 0.909 and the average for online classes being 0.908. As we can see from table 2, within this category the students claimed that assignments were returned slightly faster for online classes than in comparison to face to face classes (0.997 vs 0.970). Students felt that the topics were explained, presented, and demonstrated slightly better in online classes than in comparison to face to face

classes (0.886 vs 0.874). They clearly felt more stimulated to think critically about the subject matter in face to face classes than in comparison to online classes (0.922 vs 0.897). According to the students the variety of teaching methods used in face to face classes were almost similar to those used for online classes (0.788 vs 0.785). The students also claimed that the course materials were presented in more clear and logical way in face to face classes than in comparison to online classes (0.943 vs 0.911). Finally, the students felt that the tone of announcements in the online classes were more welcoming than that of the face to face classes. These findings suggest that although the overall course readings and feedback aspects for face to face and online classes were almost equivalent there are some specifics which are clearly more valued in one delivery versus the other showing that each delivery mechanisms have certain strengths and weaknesses. Having prior knowledge of these differences can be helpful to educators to mitigate the weaknesses inherent in a delivery mechanism.

Table 2: Course readings and feedback

Category	Criteria	On-Ground	On-Line
Course Readings and Feedback	Returned assignments within a reasonable time	**0.970**	**0.997**
	Explained and presented/demonstrated topics clearly	**0.874**	**0.886**
	Stimulated me to think critically about subject matter	**0.922**	**0.897**
	Used a variety of teaching methods which helped my learning	**0.788**	**0.785**
	The course materials were presented in a clear and logical manner	**0.943**	**0.911**
	Overall tone of announcements was welcoming and friendly	**0.956**	**0.971**

The course design and delivery aspects were slightly more favorable for face to face classes as compared to the online classes (0.937 vs 0.923). As we can see from table 3, within this category the students approved of the organization of the face to face classes slightly better than that of the online classes (0.929 vs 0.913). The students claimed that the delivery of the face to face classes were more in line with their expectation than in comparison to the online classes (0.928 vs 0.889). However the students clearly felt that the overall quality of the online classes met their expectations better than the face to face classes (0.957 vs 0.917). The course activities met student expectations more for face to face classes than in comparison to online classes (0.970 vs 0.923). Finally the students claimed that the course activities scheduling was more convenient to the university schedule for face to face classes than the online classes. These findings provide some rich insights about student perceptions and could be valuable to educators to design better courses that provide better satisfaction and learning to students.

Table 3: Course design and delivery

Category	Criteria	On-Ground	On-Line
Course Design and Delivery	The organization of the course met my expectation (if you evaluate this as a C or D, please tell us what to do to improve)	0.929	0.913
	The delivery of the course was as I expected (if you evaluate this as a C or D, please tell us what to do to improve)	0.928	0.889
	The overall quality of this course met my expectation (if you evaluate this as a C or D, please tell us what to do to improve)	0.917	0.957
	My expectation of the course activities was met best in (if you evaluate this as a C or D, please tell us what to do to improve)	0.970	0.923
	Course activities scheduling was more convenient to my university schedule with (if you evaluate this as a C or D, please tell us what to do to improve)	0.941	0.934

CONCLUSIONS AND FUTURE RESEARCH

Student performance is a very important measure of the success of an online course. However student perception and satisfaction is equally important for better design of online courses and programs leading to continued success of such courses and programs. In this study we accomplished this by gauging students' perceptions and feelings about the online and face to face components of ten hybrid courses.

Overall it was encouraging to find that students' perceptions about online and the face to face classes related to student aspects were equivalent. However we noticed a few differences in how students felt about some of the underlying measures. For example students felt that they put more time and effort in face to face classes than in comparison to online classes. Requirement to be in class in a specific time could be a possible reason for this feeling which could come in the way for non-traditional students' schedule. Students also suggested that they gained better understanding of concepts and principles and felt more confident in applying the principles in new situations in a face to face class than in comparison to online classes. This suggests that the engagement with the instructor and peers in class is a valuable aspect of face to face classes that somewhat gets lost in an online class. However instructors can use discussion boards and more real time collaboration with the students to have this aspect in an online course. The idea is that the students should not feel lost and alone in cyber space. Finally, the students'' felt that technology used was more helpful in their learning in online classes. This is an important contribution of online courses because students can be better prepared to utilize technology in the real world due to their online class experiences.

Students' perceptions about course readings and feedback for face to face and online courses were also equivalent. However there were some differences in underlying measures. For example students felt that assignments were returned faster in an online class. Also topics were more clearly demonstrated in online classes. This is a very positive finding demonstrating the strength of a structured online class. Online classes are potentially more organized than face to face classes. However students also claimed that face to face classes were more stimulating to them thus highlighting the importance of student engagement with faculty and peers in their learning satisfaction. Students also felt that course materials were presented more clearly in face to face classes also suggesting the need that online classes must be more organized so that students do not feel lost. Students also felt more positive tone in announcements in online classes. The reason could be that instructors put more time and thought in making these announcements which give more positive feeling than when they announce in class.

Students' perceptions about course design and delivery were more favorable for face to face classes. The course delivery met students' expectations better in face to face classes. This again shows that online classes must be more organized and instructors must make sure that there is no confusion in terms of the course requirements. The students felt that the overall quality of the course met their expectation better for online classes. This is a very positive finding suggesting that the quality of the online classes in terms of meeting expectation were higher than face to face classes. However the students' felt that the course activities met their expectations in face to face classes better. These findings suggest that online course design and delivery is still not very matured and needs lot more work from educators albeit there is some strength in online classes.

Online teaching and learning responds to changing needs and abilities of students. Online classes have the potential to enhance student centered learning experience and can better respond to individual students. Such classes open up new opportunities by saving costs for both the universities and students. They expand market reach globally as well as locally and enhance competitiveness. The results of this study based on preliminary data analysis suggest that online classes have huge potential in Business education particularly in the area of Decision Science. However, it is important to understand the challenges in online classes to make sure that they are mitigated. It is also important to bring the best experiences of a face to face class in an online class through better use of technology. In this endeavor technical support for educators will be a very important factor.

In future we want to expand this research by performing more advanced statistical analysis on the student perception data. We also want to study if there is any difference in student perceptions based on age and gender. Finally, we also want to evaluate student learning outcomes and compare the two delivery mechanisms. Our goal is to come up with strategies to design better courses to improve the learning experience for our students.

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Optimal Marketing-mix Strategies for Subscription Services

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ABSTRACT

Upon incorporating price and advertising into a well-known diffusion model for subscription services, optimal dynamic marketing–mix variables over time are characterized qualitatively. A monopolistic market is analyzed for which customers' disadoption, discounting of future profit streams and service cost learning are allowed. The analytical findings indicate that the marketing – mix policies of the firm could be very different in the presence of customers' disadoption than their counterparts in its absence. Static optimization techniques are employed to examine the sensitivity of the optimal solution to a change in customers' disadoption at the steady state.

KEYWORDS*:* Marketing-mix, Diffusion models for subscription services, Optimal control theory

INTRODUCTION

With the development of new technologies and the deregulation of several industries, the number of suppliers of subscription services has grown significantly during the last two decades (Libai et al., 2009; Fruchter and Sigué, 2013). The importance of studying subscription services becomes self-evident in light of the fact that, at present, about every household in a western country is involved, in one way or another, in these services. Examples of subscription services include fixed-line phones, cable or satellite television, health clubs and the internet (Mesak and Darrat, 2002; Fruchter and Sigué, 2013).

New subscription service innovations need to be introduced into their markets with appropriate marketing strategies. The most important marketing variables that affect the diffusion of new subscription services are price and advertising. This paper seeks to qualitatively characterize optimal pricing and advertising policies the service provider should pursue over time. The problem is defined in a continuous-time frame to take advantage of the powerful optimal control methodology.

The extant research focuses on consumer churn occurring when a competitor acquires an existing customer. However, a customer can also disadopt and leave the service category altogether as illustrated in previous research (Reichheld and Schefter, 2000; Meuter et al., 2005). Thus the attrition rate is the sum of the churn plus the disadoption rate (Libai et al., 2009). Three of the major challenging questions that marketing academicians and managers face are (1) How to price and advertise subscription services over time? (2) How the marketing mix policies of the firm differ in the presence and absence of an attrition rate? and (3) When the market gets stabilized in terms of the number of subscribers, how a service provider would change the marketing-mix policies in response to an increase in the attrition rate to mitigate its adverse impact on profit? The answers to the above three research questions that have not been fully addressed in the literature constitute the main contributions of the present study. The above research questions are relevant as managing services is different from managing goods, due to long-recognized differences between the nature of services and the nature of

goods. Services are usually highly intangible (cannot be seen, handled, smelled, etc.), heterogeneous (customized making its mass production difficult), perishable and are produced and consumed simultaneously (lack of transportability) (Zeithmal and Bitner, 2003). Unlike the diffusion of durable goods, the growth of a subscription service does not only depend on the number of adopters each period but also on the number of subscribers who renew the subscription in ensuing periods. When the simultaneous presence of the acquisition and attrition processes stabilizes the number of subscribers for a sufficiently large planning horizon, static optimization techniques, according to Feinstein and Luenberger (1981) and Haurie (2002) as well as others could be employed to characterize the optimal solution at the steady state.

The analytical modeling effort employed in this study considers the learning cost curve and the discount rate. More specifically, the model incorporates the key marketing-mix variables of price and advertising into the diffusion model of services articulated by Libai et al. (2009) and thus it explicitly considers the customer attrition rate. The price variable is represented by the subscription fee. Other charges such as that related to usage are not considered. This situation is relevant to a variety of subscription services such as cable television, health clubs and the internet, to name a few. In addition, subscription services for which advertising is a main source of revenue instead of being an instrument for generating subscriptions such as newspapers, magazines and contemporary electronic media (internet websites) are beyond the scope of the present study. Kumar and Sethi (2009) provide a review of this particular literature.

The second section provides a related literature review. The third section outlines a general dynamic diffusion model for new subscription innovations, formulates the problem and presents the solution method. The fourth section characterizes the optimal marketing-mix policy for the general diffusion model as well as specific diffusion models in a dynamic setting. The last section summarizes and concludes the study. The derivation of key formulas and proofs of all reported propositions are included in separate appendices available from the authors upon request.

LITERATURE REVIEW

Notable early examples of diffusion models for subscription services that have used the Bass (1969) model include Dodds (1973) who presented an early diffusion model of cable TV services, Kim et al. (1995) who modelled the diffusion of cell phone services and Rai et al. (1998) who studied the diffusion of the internet. More recent articles that aimed at forecasting the service growth in some sectors such as telecommunications include Islam and Fiebig (2001), Lee and Lee (2009). Additionally, studies have modelled diffusion in social networks, wireless voice/data services, and gaming consoles. (Susarla, et.al., 2012; Niculescu and Whang, 2012; Altinkemer and Shen, 2008).

In the above references, the models did not account for the influence of marketing mix variables in the diffusion process. A few researchers (e.g., Fruchter and Rao, 2001; Mesak and Darrat, 2002) have examined specific aspects of subscription service dynamics in relation to usage and/ or access fees whereas Mesak and Clark (1998) considered both optimal dynamic pricing and advertising. The above studies treat subscription services as if they were durable goods. However, services diffusion differs from durable goods diffusion by the presence of two processes - the adoption process and the retention process.

Libai et al. (2009) were probably the first to incorporate customer attrition into the Bass diffusion model. They showed that customer attrition affects considerably the market growth of a new service. However, their modeling framework did not incorporate marketing-mix variables. Based

on the Libai et al. (2009) diffusion model for services, Fruchter and Sigué (2013) model optimal dynamic pricing decisions for subscription services whereas Mesak et al. (2011) model optimal dynamic advertising decisions for such services that consider service cost learning. Empirical research related to the diffusion of subscription services that incorporate marketing-mix variables is scarce. Employing a logistic model for which market potential is price dependent, Bagchi et al. (2008) examine the impact of price decreases on land telephone and cell phone diffusion. Using a modified Bass (1969) model that does not incorporate attrition, Mesak and Darrat (2003) show that price affects both the innovation and imitation coefficients. Mesak and Clark (1998) conclude that price affects the coefficient of imitation and advertising affects the coefficient of innovation. Employing a modified Libai et al.(2009) model that includes advertising, Mesak et al. (2011) find out that advertising affects the coefficient of innovation. With the initial intent of empirically examining how price and advertising affect the diffusion of a multi-generational cellular phones service model in Europe that incorporates attrition, Danaher et al. (2001) conclude that advertising has an insignificant effect whereas the interaction in price response across generations is significant.

The above brief literature review suggests that (i) there is a belief that marketing-mix variables do affect the diffusion process of new subscription services, (ii) the substance of these effects is basically an empirical question, and (iii) the literature lacks the examination of a general price-advertising dynamic diffusion model for new subscription service innovations.

GENERAL MODEL FORMULATION AND SOLUTION CONCEPT

Let us consider the adoption of a new subscription service in a monopolistic market. A firm manipulates its service charge P_t and advertising expenditure U_t (both assumed to be bounded from above) at each time t over a fixed planning period T, $0 \le t \le T$. The monopoly assumption may seem reasonable in situations in which the firm enjoys a patent protection, a proprietary technology, or a dominant market share. A general service diffusion model is given by

$$dN_t / dt = \dot{N}_t = f(N_t, P_t, U_t),\ N_0 \ge 0 \text{ and fixed}, \tag{1}$$

where N_t and $\dot{N}_t$ represent the number of subscribers at time t and its rate of change at t, respectively. Expression (1) suggests that the current subscription rate is related to the current number of subscribers and the current rate of the marketing variables. Function f is assumed to be twice differentiable with the following properties related to the marketing variables where a subscript on a variable denotes partial differentiation with respect to that variable:

$$f \ge 0;\ f_P < 0;\ f_U > 0;\ f_{PU} \le 0;\ f_{PP} < 0;\ f_{UU} < 0;\ \text{and } f_{PP}\, f_{UU} - f_{pU}^2 > 0. \tag{2}$$

The inequalities (2) imply that the subscription rate is non-negative (new customers' adoption rate is at least equal to customers' disadoption rate), decreases with an increase in the subscription charge, increases with an increase in advertising and is concave in both marketing variables. Inequality (2) further asserts that price may interact with advertising in affecting the subscription rate f and the nature of the interaction is non-positive. The last inequality is stated to ensure that one of the sufficiency conditions of optimality is satisfied (details are found in an Appendix).

We introduce next a cost learning curve by assuming that marginal costs, denoted by C, depend on the number of subscribers such that marginal costs decrease with increasing the number of subscribers (experience) (Chambers and Johnson, 2000; Boone et al., 2008),

$$C_t = C(N_t),\ dC(N_t)/dN_t = C'(N_t) \leq 0. \quad (3)$$

Note that marginal costs could be constant ($C' = 0$). C_t is mainly a function of efforts related to service activation (e.g., installation) and account maintenance (e.g., billing, computer server space, and help provided by the service firm).

For a firm that aims to find the optimum trajectories P_t^* and U_t^* to maximize the discounted profit stream over the planning period T, the problem is formulated as follows for a discount *rate* $r \geq 0$:

$$\underset{P_t,\ U_t}{Max} \int_0^T [(P_t - C(N_t))\ N_t - Q(U_t)]\ dt, \quad (4)$$

subject to $\dot{N}_t = f\ (N_t, P_t, U_t)$, and the initial number of subscribers $N_0 \geq 0$ is fixed and N_T is free.

In expression (4), $P_t\ N_t$ represents the total revenue generated from subscribers and $C(N_t)\ Nt$ is the related total variable cost. In expression (4), $Q(U_t)$ is the advertising cost function assumed to be non-negative and convex with respect to its argument with the properties $Q' > 0$ *and* $Q'' \geq 0$ (Piconni and Olson, 1979). As in earlier monopolistic models (Dockner and Jørgensen, 1988a; Thompson and Teng, 1984; Kalish, 1985), we assume no salvage value for the final number of subscribers at time T. Dockner and Jørgensen (1988b) assert that this assumption is particularly plausible when the firm is more concerned with its profits stream over the planning period than profits to be made after instant T. This assumption also makes results for new subscription services readily comparable with their counterparts related to new products.

The optimal control problem (4) can be solved by applying Pontryagin's maximum principle optimization technique (Pontryagin, 1962). To apply the maximum principle, we start by forming the current value Hamiltoian (Sethi and Thompson, 2000)

$$H_t\ (P_t, U_t, N_t) = (P_t - C(N_t))\ N_t - Q(U_t) + \lambda_t\ f(N_t, P_t, U_t), \quad (5)$$

where λ_t is a costate variable that must satisfy the ensuing requirements:

$$d\ \lambda_t / dt = r\ \lambda_t - \partial H_t / \partial\ N_t\ ,\ \text{and the transversality condition } \lambda_T = 0. \quad (6)$$

An economic interpretation of λ_t is found in Sethi and Thompson (2000). Briefly, λ_t has the interpretation of a *shadow price* of the stock of subscribers N_t. In this paper, as in Dockner and Jørgensen (1988a), we consider admissible controls that are twice differentiable in t and satisfy $P_t \geq 0$ and $U_t \geq 0$ for all relevant t. (In what follows, the time argument is eliminated to minimize confusion and improve clarity). Confining our interest to admissible controls, the partial derivatives of the current value Hamiltonian with respect to P and U along the optimal trajectories, as in Feichtinger (1982), must satisfy the following conditions for an interior solution for which $0 \leq \underline{P} \leq P \leq \bar{P}$ and $0 \leq \underline{U} \leq U \leq \bar{U}$:

$$\partial\ H / \partial P = 0,\ \partial\ H / \partial U = 0, \quad (7)$$

where $\underline{P}$ and $\bar{P}$ are the lower and upper bounds of P, $\underline{U}$ and $\bar{U}$ are the lower and upper bounds of U, and

Matrix **HM** is negative definite, (8)

such that **HM** is non-singular Hessian matrix of the second partial derivatives of the Hamiltonian H, and

$$\boldsymbol{HM} = \begin{bmatrix} \partial^2 H/\partial P^2 & \partial^2 H/\partial P \partial U \\ \partial^2 H/\partial U\,\partial P & \partial^2 H/\partial U^2 \end{bmatrix}. \quad (9)$$

It is noted that the last three inequalities in (2) guarantee that the elements lying on the diagonal of matrix ***HM*** are negative and ***HM*** is negative definite. Conditions (6) and (7) are the necessary conditions of optimality. The last condition (8) is one of several sufficiency conditions of optimality implying that the Hamiltonian *H* is jointly concave in the control variables *P* and *U* together with the state variable *N* (Seierstad and Sydsaeter, 1977). If a sufficiency condition is violated (e.g., $\partial^2 H/\partial P^2 > 0$) the optimal pricing policy would be either the constant $\underline{P}$ or the constant $\overline{P}$. By substituting into the Hamiltonian *H*, the constant that maximizes it would be chosen as P_t^* (Teng and Thompson, 1985 p. 192).

MARKETING-MIX STRATEGIES

This section starts first by analyzing the situation of the general diffusion model (1) followed by an analysis related to a specific diffusion model for subscription services.

Analysis of the General Diffusion Model

Using conditions (7) in conjunction with expressions (5) and (6), it can be shown that the first derivative of the optimal trajectories P^* and U^* with respect to time *t*, represented by a (2 x 1) column vector ***DER***, are uniquely determined by the equations written in a matrix format

$$\begin{bmatrix} dP/dt \\ dU/dt \end{bmatrix} = \boldsymbol{DER} = -\boldsymbol{HM}^{-1}\,\boldsymbol{CV}. \quad (10)$$

In (10), $\boldsymbol{HM}^{-1}$ is the inverse of the (2 x 2) matrix ***HM***, and ***CV*** is the (2 x 1) column vector

$$\boldsymbol{CV} = \begin{bmatrix} f + N(f_N - f f_{PN}/f_P) - f_P(P - C - NC_N) + r\lambda f_P \\ -Q'(f_N - f f_{UN}/f_U) - f_U(P - C - NC_N) + r\lambda f_U \end{bmatrix}. \quad (11)$$

Substituting ***HM*** given by (9) and ***CV*** given by (11) in (10) produces

$$\begin{bmatrix} dP/dt \\ dU/dt \end{bmatrix} = \frac{1}{\Delta}\begin{bmatrix} -\partial^2 H/\partial U^2 & \partial^2 H/\partial U \partial P \\ \partial^2 H/\partial P \partial U & -\partial^2 H/\partial P^2 \end{bmatrix}\begin{bmatrix} f + N(f_N - f f_{PN}/f_P) - f_P(P - C - NC_N) + r\lambda f_P \\ -Q'(f_N - f f_{UN}/f_U) - f_U(P - C - NC_N) + r\lambda f_U \end{bmatrix}, \quad (12)$$

where $\Delta = (\partial^2 H/\partial P^2)\,(\partial^2 H/\partial U^2) - (\partial^2 H/\partial P \partial U)^2 > 0$, given the last condition in (2).

It is observed from (12) that *dP/dt* would possess the same sign as that related to the sign of the first entry of the column vector in (11) and *dU/dt* would possess the same sign as that related to the sign of the second entry of the column vector in (11) for $\partial^2 H/\partial P \partial U = \partial^2 H/\partial U \partial P = 0$. That is, the qualitative characterization of the optimal pricing policy for a model that includes also advertising would be similar to that for a model that includes price alone. Similarly, the qualitative characterization of the optimal advertising policy for a model that includes also price would be similar to that for a model that includes advertising alone. For $\partial^2 H/\partial P \partial U \neq 0$, on the other hand, the sign of *dP/dt* in the presence of advertising, could be different from its univariate counterpart and the sign of *dU/dt* in the presence of price, could be different from its univariate counterpart. In short, for the latter case ($\partial^2 H/\partial P \partial U \neq 0$), the qualitative characterization of the

two optimal policies of price and advertising are said to be i*nterdependent*. Policy interdependence occurs when price and advertising interacts in affecting the subscription rate *f*. That is when $f_{PU} \neq 0$ (details are found in an Appendix available from the authors upon request).

Based on the necessary conditions (6) and (7) and the general specification of the subscription rate (1), the following proposition is introduced:

Proposition 1. *With subscription rate given by (1) and a presence of a service cost learning the following relationship holds at any point in time along the optimal trajectories of the marketing variables for new subscription services: The ratio of the advertising elasticity of the subscription rate ($\xi = Uf_U/f$) to its price elasticity ($\Lambda = -Pf_p/f$) is equal to the ratio of advertising to sales revenue (U/NP), multiplied by the marginal cost of advertising (Q´).*

The above result, in essence, is the well-known theorem of Dorfman and Steiner (1954), for a monopolist facing a price and advertising–dependent static demand for a product, and a linear advertising cost function *Q*, generalized to a dynamic setting for a subscription service. When both price (service charge) and advertising elasticities are constant, the above proposition provides a defense for an advertising policy based on a percentage of sales revenue since (*U/NP*) becomes a constant for a linear advertising cost function. Based on the general expression (12), two propositions are presented below.

Proposition 2. *For a considerably large interest rate and in the presence of service cost learning, optimal service charge decreases over time whereas optimal advertising increases over time.*

Proposition 2 implies that a myopic service provider interested in maximizing short-term profit because of high uncertainty in the market (Bayus,1994) would be inclined to decrease the service charge and increase advertising over time.

Proposition 3. *For r = 0, presence of cost learning curve and subscription rate given by (1) such that* $f + N(f_N - f f_{PN}/f_p) \geq 0$, $f_N - f f_{UN}/f_U \geq 0$,
(i) Optimal subscription fee is increasing over time.
(ii)Optimal advertising is decreasing over time.

Proposition 3 asserts that it would be *sufficient* that both the price elasticity of the subscription rate and the advertising elasticity of the same to decrease with the number of subscribers *N* for the optimal subscription fee to be increasing over time and optimal advertising to be decreasing over time. It is noted here that $\frac{\partial}{\partial N}(-f_p P/f) \leq 0$ implies that $f_N - f f_{pN}/f_p \geq 0$ and $\frac{\partial}{\partial N}(f_U U/f) \leq 0$ implies that $f_N - f f_{UN}/f_U \geq 0$. Continuous improvement of the quality of subscription services is the rule rather than the exception. For example, a provider of cable TV is inclined to modify the service (cable channels) to meet consumer needs better (Gatignon and Robertson, 1985; Mesak et al., 2011). Parker (1992) asserts that such continuous improvement in quality can result in greater perceived need and may, therefore, explain a decline in price elasticity. Similar arguments can be made to explain a decrease in advertising elasticity. Plausible examples of specific service diffusion models that satisfy the above two properties are demonstrated in Propositions 4, 6(a) and 7(a). As the interest rate measures how profits at present are preferred to those earned in the future, a low interest rate (r = 0) could be a sensible approximation when the planning period is short or in a low growth economy that approaches disinflation. Since expression (12) does not clearly characterize the trajectories of the marketing variables P_t^* and U_t^*, a diffusion model of a specific functional form is analyzed next.

Analysis of a specific Diffusion Model

The original Bass model (1969) as modified by Libai et al. (2009) to represent the diffusion of new subscription services in continuous time that explicitly considers customers' disadoption is given by the following expression:

$$d N_t/ dt = p (M – N_t) + q (1 – \delta) (N_t/ M) (M – N_t) – \delta N_t , \quad (13)$$

where N_t is the number of subscribers at time t, M is the market potential, p is the coefficient of innovation, q is the coefficient of imitation, and δ is the disadoption rate. The Bass model (1969) for the diffusion of new durable goods is obtained from (13) upon putting $\delta = 0$. The above authors assume that only those who did not disadopt spread positive word-of-month communications about the service. Therefore, the level of word-of-mouth promotion by retained customers remains the same (q), but its effective impact is reduced due to disadoption from [$(qN_t)/M$] to [$q (1 – \delta) N_t/ M$]. As disadopters consider readoption, the remaining market potential is $M – N_t$ and is not affected by the disadoption process (Libai et al., 2009). Using diffusion data related to cell phones, cable television and online banking in the US, Libai et al. (2009) show that their service diffusion model is empirically appealing for the above service categories. The authors also illustrate that the following relationship among the parameters of their model holds:

$$q (1 – \delta) – p – \delta > 0. \quad (14)$$

The inequality (14) is influential in arriving at a proof of an ensuing proposition. Whenever a parameter or quantity in the Libai et al.(2009) model is assumed to depend on one or more of the marketing variables, this parameter or quantity is simply multiplied, as appropriate, by one or more of the functions *w(P)* which is a pricing response function, *h(U)* which is an advertising efficiency function, or both. These functions are envisioned to possess the following properties:

$$w > 0; h > 0; w' < 0; h' > 0; w'' < 0 ; h'' < 0. \quad (15)$$

The results obtained upon analyzing a diffusion model for which price affects market potential (Bagchi et al., 2008) and advertising affects the coefficient of innovation (Mesak et al., 2011) is introduced in Propositions 4.

Proposition 4. *For a low interest rate, presence of service cost learning, and a service diffusion model* $d N_t/ dt = ph (wM – N_t) + q (1 – \delta) (N_t/wM) (wM – N_t) - \delta N_t$,
(ai)For $\delta = 0$, *optimal subscription fee is increasing over time.*
(aii) For $\delta = 0$, *optimal advertising is decreasing over time.*
(bi) For $0 < \delta < 1$, *optimal subscription fee is increasing (or increasing first then decreasing later).*
(bii) For $0 < \delta < 1$, *optimal advertising is decreasing (or decreasing first then increasing later).*

Proposition 4 demonstrates that the optimal pricing and advertising policies of the service firm in the presence of customers' disadoption [parts (bi) and (bii)] could be different from their counterparts in the absence of the same [parts (ai) and (aii)].

STEADY STATE STATIC OPTIMIZATION

The optimal control problem analyzed thus far is "autonomous". It is said to be autonomous as time enters only through the discount rate. In this regard, Kamien and Schwartz (1981, p.159)

mention that “In infinite horizon problems, a transversality condition needed to provide a boundary condition is typically replaced by the assumption that the optimal solution approaches a steady state. This assumption is plausible since one might expect that, in the long run, the optimal solution would tend to “settle down” since the environment is stationary by hypotheses”.

Considering a stable equilibrium at the steady state, this section is mainly preoccupied with developing and applying an analytical structure that aims at assessing the sensitivity of the optimal steady state marketing-mix variables *U* and *P* together with the corresponding optimal steady state profit rate π to a change in the disadoption rate δ.

The steady state number of subscribers *N* is obtained from (1) upon putting $dN_t / dt = 0$ and solving afterwards $f(N_t, P_t, U_t)$ for *N* to become a function of *U* and *P* and other pertinent parameters. For $r = 0$, the integrand of the objective functional in (4) takes on the following form:

$$\pi = (P - C)\, N(U, P) - Q(U). \tag{16}$$

To make the analysis simple, no cost learning is assumed to exist at the steady state so that the marginal cost C becomes a constant quantity independent of *N*. To maximize the steady state profit π, the necessary conditions of optimality leads to the following two expressions:

$$\Psi = \partial\pi/\partial U = (P - C)\, N_U - Q_U = 0. \tag{17}$$
$$\Phi = \partial\pi/\partial P = (P - C)\, N_P + N = 0. \tag{18}$$

From (17), one obtains upon differentiation with respect to δ
$d\Psi / d\delta = (\partial\Psi/\partial U)(\partial U/\partial\delta) + (\partial\Psi/\partial P)(\partial P/\partial\delta) + (\partial\Psi/\partial\delta) = 0$, *resulting upon minor arrangement of terms in the following:*

$$[(P - C)\, N_{UU} - Q_{UU}](\partial U/\partial\delta) + [N_U + (P - C)\, N_{UP}](\partial P/\partial\delta) = -(P - C)\, N_{U\delta}. \tag{19}$$

From (18), one obtains upon differentiation with respect to δ
$d\Phi / d\delta = (\partial\Phi/\partial U)(\partial U/\partial\delta) + (\partial\Phi/\partial P)(\partial P/\partial\delta) + (\partial\Phi/\partial\delta) = 0$, *resulting upon minor arrangement of terms in the following:*

$$[(P - C)\, N_{PU} + N_U](\partial U/\partial\delta) + [(P - C)\, N_{PP} + 2\, N_P](\partial P/\partial\delta) = -(P - C)\, N_{P\delta} - N_\delta. \tag{20}$$

Using matrix notation, one can write (19) and (20) as follows:

$$\begin{bmatrix} (P - C)N_{UU} - Q_{UU} & N_U + (P - C)N_{UP} \\ (P - C)\, N_{PU} + N_U & (P - C)\, N_{PP} + 2\, N_P \end{bmatrix} \begin{bmatrix} \partial U/\partial\delta \\ \partial P/\partial\delta \end{bmatrix} = \begin{bmatrix} -(P - C)\, N_{U\delta} \\ -(P - C)\, N_{P\delta} - N_\delta \end{bmatrix}. \tag{21}$$

It is noted that the 2 x 2 square matrix in (21) is not but the Hessian matrix H of second order partial derivatives shown below

$$\boldsymbol{H} = \begin{bmatrix} \partial^2 H/\partial U^2 & \partial^2 H/\partial U\partial P \\ \partial^2 H/\partial P\,\partial U & \partial^2 H/\partial P^2 \end{bmatrix}.$$

The sufficient conditions of optimality imply that $\partial^2 H/\partial U^2 < 0$, $\partial^2 H/\partial P^2 < 0$, *and* $(\partial^2 H/\partial U^2)(\partial^2 H/\partial P^2) - (\partial^2 H/\partial U\partial P)^2 > 0$.

Substituting from (17) and (18), $P - C = Q_U/N_U = -N/N_P$ into (21) and solving for the vector $[\partial U/\partial\delta \;\; \partial P/\partial\delta]'$ afterwards, one obtains the following:

$$\begin{bmatrix} \partial U/\partial \delta \\ \partial P/\partial \delta \end{bmatrix} = (1/D) \begin{bmatrix} (-NN_{PP} + 2N_P^2)/N_P & -(-NN_{PU} + N_P N_U)/N_P \\ (-NN_{PU} + N_P N_U)/N_P & (Q_U/N_U)\, N_{UU} - Q_{UU} \end{bmatrix} \begin{bmatrix} Q_U\, N_{U\delta}/N_U \\ NN_{P\delta} - N_\delta\, N_P)/N_P \end{bmatrix}, \quad (22)$$

and the determinant $D = \{(-NN_{PP} + 2N_P^2)/N_P\}\{(Q_U/N_U)\, N_{UU} - Q_{UU}\} - (-NN_{PU} + N_P N_U)^2/N_P^2$

Expression (22) represents a general analytical framework for obtaining the comparative statics (sensitivities) of optimal steady state marketing mix policies for any service diffusion model. To operationalize expression (22) for alternative service diffusion models based on the Libai et al. (2009) model represented by (13), one needs to first obtain the steady state *N*. This quantity is obtained from (13) upon putting $d N_t/dt = 0$ and solving the quadratic equation for *N* to obtain the unique solution

$$N = \frac{q(1-\delta) - (p+\delta) + \sqrt{(q(1-\delta) - (p+\delta))^2 + 4pq(1-\delta)}}{2q(1-\delta)/M}. \quad (23)$$

Except for parameter *δ*, when one of the parameters *p*, *q,* or *M* is assumed to depend on one or more of the marketing mix variables, this parameter is simply multiplied by the pricing response function *w(P)*, the advertising efficiency function *h(U)*, or both. Functions *w* and *h* satisfy the properties depicted in (15). It is also noted that the first derivative of the right-hand side of (13) with respect to N is negative. This implies that the solution of (13) is asymptotically stable (Fruuchter and Sigué, 2013, p. 2186).

We are now in a position to report the comparative statics $\partial U/\partial \delta$ and $\partial P/\partial \delta$ for the service diffusion models shown in Table 1.

Table 1 Comparative statics at the steady state for selected diffusion models

Diffusion models	N	$\partial U/\partial \delta$	$\partial P/\partial \delta$
M1.*dN/dt=[p+q(1–δ)N/Mwh][Mwh-N]-δN*	*Expression(23) with M multiplied by wh*	-	*0*
M2. *dN/dt=[p+q(1– δ)N/M(h+dw)][M(h+dw)-N]-δN*	*Expression (23) with M multiplied by (h+dw)*	-	-
M3. *dN/dt=[ph+q(1–δ)N/Mw][Mw-N]-δN*	*Expression (23) with p multiplied by h and M by w*	+	*0*
M4. *dN/dt=[p+qh(1–δ)N/Mw][Mw-N]-δN*	*Expression (23)* with *q multiplied by h and M by w*	+	*0*
M5. *dN/dt=[p+qw(1–δ)N/Mh][Mh-N]-δN*	*Expression (23)* with *q multiplied by w and M by h*	-	-
M6.*dN/dt=[pw+q(1–δ)N/Mh][Mh-N]-δN*	*Expression (23) with p multiplied by w and M by h*	-	-
M7. *dN/dt=p(Mwh-N)-δN*	*Mphw/(δ+p)*	-	*0*
M8. *dN/dt=p(M(h+dw)-N)-δN*	*Mp(h+dw)/(δ+p)*	-	-
M9. *dN/dt=ph(Mw-N)-δN*	*Mphw/(δ+ph)*	*sighn (ph-δ)*	*0*
M10. *dN/dt=pw(Mh-N)-δN*	*Mphw/(δ+pw)*	-	-
M11. *dN/dt=q(1-δ)(N/Mwh)(Mwh-N)-δN*	*Mhw[q(1-δ)–δ]/q(1-δ)*	-	*0*
M12. *dN/dt=q(1-δ)[N/M(h+dw)][M(h+dw)-N]-δN*	*M(h+dw)[q(1-δ)–δ]/q(1-δ)*	-	-
M13. *dN/dt=qh(1-δ)(N/Mw)(Mw-N)-δN*	*Mw[qh(1-δ)–δ]/qh(1-δ)*	+	*0*
M14. *dN/dt=qw(1-δ)(N/Mh)(Mh-N)-δN*	*Mh[qw(1-δ)–δ]/qw(1-δ)*	-	-

In Table 1 where d is a constant parameter, models M1 through model M6 represent mixed effect models where both the external effect (process of innovation) and the internal effect

(process of imitation) are present ($p > 0$ and $q > 0$). Models M7 through M10 are external effect models where diffusion is mainly attributed to innovators ($p > 0$ and $q = 0$). Models M11 through M14 are internal effect models where diffusion is mainly attributed to imitators ($p = 0$ and $q > 0$). For a few diffusion models, advertising would decrease in response to an increase in the disadoption rate. Though such a finding appears counterintuitive, it should be noted that a decrease in advertising cost could moderate the impact on profit. The comparative statics reported in Table 1 reveal that how the marketing-mix variables would change in response to a change in the disadoption rate is basically an empirical question. The answer of such a challenging question depends on whether the diffusion process is of the mixed effect type, the external effect type, or the internal effect type. Furthermore, the answer to the question is also dependent on how the marketing-mix variables are included in the diffusion model. We are now in a position to introduce one more proposition.

Proposition 5. *For r = 0 and a constant marginal cost, irrespective of the type of the diffusion process or how the marketing-mix variables affect the Libai et al. (2009) service diffusion model (13)*
(i) For a given adverting U and price P, an increase in the disadoption rate δ leads to a decrease in the steady state number of subscribers N, and
(ii) An increase in the disadoption rate δ decreases the optimal steady state profit π.

Proposition 5 indicates that doing nothing in response to an increase in the disadoption rate results in a decrease in the number of subscribers and its stabilization together with related profit at lower levels. Responding optimally by making appropriate changes in the marketing-mix variables would also lead to a decrease in profit. In order to remain profitable, service providers have to limit customer attrition actively (Bolton, 1998; Musalem and Joshi, 2009).

SUMMARY AND CONCLUSIONS

This section summarizes the main theoretical and empirical findings of the study, highlights managerial implications, and proposes directions for future research. The diffusion models analytically explored in this article represent a unique attempt in the literature that aims at deriving optimal pricing and advertising policies for new subscription service innovations.

Our approach considers demand dynamics, learning curve, and discounting that are managerially relevant. Demand dynamics are reflected in the differential equation of the diffusion model through incorporating saturation, word of mouth and disadoption effects. In introducing new subscription service innovations, the decision maker may not be interested in setting the pricing and advertising policies in isolation, but rather he or she would be more satisfied by considering the interactive influence of such policies upon the subscription rate.

This study addresses such concern by recognizing the simultaneous impact of the studied two marketing variables on the diffusion process. The analytical findings of the study summarized in Propositions 3 and 4 generally argue in favor of increasing the subscription fee for new subscription services overtime, perhaps followed by a period in which the fee may be decreasing when disadoption is significant, and decreasing the advertising expenditure, perhaps followed by a period in which advertising is increasing when disadoption is significant to win back customers who disadopted the service. Proposition 5 indicates that customers' disadoption, in the long-run, has an adverse effect on profitability and therefore it must be controlled. For example, long-term contracts are common in the American mobile telecommunications market and contract-bound customers incur high procedural and financial swiching costs for breaking or modifying a contracted agreement (mesak et al., 2011).

The dominant policies of increasing price and decreasing advertising for new subscription service innovations are interesting and deserve an explanation. The service provider charges a low fee and advertises heavily at the beginning to generate positive word of mouth, speed up the learning of the service provider offering and build a large base of consumer adopters who keep on repurchasing the service upon their satisfaction with their initial experiences, causing the perceived value of the service to get enhanced over time. Also, because revenues of a subscription service in a given time period are not solely generated from new adopters during that period but also from adopters in previous periods, subscription fee is motivated to increase and advertising is invigorated to decrease in order to increase profits (Nagle, 1987; Mesak and Darrat, 2002).

The modeling effort developed here is exploratory revealing many possibilities for future research. First, one would consider optimal pricing and advertising of a "secondary" subscription service that is contingent on the subscription of a "primary" subscription service (e.g., a customer cannot subscribe to a secondary pay service such as HBO unless he or she is a subscriber to the primary basic cable service). The study of Fruchter and Rao (2001) is useful in this respect.

A plausible second direction for future research is to incorporate service bundling in the modeling effort (Guiltman, 1987). For example, a cable TV provider may expand the business by providing internet access services together with telephone services. Whether to use a mixing bundling strategy or a pure bundling strategy (i.e., selling the bundle only) is an interesting research topic (Ansari et al., 1996).

Third, other marketing mix variables such as service quality (Rust, et al., 1995; Van Mieghem, 2000), service guarantees (Fruchter and Gerslner, 1999; Kumar et al., 1997) and distribution (Jones and Ritz, 1991; Bronnenberg et al., 2000) could be considered endogenously to enrich the modeling effort.

Fourth, this article assumes that the market has only one service provider operating (as in the case of cable TV). An interesting direction for future research is to characterize optimal pricing and advertising policies under the threat of competitive entry (Gupta and Di Benedetto, 2006). Alternatively, competition could be modeled in a (non-cooperative) game- theoretic framework within the same industry (Thompson and Teng, 1984; Dockner and Jørgensen,1988b, Prasad et al. 2012), or between industries such as cable TV and satellite dish (Ross, 1999).

A fifth direction for future research is to extend the modeling effort to consider different generations of the new service innovation. The notable studies of Danaher et al. (2001) and Danaher (2002) should be particularly informative as they provide lucid reviews of research undertaken in this area. Addressing the above research issues, and perhaps several others, should be beneficial to both academicians and practitioners in the service sector.

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Optimizing Transportation Process of a Large-Scale Lunch Box Delivery System - A Simulated Annealing Approach

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ABSTRACT

In this paper, we study a unique large-scale, green lunch box delivery system of Mumbai, and identify that it is further possible to improve the collection and delivery processes by following new routes and evenly distributing the loads. We suggest implementing multiple depots vehicle routing concept for this purpose. Using a real-coded simulated annealing algorithm, we propose new routing and collection load decisions. Suggested improvements are shown with the help of a case example.

KEYWORDS: Transportation, Lunch Box Delivery, Multiple Depots Vehicle Routing Problem.

INTRODUCTION

The lunch box delivery system (LBDS) of Mumbai is considered as a classical example of a very large scale, green transportation management problem (Baindur & Macário, 2013). There are approximately 0.2 million lunch boxes transported from household to offices, and the same number of empty boxes are returned from offices to households every day. The LBDS created in Mumbai has many unique features concerning its operations, services, management practices, and overall business model. It is a wonder to both academic and corporate worlds that how such a vast system operates almost perfectly with the help of the illiterate or semi-literate workforce (an average literacy standard is 8th grade in school) without the use of any sophisticated technology. They have shown to the corporate world that the system in place is more critical than the workforce for achieving astonishing results. The accuracy of delivery is Six Sigma certified. The accuracy level is no less than that achieved by Motorola or GE (Mallik Mukherjee, 2007).

Unfortunately, the problem has not been studied extensively. The literature reports only a limited number of studies on this topic. Only a handful number of research articles are available in the literature (Mallik & Mukherjee, 2007; Pathak, 2010; Baindur & Macário, 2013; Chakraborty & Hargude, 2015). A few case studies also appear in the literature (Ravichandran, 2005; Thomke, 2012). In these works, authors have critically examined the system and tried to find out success factors, and the possibility of replicating it to similar situations of any other part of the world.

Some cases are also taught at the world's top B-Schools to understand how a simple operating process leads to such a superior level of service.

In this work, we review the LBDS of Mumbai and identified that the better collection and delivery routing decisions are possible. We formulate the collection and delivery processes as a multiple depots vehicle routing problem (MDVRP). With the help of a numerical example, we find that it is possible to reduce collection and delivery times by following better routes. A simulated annealing algorithm is used for arriving new routing decisions. Therefore, it is possible to bring improvement into an existing world-class system.

LUNCH BOX DELIVERY SYSTEM OF MUMBAI

This massive system which is existing now has its origin way back in 1890. It has started with one lunch box carrier delivering lunch to one person who was a bank employee during the British era in India. The service has grown and sustained over the last 128 years. The number of lunch box carriers has reached to around 5000 in 2017. Their collective efforts are nearly US$12 million annually.

The lunch box carriers are the smallest and the most important units of the system. They provide this service on all working days throughout the year. They start their operations by reaching to residential areas (RA) to collect boxes either by walk or by using bicycle. Each of them is responsible for collecting 35-40 boxes from pre-specified locations. The collection of lunch boxes is completed between (8:30 – 9:00) AM. After collecting the boxes, they reach the designated railway station. Another set of chosen carriers wait at the station for sorting the boxes. A unique coding system is used for this purpose. Immediately after the sorting, lunch boxes are bundled into groups as per their destinations. Designated carts are used for this purpose. This part of transportation is managed by selected carriers in a pre-determined railway station. Another round of sorting is done after the lunch boxes reach destination railway stations. A new set of carriers performs this task and complete the delivery to the respective customers. This process is completed before 01:00 PM. The collection of empty lunch boxes from offices and delivery to the respective households are done following an exact reverse process. This process is completed before 05:30 PM. The railway extends its support by providing areas required for shorting of 'Dabbas' at platforms as well as by running trains having special compartments suitable for loading carts containing lunch boxes during (10:00 – 11:30) AM in the south Mumbai direction.

The efficient running of the system is largely credited to a simple and visual coding structure appropriate for the illiterate or semi-literate carriers. As the lunch boxes are transported through suburban railway network, the coding structure must suitably relate railway stations. These two major concerns are very well incorporated while designing the coding structure. Figure 1 shows the lunch boxes with codes on the lid of each lunch box.

Figure 1: Coding structure of lunch box delivery system of Mumbai Dabbawalas

(Source: Linderman, 2011)

IMPROVING THE EFFICIENCY OF COLLECTION AND DELIVERY PROCESSES

There are two similar problems related to the collection and delivery processes of LBDS. The first problem is concerned with the collection of lunch boxes from individual houses located at residential areas adjacent to different railway stations by the carriers and accumulate them in respective stations. The other problem is concerned with the delivery of lunch boxes to offices after the collection from different railway stations. The transportation problem for both the processes considered for the entire network can be mapped to multiple depots vehicle routing problem (MDVRP) (Montoya-Torres et al., 2015). We consider the case of collection process for illustration. The delivery process can similarly be illustrated.

The mathematical model of the problem can be written as follows:

$$\min: \sum_{i=1}^{n+m}\sum_{j=1}^{n+m}\sum_{k=1}^{K} d_{ij}\, y_{ijk} \tag{1}$$

Subject to

$$\sum_{i=1}^{n+m}\sum_{k=1}^{K} y_{ijk} = 1, j = 1,2,\dots,n \tag{2}$$

$$\sum_{j=1}^{n+m}\sum_{k=1}^{K} y_{ijk} = 1, j = 1,2,\dots,n \tag{3}$$

$$\sum_{i=1}^{n+m} y_{ihk} - \sum_{j=1}^{n+m} y_{hjk} = 1, k = 1,2,\dots,K; h = 1,2,\dots,n+m \tag{4}$$

$$\sum_{i=1}^{n+m} Q_i \sum_{j=1}^{n+m} y_{ijk} \le P_k, k = 1,2,\dots,K \tag{5}$$

$$\sum_{i=1}^{n+m}\sum_{j=1}^{n+m} d_{ij} y_{ijk} \le T_k, k = 1,2,\dots,K \tag{6}$$

$$\sum_{i=n+1}^{n+m}\sum_{j=1}^{n} y_{ijk} \le 1, k = 1,2,\dots,K \tag{7}$$

$$\sum_{j=n+1}^{n+m}\sum_{i=1}^{n} y_{ijk} \le 1, k = 1,2,\dots,K \tag{8}$$

$$x_i - x_j + (m+n) y_{ijk} \le n + m - 1, \forall i,j \in [1,n], i \ne j;\ k \in [1,K] \tag{9}$$

$$y_{ijk} \in \{0,1\}, \forall i,j,k \tag{10}$$

In this formulation, y_{ijk} is the binary decision variable to be equal to 1 if the arc connecting (*i*, *j*) is served by the lunch box carrier *k* and 0, otherwise. The objective function (1) minimizes the total distance travelled, constraints (2) and (3) ensure that each RA is served by one lunch box carrier, constraint (4) represents continuity of routes, constraint (5) represents the collection capacity of lunch box carriers, constraint (6) represents the restriction on route cost, constraints (7) and (8) represent the availability of lunch box carriers, and constraint (9) represents the condition fir eliminating sub tours. It is assumed that availability of lunch boxes at each node does not exceed the carrying capacity of each carrier.

NUMERICAL EXAMPLE

We consider an instance of collecting 370 lunch boxes from 31 RAs located around the Boriville railway station in Mumbai. At the end of collections, lunch box carriers will bring them to the same railway station. Table 1 represents the longitude, latitude, number of lunch boxes available for collection at RAs (2 to 32). The railway station is denoted by 1.

Table 1: Lunch box collection related data

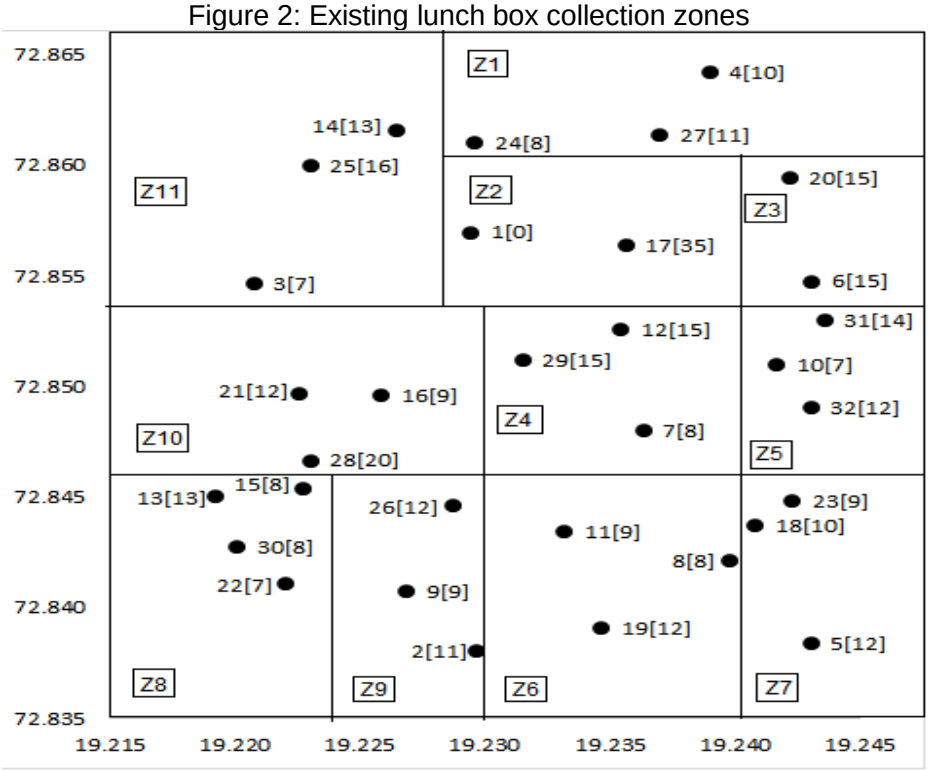
Number	Longitude	Latitude	# Lunch boxes available for collection
1	19.229389	72.856998	0
2	19.229587	72.838105	11
3	19.220730	72.854694	7
4	19.238912	72.864214	10
5	19.242959	72.838453	12
6	19.243015	72.854779	15
7	19.236298	72.848048	8
8	19.239732	72.842170	8
9	19.226823	72.840754	9
10	19.241580	72.851033	7
11	19.233122	72.843478	9
12	19.235389	72.852582	15
13	19.219192	72.845072	13
14	19.226405	72.861590	13
15	19.222681	72.845413	8
16	19.225826	72.849635	9
17	19.235619	72.856406	35
18	19.240763	72.843777	10
19	19.234617	72.839127	12
20	19.242121	72.859455	15
21	19.222511	72.849721	12
22	19.221976	72.841156	7
23	19.242214	72.844861	9
24	19.229522	72.861034	8

25	19.222981	72.860013	16
26	19.228668	72.844680	12
27	19.236964	72.861369	11
28	19.222998	72.846692	20
29	19.231496	72.851250	15
30	19.220080	72.842804	8
31	19.243523	72.853008	14
32	19.242987	72.849063	12

RESULTS AND ANALYSIS

At present, RAs around the Boriville railway station are divided into few zones. One carrier is responsible for collecting boxes from each zone. The zones are shown in Figure 2.

Figure 2: Existing lunch box collection zones



In the Figure 2, longitudes are shown along the x-axis, and the latitudes are shown along the y-axis. For the considered case example, a real-coded simulated annealing (SA) approach is used, which is coded in MATLAB. A comparison of the existing and suggested solutions is presented in Table 2.

Table 2. Existing and proposed routes

Existing Routes			SA Routes		
Route/Zone	# Lunch box collected	Distance Travelled (km)	Route	# Lunch box collected	Distance Travelled (km)
1	29	2.85	1	37	1.97
2	35	1.39	2	40	4.24
3	30	3.47	3	37	2.87
4	38	2.58	4	39	4.81
5	33	3.80	5	36	3.93
6	29	4.55	6	38	4.96
7	31	5.08	7	36	4.10
8	36	4.10	8	36	3.52
9	32	4.15	6	35	1.39
10	41	2.71	10	36	3.38
11	36	2.61	Total	370	35.16
Total	370	37.29			

The existing solution shows the requirement of 11 lunch box carriers, one for each zone. However, the suggested solution shows the requirement of 10 lunch box carriers. The total distances traveled along all the routes are 37.29 km and 35.16 km, respectively. This implies that the proposed approach suggests a saving of 5.71% in terms of distance traveled. The lunch box carriers follow an extremely busy schedule during their hours of operations. The reduction in distance traveled will provide some space for them. It will be even more effective for the elderly lunch box carriers. In terms of carrying the number of boxes, the suggested solution is more rational.

CONCLUSIONS

We reviewed the LBDS of Mumbai from the transportation aspects and investigated its vast scale of operation, environment friendliness, cost efficiency, supervision of the system at different nodes of operations. It is observed that the accuracy of delivery of lunch boxes is near perfect and may not be possible to improve further. The coding structure followed in the system is a major constituent for the success of the overall transportation process. The role of semi or illiterate lunch box carriers is extremely important for the accurate delivery and optimum functioning of the transportation system. We identified an area where improvement is possible. It is regarding the routes followed during the collection and delivery processes of lunch boxes. The results indicate the possibility of reducing the collection time by about 6% compared to the existing one.

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Performance Dashboard in Higher Education: A University Career Service Case Study

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ABSTRACT

This research documents the process of developing a performance dashboard system for one university's career services center to overcome challenges including lack access to relevant information, stakeholders not taking advantage of what is being offered, students' anxiety about not being able to find a job, and strategic planning. Through theory foundation grounded on the literature, the research aims to integrate data into actionable information, to present the right information to the right user at the right time, to provide a platform for communication between all stakeholders, and to improve stakeholder satisfaction through self-serve ad-hoc reporting.

KEYWORDS: Performance Dashboards, Higher Education, Data Visualization

I. INTRODUCTION

Recent developments in higher education have spurred the need for more effective planning and management (Duffy, 2005) . With pressure to become active, innovative, results-oriented and effective, universities to operate strategically (Kassahun, 2010). Higher education institutions are transforming into entrepreneurial enterprises in which performance is linked to various university strategies (Nayeri et al., 2008). Some of the challenges that universities face include a tighter job market, competition among schools for applicants, rising tuition, concerns regarding return on investment, relationships with employers, economic volatility and the need for a common platform to communicate with all stakeholders.

A performance dashboard builds on business intelligence (BI) platform to provide interactive visual display of data to effectively measure, monitor and manage business performance of an organization toward predefined goals (Eckerson, 2010; Min, 2015, Lea, Yu, & Min, 2018). With the self-service business intelligence (BI) capbability to deliver the right information to the right users at the right time, a performance dashboard presents opportunities for universities to improve their institutional operation and strategic management capabilities.

This study documents design, development, and implementation of a performance dashboard for a career opportunities and employer relations center (referred as COER hereafter) to overcome challenges and to support the strategic management at a university located in Midwest of U.S.A. The proposed literature review shows how higher education institutions can recreate their strategies and business performances to adapt with the changing environment and to become more technologically advanced. A performance dashboard is proposed as a novel approach to achieve this goal.

This paper first reviews the literature concerning performance dashboards, career services in higher education, and the use of performance dashboards in higher education. Then, the research method will be explained, including the creation of a performance dashboard prototype. The paper will conclude with a summary of the findings, recommendations, contributions and directions for future research.

II. LITERATURE REVIEW

With nearly 15 million students who need assistance in determining their career paths and finding employment (Felix, 2006), career services impact the key aspects of student lives and career plans/opportunities in higher education institutions. Research has shown that the degree of satisfaction of students and parents is directly proportional to the reputation of the university, the placement rate and the expected income after graduation (Zhen, 2004). Therefore, offering students better and effective career assistance can increase the university's reputation and attract more students (Kerr, 1993). In addition to students and their parents, employers, alumni, and faculty of various academic departments are key stakeholders of career service center at a university (Yi & Rui, 2009).

Apart from on-campus placement activities, career services often include providing personality development workshops, mock interviews, resume critiques, job search training, employer information sessions and much more. Universities typically fund career services to make students more marketable (McCorkle et al., 2003) as a result of pressure from competitive job market (McGrath, 2002), high competition for applicants among universities (Howard-Vital, 2006; Garver et al. 2008), higher ROI expectation from higher tuition (Snow, 1995; Domino et al., 2006; Garver et al. 2008), the need for better employer relationship (McGrath, 2002), demand for well-rounded student candidates (Garver et al, 2008), and the use of placement statistics as a measure of educational quality and value (Garver et al., 2008)

Accurate, easily accessible information leads students to make better career choices and benefits the economy (Mayston, 2002), so universities thrive to provide accessible career services centers that provide the stakeholders with good information about various career services programs, events and classes. Lalande and Huston (2005) identified three priorities for measuring stakeholder outcomes from services provided by a career center: implementing an efficient communication strategy with stakeholders, clarifying desirable outcomes for career development practices and developing a system for archiving and easily obtaining information about the career center. Increased importance has been placed on career-related information and guidance, thus pressuring career services to explore better ways to disseminate information to their stakeholder (Grubb, 2022). Higher education institutions across the world have found various ways to disseminate information including individual or group career advising (Maguire & Killeen, 2003; Mayston, 2002), technology enabled self-service (Grubb, 2002), published statatistics amd reports (Spradlin et al., 2010), and consultation and promotion management (Mayston, 2002).

A performance dashboard is a multilayered interactive visual display mechanism built on a business intelligence and data integration infrastructure that conveys key performance information at a glance to allow users to effectively measure, monitor, and manage business performance of an organization toward predefined goals (Lea, et. al., 2018; Lea and Nah, 2013; Eckerson, 2010; Lea, 2011 Few, 2006). A performance dashboard often presents information in three different

layers including a summarized graphical layer, a multidimensional data layer, and a detailed transactional data layer to support its monitor, analysis, and management functions effectively (Eckerson, 2010, Lea, 2011). As a result, performance dashboards are gaining popularity as information delivery mechanism at different organizational levels, as achieved by integrating various data sources and utilizing different information layers to display and communicate data effectively.

Performance dashboards are typically classified into strategic dashboards, tactical or analytical dashboards, and operational dashboards (Eckerson, 2010, Few, 2006). A strategic dashboard aims at assisting top management in charting progress of an organization's strategy execution (Eckerson, 2010; Lea, 2012) and in providing high-level business performance overview. A tactical or analytical dashboard focuses on operational and tactical aspects of an organization and utilizes descriptive, predictive, and prescriptive analytics that allow users to interact with the data needed to understand the context. An operational dashboard focuses on monitoring daily transactions and real-time events that are constantly changing and requiring timely attention and thrives on providing most granular reports and live operational data (White, 2006) to accountability through tangible evidence and its impact on corporate goals (Miller & Cioffi, 2004).

Performance dashboards are designed to serve as a self-service business intelligence (BI) tool with an intuitive and user-friendly interface that require minimum or no user training.to deliver the right information to the right users at the right time. The reported advantages of performance dashboard adoptions include enhanced operational efficiency (Lea, 2011, White, 2006), optimize decision making (Eckerson, 2010, Lea and Nah, 2013), improve data visibility, process transparency, and strategy communication and alignment (Lea, et., al. 2018; Eckerson, 2010), reduce costs and resources required to prepare performance reports and management business (Eckerson, 2010; Few, 2006), and improve profitability.

III. Case Description

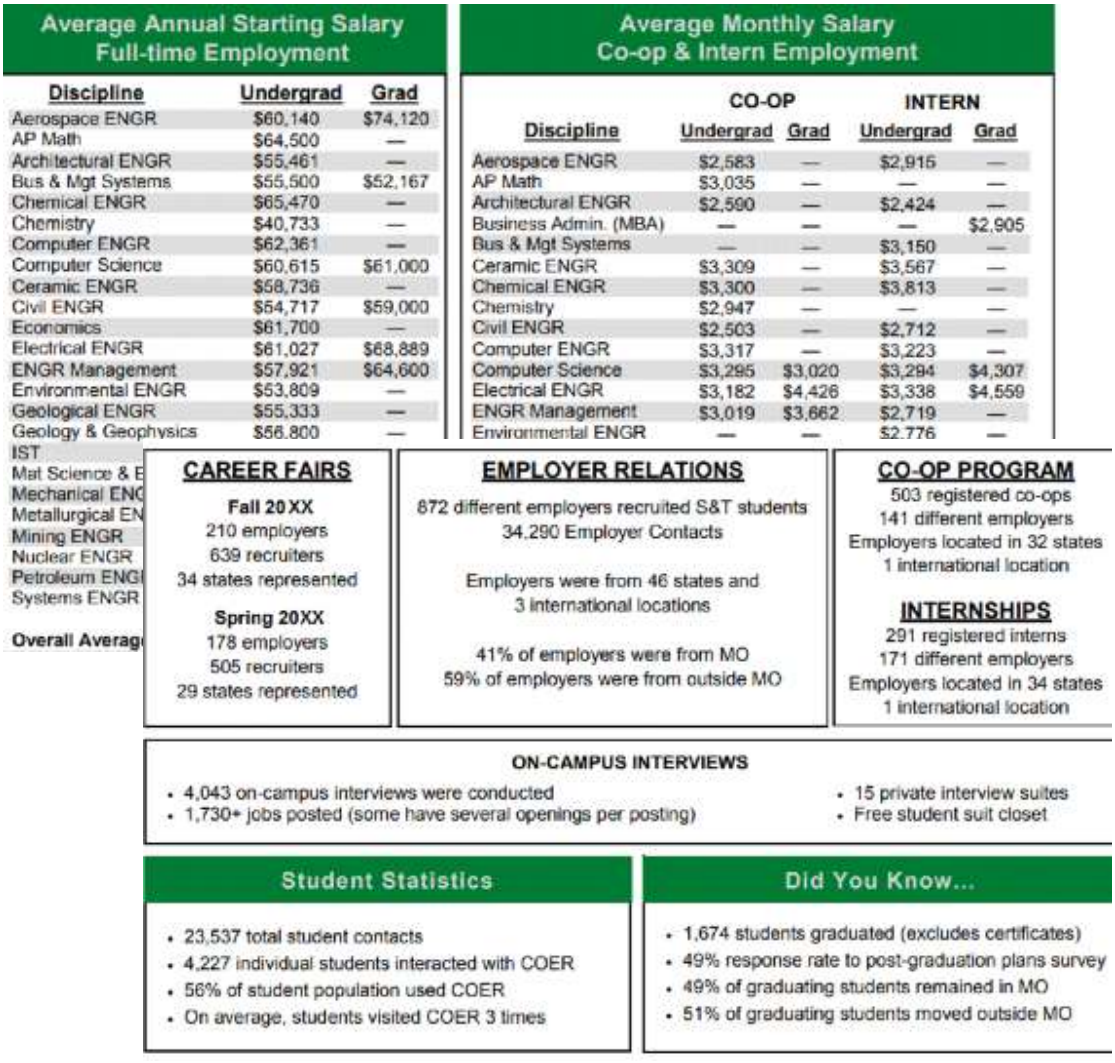
The case studied in this research is a career opportunities and employer relations center (COER) at a highly reputed STEM-focus university located in the Midwest. The goal of COER is to help students develop their careers and reach their professional goals while maintaining partnerships with diverse employers and university department staff. Education plays a significant role in students' career success in life, and COER helps to make the most of educational opportunities by helping students find full-time employment, summer internships and cooperative education experiences, thus bridging the gap between students and employers.

COER uses a database to post job opportunities for students. It is very important for COER to make its services and statistics easily accessible so that external and internal stakeholders can utilize them and enrich their educational experience. However, COER faces various challenges in reaching its stakeholders and user groups. One challenge is that students do not take advantage of all the resources that COER provides. Unfortunately, most students do not realize the potential opportunities that they can take advantage of by utilizing COER services that are tailored to meet students' job search and career development demands. Another challenge COER battles is the lack of access to sophisticated software tool and expertise to appropriately market and present the university's recruitment statistics and trends, which could serve various user groups by helping relieve their questions and doubts.

Currently, COER disseminates information mainly through published reports and handouts on their web sites and in office, as shown in Figure 1. These static reports are published on the web site annually, but do not have drill-down or drill-across capabilities to provide customized

report or deliver right information to right user at right time. The lack of interactive and accessible statistics leads to insufficient or outdated information provided to departments, faculty and staff and often resulted in time consuming and manual process information requests from COER's stakeholders. For example, when a department asks for a report or statistics, COER staffs must manually develop the report according to the unique requirements of the different departments. This task is time consuming and requires a great deal of manual intervention. Due to the lack of technology proficiency among COER staffs, user groups such as parents and employers are not involved heavily in the process of students' career and professional development.

Figure 1. COER's Static Reports and Statistics



Average Annual Starting Salary
Full-time Employment

Discipline	Undergrad	Grad
Aerospace ENGR	$60,140	$74,120
AP Math	$64,500	—
Architectural ENGR	$55,461	—
Bus & Mgt Systems	$55,500	$52,167
Chemical ENGR	$65,470	—
Chemistry	$40,733	—
Computer ENGR	$62,361	—
Computer Science	$60,615	$61,000
Ceramic ENGR	$58,736	—
Civil ENGR	$54,717	$59,000
Economics	$61,700	—
Electrical ENGR	$61,027	$68,889
ENGR Management	$57,921	$64,600
Environmental ENGR	$53,809	—
Geological ENGR	$55,333	—
Geology & Geophysics	$56,800	—
IST		
Mat Science & E		
Mechanical ENG		
Metallurgical EN		
Mining ENGR		
Nuclear ENGR		
Petroleum ENGI		
Systems ENGR		
Overall Averag		

Average Monthly Salary
Co-op & Intern Employment

	CO-OP		INTERN	
Discipline	Undergrad	Grad	Undergrad	Grad
Aerospace ENGR	$2,583	—	$2,915	—
AP Math	$3,035	—	—	—
Architectural ENGR	$2,590	—	$2,424	—
Business Admin. (MBA)	—	—	—	$2,905
Bus & Mgt Systems	—	—	$3,150	—
Ceramic ENGR	$3,309	—	$3,567	—
Chemical ENGR	$3,300	—	$3,813	—
Chemistry	$2,947	—	—	—
Civil ENGR	$2,503	—	$2,712	—
Computer ENGR	$3,317	—	$3,223	—
Computer Science	$3,295	$3,020	$3,294	$4,307
Electrical ENGR	$3,182	$4,426	$3,338	$4,559
ENGR Management	$3,019	$3,662	$2,719	—
Environmental ENGR	—	—	$2,776	—

CAREER FAIRS

Fall 20XX
210 employers
639 recruiters
34 states represented

Spring 20XX
178 employers
505 recruiters
29 states represented

EMPLOYER RELATIONS

872 different employers recruited S&T students
34,290 Employer Contacts

Employers were from 46 states and
3 international locations

41% of employers were from MO
59% of employers were from outside MO

CO-OP PROGRAM

503 registered co-ops
141 different employers
Employers located in 32 states
1 international location

INTERNSHIPS

291 registered interns
171 different employers
Employers located in 34 states
1 international location

ON-CAMPUS INTERVIEWS

- 4,043 on-campus interviews were conducted
- 1,730+ jobs posted (some have several openings per posting)
- 15 private interview suites
- Free student suit closet

Student Statistics

- 23,537 total student contacts
- 4,227 individual students interacted with COER
- 56% of student population used COER
- On average, students visited COER 3 times

Did You Know...

- 1,674 students graduated (excludes certificates)
- 49% response rate to post-graduation plans survey
- 49% of graduating students remained in MO
- 51% of graduating students moved outside MO

IV. Solution Approach

This study proposes to adopt a strategic planning process and a performance dashboard to address challenges faced by COER. The study is grounded on literature review of performance dashboards implementation in higher education and utilized surveys, interviews, prototyping,

and statistical analysis to validate findings. Software development Life Cycle (SDLC) was utilized in the proposed dashboard prototype development to incorporate theories and best practices from the literature review and the unique challenges faced by COER.

Effectiveness of a dashboard is the extent to which the intended goals of the dashboard through the implemented dashboard functionalities. In-person, email, and web conference interviews were conducted with COER staff and selected stakeholders to understand COER processes and how reports are developed in its current environment. The interview utilized a semi-structured approach that enabled interviewees to speak freely and ask questions. Figure 2 illustrated sample documentation from activity analysis and measures and dimension analysis from the structured and semi-structured interview process. Meeting records were kept and reviewed regularly to revise or validate project scope and timeline. The interview process helped to clarify various rules and definitions used in the process.

Figure 2. Sample Interview Results: Activity Report Analysis and Measure and Dimension Analysis

Report title		Internal	Public	Web
Employer Activity				
	# of States		XX	
	# of Employers per State (w/Geographic Map)		XX	
	% in MO		XX	
	% out of MO		XX	
	Employer States vs Student Home State	XX		
# of Degrees Awarded		XX		
	% of Students Reporting to COC		XX	
	Degree Count by Major	XX		
	Students by class standing	XX		
Firm Plans (with graph)				
	By State	XX		
	# of States		XX	
	# of Firm Plans per State	XX		
	% of Students that Stayed in MO		XX	
	Top 5 States		XX	

Full-Time	Measures	Dimensions
	Students	
	Percentage of student going on co-op or intern	Year, semester, department, gender
	Student converting co-op or intern to full time with the same company	Department, year, semester, gender
	Salary trends for co-op / intern / full time as well as comparison	Department , semester, year, company category (i.e. electrical, systems etc), masters or PhD , gender
	Number of students attending career fair and how many do get offers	Year, semester, department, gender
	Students obtaining full time job upon graduation	Co-op / intern experience or no experience
	Students who benefited from COC services or attended COC services	Dept, year, semester
	Students continuing courses on co-op / intern	Dept, semester, year
	Employers	
	Number of employers coming to the career fair	Year, semester, department, state, region
	How many employers give job offer at the career fair	Year, Semester, department
	Type of internship / co-op offered	Paid, non-paid, for credit hrs
	Number of employers who return for next career	Semester, year

Strategic planning process was incorporated into the performance dashboard development process. The project team worked with COER staffs to draft mission, vision and value statements

relevant to the business and its organizational chart. The next step involved identifying performance measures, which focus on business performance. Once the performance measures were defined, they were classified into four perspectives including included value creation, stakeholder, and internal process using a Balanced Scorecard approach. Next, strategic objectives and corresponding goals were defined. In this study, to address the strategic objective of enriching the student experience, COER's goal was to expand and increase the quality of the resources, facilities, programs and personnel focused on teaching, learning and the student experience. After these processes are structured, a strategic map was developed that demonstrates the various objectives and their associated goals from different perspectives that influence the business process.

After reviewing the literature and studying COER's challenges, the implementation of a tactical dashboard prototype is proposed to tailor COER's specific performance measures to provide actionable information to internal and external stakeholders and to eventually benefit the university as a whole. A tactical dashboard aims to assist managers in monitoring and tracking performance and progress towards the targets of their functional areas. Furthermore, tactical dashboards give managers deeper insight into the data to identify the root causes of problems and trace the history behind and reason for their occurrence, which helps managers to take corrective actions to improve the situation (Kaplan & Norton, 2004). These business tactics help to align and optimize actual balanced performance with planned performance (White, 2006). The tactical dashboard analyzes business performance over a period of days, weeks or months (White, 2006).

Data were collected from COER legacy database and its custom job database. Data cleansing, which encompasses both data validation and data cleaning, was the most important and time-consuming part of the project. Data cleansing identified inaccurate and incomplete data and then improves its quality by correcting the detected errors through format checks, completeness checks, checks for the use of special characters, and duplicate removal.

Once data were cleaned and initial dashboard functionalities were determined, the data warehouse technical framework using a star schema was developed and implemented using the SAP business warehouse (BW). Queries were than created per COER requirements to publish the dashboard visuals.

Rapid prototyping methodology was adopted to create a portion of the dashboard's solution to COER's challenges in order to demonstrate its functionality and make necessary refinements before the deployment. The project team provided dashboard prototype demonstrations to the COER staffs and selected stakeholders to solicit feedbacks and address concerns on the agreed milestone dates or at least once a month. This methodology proved useful in confirming understandings of COER's requirements and ensuring consistency between the proposed solution and business expectations throughout the entire dashboard development iterations.

Dashboard prototype validation involved checking the data for accuracy and validating it against COER reports. COER staffs conducted a comprehensive and detailed cross verification of the dynamic reports produced by the dashboard prototype to confirm data accuracy. At this step, COER had another the opportunity to use and check the functionalities of the dashboard prototype before the deployment. Modifications were made based on COER feedback in an iterative process that continued until COER approved the prototype's release for production.
After confirmation from COER, the dashboard prototype was published on the official COER's university web site. Once published on the website, all the users, such as students, employers,

and parents, were able to access the new, interactive performance dashboard to analyze the various statistics and reports.

A feedback survey was designed and deployed to identify realized benefits and advantages the dashboard from various COER stakeholders. It also served as a means by which to communicate with stakeholders to learn improvements to the dashboard and additional types of information and dynamic reports users would like to have on the dashboard. The survey instrument was approved by the Institutional Review Board (IRB) to ensure that the survey involving human subjects met the requirement of the U.S. Department of Health and Human Services (HHS). The feedback survey was incorporated into the dashboard prototype and announcements were published in newspaper for both students and employees and sent to COER's employer list, COER's corporate advisory board, Provost and his cabinet, department chairs, presidents of Undergraduate and graduate student councils, president of staff council, and selected parents and alumni.

V. Dashboard Prototype Implementation

This section documents design and key user-centered design principles used in the proposed tactical performance dashboard. The dashboard's functionalities and how its functionalities helps to solve COER challenges and can be used by various COER stakeholders, is described.

5.1 Design for Dashboard Functionalities

The proposed COER performance dashboard prototype intends to help various stakeholders to perform their tasks, such as finding and analyzing department and university statistics, understanding job employment data and career fair statistics, and comparing statistical trends for different job types. Through analysis of peer institutes, COER staff activity reports, stakeholders, and key performance indicators and dimensions, the dashboard's content is divided into three tabs: Major Statistics, Job Statistics, and Recruitment.

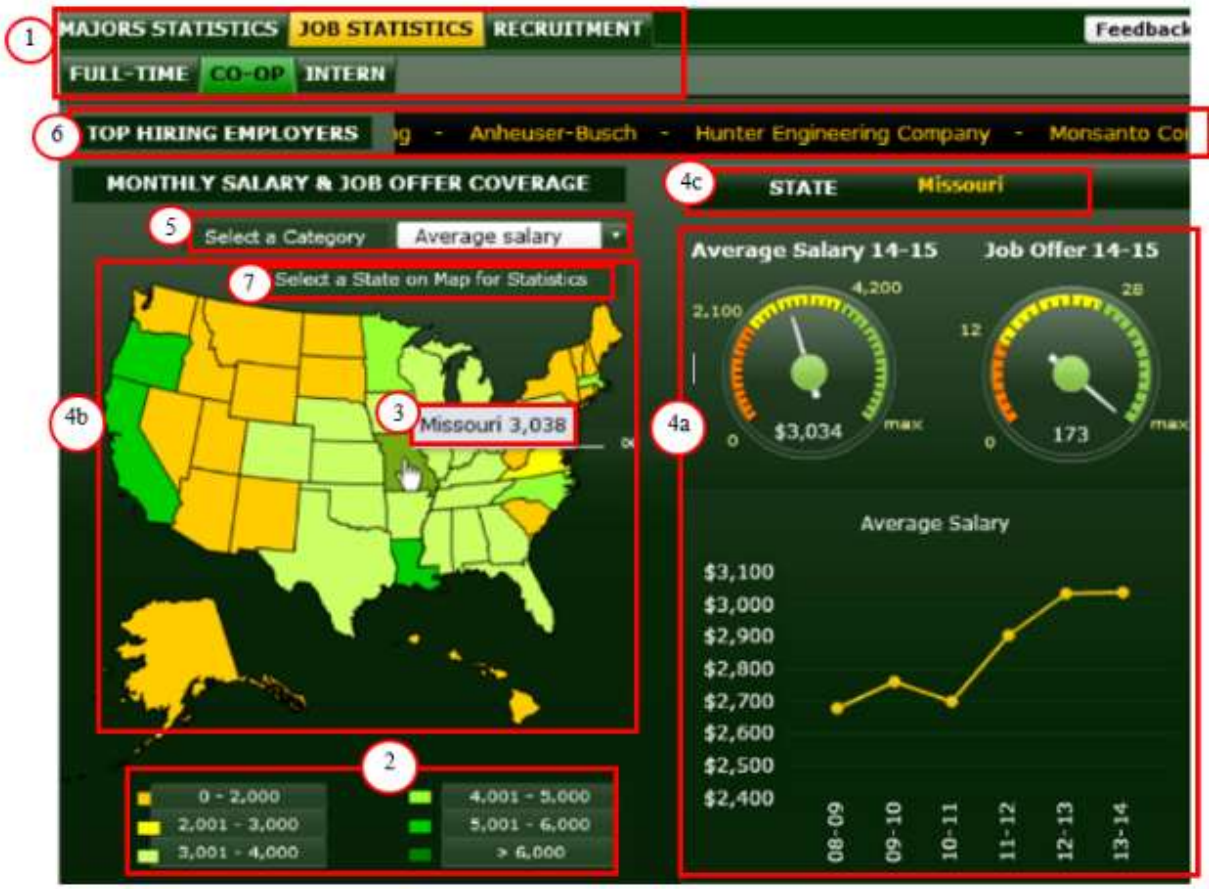
The job statistics tab is used to illustrate Key functionalities. It is deigned to help students to understand the differences that exist between different states' average salaries, which helps them know what to expect in terms of salary when they receive a job offer. This tab also helps COER staffs, faculty, university management, and other stakeholders to understand from which states its students are receiving job offers and that could help them strategize to expand their relationships with employers in other states.

The design of major statistics tab is provided below and is illustrated by Figure 3:

(1) The job statistics are further divided into three tabs according to job type: full time, co-op and intern. The default view is the full-time job statistic. The co-op view is used for illustration, but the format of the data and screen design remains the same for the full-time and internship positions.
(2) The drop-down menu, denoted as 1 in Figure 3, allows the user to select either the average salary or job offer category to display the statistics on the U.S. map, denoted as 2a in Figure 3. The interactive map offers a geographic visualization of the selected category. To help users visualizing the geographic distribution of job offers and average salaries across the country, the color-coding scheme is listed at the bottom of the map, denoted as 3 in Figure 3.
(3) Once a user clicks to select a state on the map, the two dials gauges show the current year's average salary and number of job offers for the selected state on the top of area 2b in Figure 3. The 5-year average salary trend of the selected state is also provided.

(4) The ticker text box shows the current year's top hiring company for co-ops, denoted as 3 in Figure 3.

Figure 3. Job Statistics Screen Design



5.2 Design Principles for intuitive and user-friendly Interface

The benefit of information disseminated depends on the user's sophistication in accessing and comprehending it and on the degree of its sufficiency for making appropriate decisions (Grubb, 2002). Accessibility refers to all users having easy access to information and services, taking into account their different requirements. As performance dashboards are often used by executives and users who are not necessarily technology savvy, it is important for the dashboard to have a user-friendly and intuitive interface. Lichiello and Turnock (2005) indicated that a performance dashboard has a user-friendly interface when it defines and selects the performance measures that are meaningful, relevant and that best allow users to find solutions to their questions. Cowart (2008) indicates that a dashboard is easy to understand because of its bright colors, consistent format, and easy interpretation of complex integrated data, which helps to catch the user's attention. The proposed dashboard prototype utilizes principles learned from the literature to design an intuitive and user-friendly interface as summarized below and illustrated with Figure 3

1. ***Information categorization***: Information is broken down into different tabs, which are organized into a meaningful order and hierarchy, as in examples denoted as 7 in Figure 3.

2. ***Color Coding***: Color coding is used to represent the geographic distribution of job offers and average salaries, making it easier for the user to understand the system, as in the examples denoted as 2 in Figure 3.
3. ***Dynamic information tip***: Placing the cursor over the state gives the statistics for that state, as in the example denoted as 3 in Figure 3.
4. ***Use of common charts and diagrams***: The dashboard is easy to operate because it uses common graph types and gauges, clickable geographic maps, and clearly labeled sections, as in the examples denoted as 4a and 4b in Figure 3.
5. ***Drop-down menus:*** Common drop-down menus are utilized to allow users to select desired a information category or function. For example, a user can select to view average salary or job offer category from a drop-down menu as denoted as 5 in Figure 3.

These interface design features offer users various ways to find information and the ability to scan the dashboard at a glance rather than reading through dense text, which makes it user friendly.

5.3 Design Principles for Learnability

Learnability is an aspect of usability (Nielsen, 2003; Casaló, et. al., 2008) and refers to the ease with which new or occasional users may accomplish certain tasks, including how quickly users are able to understand the components and navigation options and to use them to locate the desired information. That is, learnability refers to the capability of the software to enable the user to learn how to use it and becomes a major concern when designing a software tool.

A dashboard is used to display information for various user groups and each user group has a different set of information requirements, so users must learn how to operate the dashboard in order to find their required information. Kassahun's (2010) indicated that dashboards are easy to learn and easy to operate as they guide different user groups with different sets of data for analysis. The dashboard becomes easier to learn because of its use of charts to compare measures to benchmarking values and its compelling presentation that directs users to the information they are seeking (Stewart & Carpenter-Hubin, 2001). When adopting the performance dashboard, users can develop agility and quickly learn to operate the dashboard to better anticipate and respond to the changing needs of the business (Brudan, 2005). Principles used to design an easy-to-learn dashboard are summarized below.

1. ***Organize the information*** to support its meaning and use: A screen is typically divided into multiple sections and each section displays related and meaningful information for analysis. For example, there are three related information sections on the major statistics screen. The top section displays current year salary by department, the bottom left section displays the five-year salary trend of a user selected department, and the bottom right section displays the five-year university salary trend, denoted as 1, 2, and 3 respectively in Figure 3.
2. ***Use of labels***: Short and self-explanatory labels are provided for various sections, as examples denoted as 7 in Figure 3 respectively.
3. ***Consistent layout design***: The dashboard's format remains consistent throughout all the tabs, making it easy for users to follow the design and to predict the effect of their actions.

Denoted as 3 in Figure 3, the Major Statistics tab and Job Statistics tab have the similar format of displaying Full-time, co-op and intern data. Also within these three sub-categories, the graphical display remains the same.

4. ***Use of instructions***: Clear information is provided where users must select an option to display the information pertaining to that option, denoted as 7 in Figure 3.

VI. Deployment and Assessment

The section is to assess the design aspects and to examine benefits gained by COER after implementing a performance dashboard. The data were collected from the target users through the feedback survey described in the solution approach section. The responses were analyzed to validate designs and the realized benefits of using performance dashboards in higher education systems.

Of eighty-nine responses received in the first two weeks of dashboard deployment, thirty-one were females, forty-one were males, and two were "do not wish to disclose. Seventy-six percent of respondents used the dashboard prototype for the first time, 20% of respondents used the dashboard prototype two to five times, and 4% of respondents used the dashboard prototype six to ten times. About 91% of respondents indicated that they have spent less than an hour, 6% of respondents spent between one and two hours, and 3% of respondents spent between two and five hours in using the dashboard prototype at the time of taking survey.

Researchers have shown that "perceived ease of use" influences "perceived usefulness" and adoption and actual usage of a software system ((Davis, 1989; Davis, et. al., 1989; Venkatesh and Davis, 2000; Lea and Nah, 2013). Therefore, the proposed dashboard prototype is analyzed for the "perceived ease of use" dimension using the following survey statements and hypotheses:

1. The graphs, charts and maps provided by the new dashboard system are easy to understand
2. The new dashboard provides a user-friendly interface
3. I can learn to operate the new dashboard system easily
4. I can easily find university outcome data using the new dashboard system
5. I can easily find services provided by Career Opportunities & Employer Relations (COER) using the new dashboard system

For each survey statement, scale 1 represents strongly agree, 2 represents agree, 3 represents neutral, 4 represents disagree, and 5 represents strongly disagree. As shown in Figures 4, results indicated strong positive for all five "ease of use" dimensions.

In this study, effectiveness refers to user satisfaction in terms of ease of use, usefulness of results, and meeting user requirements and is measured by the degree to which the system enables a user to achieve his or her goal through performing required tasks. Therefore, following survey statements were developed to examine typical tasks performed by staff and stakeholders of a career services center:

1. I can clearly identify my department outcome data using the new dashboard system
2. As an employee at the XX (the case university name), I can use the new dashboard system to obtain statistics, charts and reports that are needed for my department and/or students
3. The new dashboard system could help me to review and compare recruitment

4. The new dashboard system could help me to review job status (full time, co-op, intern) statistics
5. The new dashboard system could help me to obtain career fair statistics
6. The new dashboard system could help me to understand job employment data (number of jobs, salary, etc.) with respect to geographical location
7. The new dashboard system could help me to analyze department recruitment statistics

For each survey statement, scale 1 represents strongly agree, 2 represents agree, 3 represents neutral, 4 represents disagree, and 5 represents strongly disagree. As shown in Figures 5, all dashboard functionality dimensions were positively received by the survey respondents.

Researchers have shown that “perceived ease of use” influences “perceived usefulness” and adoption and actual usage of a software system ((Davis, 1989; Davis, et. al., 1989; Venkatesh and Davis, 2000; Lea and Nah, 2013). Therefore, the proposed dashboard prototype is assessed for the “perceived usefulness” dimension using the following survey statements:

1. Usefulness in interpreting data and results
2. Usefulness in visualizing data
3. Usefulness in assisting the university with publicity
4. Usefulness in analyzing trends
5. Creating additional charts, reports and statistics
6. Usefulness in helping the university with continuous improvement
7. Usefulness in providing timely information
8. Usefulness in providing different details for different users for different purposes

The same 5-point Likert scale was used with a 1 represents very useless and a 5 represents very useful. As shown in Figure6, respondents show strong positive support for the usefulness of dashboard in all nine dimensions.

Figure 4. Ease of Use Survey Response

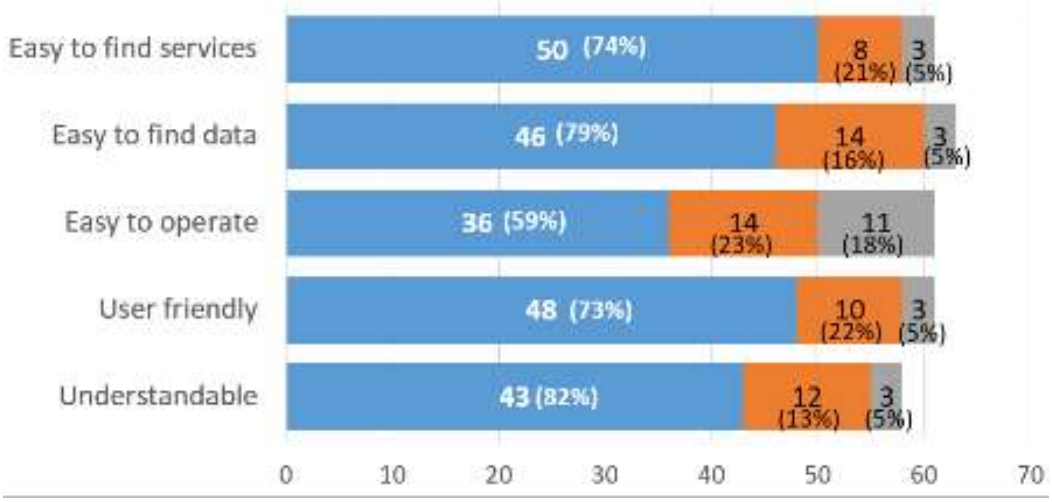


Figure 5. Task Functions Survey Response

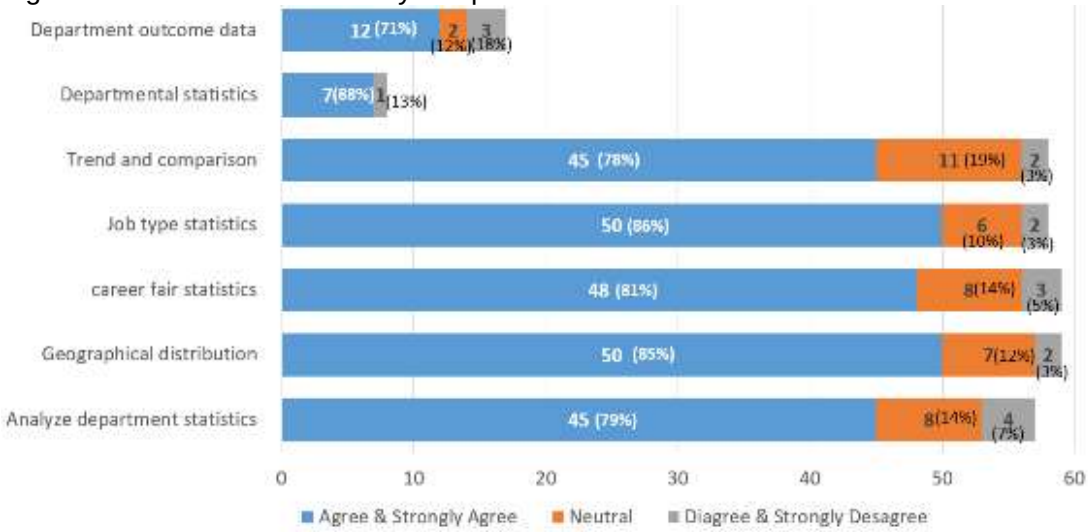
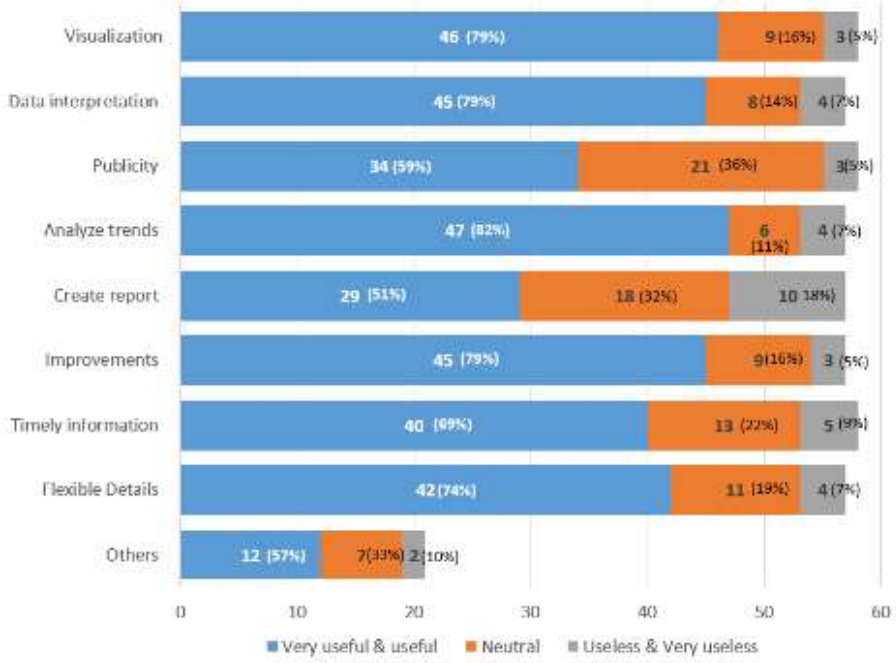


Figure 6. Survey Results on Perceived Usefulness



VII. Research Contributions, Implications, Limitations, and Future Research Directions

The objective of this research was to investigate if performance dashboards can be applied to overcome challenges faced by institutions of higher education aiming to measure and manage performance. The dashboard was implemented to support the career service center COER to communicating its recruitment statistics and services at the case university. The assessment results indicated the proposed performance dashboard provides a useful, common platform for communicating with various stakeholders. It provides an interactive platform that users can use to analyze and to facilitate decision-making. The dashboard gives university executives a higher-level picture of business performance and previous statistical trends that can be helpful for predictive analyses.

The results of this research revealed that implementing a performance dashboard offered significant improvements for COER and its stakeholders, allowing users requirements to be addressed through self-service on a timely manner. The proposed interactive dashboard addressed challenges faced by institutions of higher education, such as lack of access to information, stakeholders failing to take advantage of what is being offered, and students' anxiety about not being able to find a job and strategic planning. The dashboard prototype feaures a user-friendly interface with which to access the system easily, allow new or occasional users to adjust to their operation easily and quickly and help users to perform tasks effectively. The results from a feedback survey validated dashboard functionalities. The assessment results further support the fact that dashboards help in presenting the right information to the right users at the right time (Lea, 2011).

One of limitations faced the study was a concern for security and privacy. The career service center COER at the case university did not want to create reports and statistics because of the confidential data housed in the database. Respecting this concern has limited the development of some functionalities and reports that could have been embedded in the dashboard for better performance improvements. The second limitation was time constraints. The survey has not sufficiently reached some stakeholders, such as parents and department chairs, so analyses could not be performed from their perspective. Furthermore, the survey is still on-going and that limited data points for a more in-depth analysis.

Future research includes adopting Kaplan and Norton's Balanced Scorecard framework (1992, 1996) at COER for performance management. The novelty of balanced scorecards in higher education systems provides a rich opportunity to utilize this tool in a wide range of applications. Furthermore, a Balanced Scorecard based dashboard system allows additional strategic planning and alignment of strategies (Lea, et. al., 2018).

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DECISION SCIENCES INSTITUTE

Phubbing: Towards a Theory of Techno-Snubbing in the context of non-western culture—Part 1

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ABSTRACT

Phubbing is pervasive across cultural entities, but there is little insight of phubbing behavior. There is an urgent need for understandings into phubbing culture in cultural contexts. This study sought answer to three questions: what social factors account for phubbing? What cognitive factors motivates phubbing? And, what cultural factors discourage phubbing? A grounded theory methodology approach was adopted for the study. We used Grounded Theory because it allows for empirical theory-creation. Findings indicated three motives for phubbing in the context of nonwestern societies: social, cognitive, and cultural.

KEYWORDS: Phubbing, Smartphone addiction, Techno-Snubbing, Phubbing Theory, Phubbing Non-Western Context

INTRODUCTION

With increasing diffusion of smartphone and handheld devices and the numbers of people adopting, and using smartphones globally, the problem of phubbing is becoming more pervasive (Qian, Z. 2014; Relling, B. A. 2014; and Pheeraphuttharangkoon, S. 2015). Studies have been undertaken with a view to having a better understanding on phubbing culture. Although, extant studies are beginning to provide insights on phubbing phenomena, such studies are limited. The scarcity of studies on phubbing culture is even more limited in the context of nonwestern societies.(Simon, L. 2017; Dilonardo, M. J. 2018). No systematic account exists that explains what phubbing is, how it is practice, why it is practice and the perceptions of people in the context of non-western culture. (Davey, S. 2018; Chotpitayasunondh and Douglas, K. M. 2016). The objective of this paper is to report the result of empirical inquiry that attempt to offer a theoretical model of phubbing in the context of developing countries, case study of Kaduna, Nigeria. This study adopted grounded theory methodology to explore phubbing culture which

refers to the act of snubbing someone during conversation by focusing on smartphone. Grounded theory, was advanced by Glaser and Strauss (1967) has provided us with a frame for advancing a theory on phubbing behavior. This paper is the first part in a series of 4 part articles reporting findings on the complex social and cultural determinants of phubbing and smartphone addiction in the context of non-western societies.

LITERATURE REVIEW

Smart Phone

Over the year's smartphones have become indispensable in modern society. (Barnes, E (2017; Muhammad, S. and Soomro, T. R. 2013). Smartphones has the advantage of being portable and is used for chatting, internet browsing, watching movies, and texting (Fortunati, 2002). Smartphone has become cheap and affordable (Acharya et al. 2013; Leung 2008). Smartphone is changing lives in many societies including Africa where it is used in health care systems to improve health and wellbeing (Apple 2013; Annika 2016; Chen and Katz, 2009). Smartphones have been shown to promote deeper intimacy between family and friends (Campbell and Ling, 2009). Closely related to the use of smartphones for improved wellbeing is the challenges brought about by the improved diffusion, adoption, and use of smartphones. For instance, smartphone related mishaps are common as a result of text driving (Harwood et al. 2014).

Smartphone: The Challenge of Phubbing

Phubbing is a major challenge brought about by the improved diffusion, adoption, and use of smartphone. Phubbing refers to the act of snubbing someone by using smartphone during conversation (Angeluci, 2016). The term phubbing is a combination of the words "phone" and "snubbing", and describes the act of snubbing directly in one's company (Haigh, 2012). This term was originally coined to represent a growing problem of smartphone misuse in social situations (Pathak, 2013). In a social interaction, a "phubber" can be defined as a person who is engage in the practice of phubbing his or her companion(s), and a "phubbee" is a person who is a recipient of phubbing behavior. Phubbing has been shown to undermine relational closeness (Przybylski and Weinstein, 2012; Misra et al., 2014). Smartphones is considered as a medium that disconnects conversational partners since one might feel left out as the other person is intensively absorbed with his or her smartphone. Phubbing result in distraction during conversation and it usually provoke negative feelings (Hart et al., 2004). Studies indicate that smartphone use can lead to addiction as owners of smartphone experience urge to peep at smartphone technology (Harwood et al. 2014). Studies found that smartphone owners peep through smartphones over thirty times in a single day (Lee et al. 2014). The increasing urge to peep through smartphone result in phubbing. The consequence is that individuals may be near to each other physically, but they are more focused on their smart devices (Stop Phubbing 2014).

METHODS

This study adopted Grounded Theory methodology to explore phubbing culture which refers to the act of snubbing somebody in a communal setting by focusing on smartphone. Grounded Theory (GT), was advanced by Glaser and Strauss (1967) has provided us with a frame for advancing a theory on phubbing. In line with the GT methodology, this study is framed within qualitative research paradigm. Qualitative research methodology refers to the method of inquiry employed to gather an in depth understanding of human behavior and the reason that governs the behavior (Musa 2013). Qualitative research methods are known to be best suited for studies

whose purpose is to learn from participants about their experiences, opinion and perception within their social and cultural context (David 2012). The purpose of the study is to gain deeper understanding about the social, cognitive and cultural motives of phubbing and the experiences, perceptions or feeling about the people who engaged in phubbing when or during conversation. Purposive sampling is suited for this study, as it offers a frame for selecting participants with phubbing experiences. Participants from this study were selected using criterion sampling. Therefore, to be included as a respondents for this study, the participants most meet the following criteria: Must be a student, must be between the ages of 17-25 years, must own a smartphone for at least three years, and must have internet access at least 5 days in a week. Based on the criteria listed 15 respondents who met the study criteria were interviewed for the study.

Data Collection

Data collection is the process that enables the researcher to systematically gather relevant answers to research questions (Milanzi, 2009). The data required for achieving the objectives of this study were collected using in-depth interview. Thus, the interview was designed for collecting data on phubbing from the social and cultural setting. Phubbing: Towards a Theory of Techno-Snubbing. The interview session began with the explanation about the purpose and objectives of the research and also solicited participants' permission to voluntarily participate in the interview. The researchers followed research protocol by informing participants that their participation in the research is voluntary and were given informed written consent indicating their consent to partake in the study. Permission were asked for responses to be recorded and participants were informed of the anonymity and confidentiality of their responses. Participants were also informed of their right to withdraw from the study at any time during the interview process. Each participant wasprovided with an opportunity to ask question before the commencement of the interview.

The interview took place in five locations within the study setting. At the onset of the interview, the researchers conceptualized phubbing to each of the respondent. A smartphone was then turned on and the in-depth individual interview commenced. Each interview lasted for up to 40 minutes. The interviews were conducted between April 2018 and May 2018 by the principal investigator and co-investigators and 5 research assistance. All the interviewers were trained and experienced interviewers.

During the interviews the researchers used probing technique to solicit for in-depth information and obtain situational data to build on their responses. By the time 15 participants were interviewed, the data was saturated. Marshal (2006) explains data saturation as the point when there are no new categories, themes, or explanation is emerging. To get responses in respect to research question 1 (what are the social motives for phubbing?) The researchers asked respondents the following sub-questions: Share with me your feelings when you phubbed someone? Describes factors that encourage you to phub? Share with me your perceptions on people when you see them phubbing? Share with me any existing rule of behavior on phubbing? Similarly, to get response in respect to research question 2 ((what are the cognitive motives for phubbing?). The following sub-question was asked: Share with me occasions in which you use smartphones to get clarification during discussion with someone? In the same vein, to get response in respect to research question 3 (what cultural factors discourage phubbing?) the following sub-question was asked: share with me circumstances that will prevent you from phubbing?

Data Analysis

The data received from respondents were audio taped and then transcribed for analysis. Data from this study were analyzed using inductive analytical process (Cresswell, 2013; Graneheim and Lundman, 2004). Inductive approach is a process of condensing raw textual data into a brief summary format and establishing clear links between the research objectives and the summary findings (themes) that are derived from the raw interview data. The process of inductive analysis followed three step process of open coding, axial coding, and selective coding. These three stps process were expanded into series of steps as suggested by Graneheim and Lundman (2004) and adopted in this study.

The steps are as follows.

1. Transcribe interview verbatim
2. Read the transcribed interviews to get an overall insight of its content: To accomplish this stage the investigators together with research assistants read and re-read interview transcripts and underlined words phrases that best answer the three research questions (open codes).
3. Establish meaning units and initial codes. This was achieved collapsing open codes into categories according to similarities and differences.
4. Classifying the initial codes inductively into comprehensive emergent categories: This was done by condensing codes into themes.

Interview Analysis

Data in the form of phrases and sentences about phubbing were collected from 15 respondents in five locations within the study setting representing a diversity of voices on phubbing. The selected respondents provided multiple views and insights into the complex nature of phubbing culture. Each of the 15 interviews was transcribed read, examined, and re-examined using an analytic inductive process described by Graneheim and Lundman (2004); as well as Creswell (2013), wherein the “researcher works back and forth between the themes and the database until the researcher has established a comprehensive set of themes” (p. 186). While reading the transcribed narratives, the principal researcher, co-researchers, and research assistance highlighted sentences, phrases, and passages that dealt with phubbing culture. All the 15 interview narratives explaining phubbing culture were highlighted and recorded in Microsoft Excell spreed sheet. An iterative analysis method informed by Krathwohl (1998) and Graneheim and Lundman (2004) employed a series of steps for coding the highlighted narratives. Following these steps, the principal researcher, with the help of co-researchers, and research assistants read through the data looking for variances and similarities in the narratives.

Rigor

Three steps processes helped ensure the credibility of the analysis. First, each interview was facilitated by two persons. With the consent of the participant each interview was recorded and notes were taken. The interview notes were compared with the transcribed audio recording. This procedure has helped in establishing data credibility. Second, a triple coding was done in which the researchers work in three teams during the analysis of the transcribed data. The purpose is to check for consistency during the coding process. Each of the three teams coded the transcribed interviews on three separate occasions (triple - coding) and drafted an initial coding frame. Both teams (“peer debriefers”) identified key themes. The three coding teams made separate memos and converge to discuss the developing coding frame. Third, interview continued until emerging theory adequately reflect the data and that theoretical saturation was achieved after the researchers conducted fifteen interviews.All this is to ensure Ultimately,

credibility is about creating a coherent narrative that stands up to challenges and brings fresh ideas. Mcniff, K. 2017 and Korstjens, I & Moser, A. (2018).

RESULTS

Findings for this study are provided in this section, and are presented by research questions. The 3 research question are: What social factors account for phubbing? What cognitive factors motivates phubbing? And, what cultural factors discourage phubbing?

Descriptions of Emergent Categories

Research Question One: What social factors account for phubbing behavior?
In response to this question seven categories emerged depicting social reasons for phubbing in the study setting. These are: (1) Phubbing is normal acceptable behavior (2) I feel bad to see people phubbing (3) I phubbed when I am bored and not interested in discussion (4) I phubbed to check for important massage (5) I phubbed because I am addicted to smartphone (6) Those who phubbed are uncivilized (7) No rule exist on phubbing behavior. Each of the seven category is explain below:
Phubbing isnormal acceptable behavior. Phubbing is normal acceptable behavior is a category depicting phubbing practices as common and normal in the context of the study setting. Beck, (2016). A participant observed that there is nothing wrong in phubbing, “I feel normal when someone is phubbing during discussion”. In the same vein, another respondent stressed that “I feel comfortable when I see someone phubbing”
I feel bad seeing people phubbing. Contrary to the explanation by respondents that they see phubbing as normal, this category comprises explanations by participants explaining that even thou they considered phubbing as normal they nonetheless hate to see others engaged in phubbing. A participant noted, “I don’t like it. I hate to see people chatting when they are conversing with others, you may miss an important point”.
I phubbed when I am bored and not interested in conversation. This category suggests that participants engaged in phubbing when they are either bored or when they are not interested in an on-going conversation. This category explains the factors that let people to practice phubbing, as revealed by these respondents: “I practice phubbing usually when am bored in a conversation” Furthermore, another respondent expressed that, “only when am not interested in a discussion that is when I practice phubbing”. Similarly, a respondent observed that I engage in phubbing “when I lose interest in a discussion” Another respondent stated that “I use to practice phubbing when the discussion is not important” similarly, another respondent revealed that, “I phubbed when conversation is boring or annoying”
I phubbed to check for important massage. This category depicts responses of respondents as to the reasons why they engaged in phubbing practices. They noted that phubbing is inevitable on instances in which a person is expecting important message. A respondent stressed, I phubbed “to check an important email”. Another respondent stated that, “I do phubbing when checking important massage on WhatsApp”. Others stated, “I phubbed when I am expecting massages or when I am expecting a parcel from online shopping”. This category explains the desire to read important messages as a reason for engaging in pubbing behavior among respondents. A respondent stressed “I phubbed in order to confirm or to check credit alert transfer into my account”

I phubbed because I am addicted to smartphone to Interact with loved ones: Accounts of being addicted to smartphones are indicated as reasons for engaging in phubbing practices. Many respondents indicated that they are addicted to smartphone. A respondent noted that he is so much used to being with smartphone and cannot help to peep through the phone during conversations to interact with loved ones. This category also explained instances in which people practiced phubbing in their desire to keep in touch with loved ones. A respondent observed "I chat with my kids when am in the lecture hall, especially if the lecture is boring" Another respondent stated that: "I practice phubbing because am addicted to it

Those that practice phubbing are considered as uncivilized. This category comprises narratives revealing participants' perceptions on other people when they see them phubbing, as described by these respondents: "when I see some people phubbing I use to say they are villagers…not civilized". Another participant stated that: "it is funny when I see people phubbing during discussion" "it also annoying when I see someone phubbing in public"

No existing rule on Phubbing. This category contains participant's response on whether there is existing law on phubbing in their society. These are some of the responses: "I don't think there is any law regarding phubbing". "There is no any existing rule for phubbing". "I am not aware of any law on phubbing"

Table 1: Social Motives for phubbing behavior

Research Questions	Emergent categories
What factors account for social motives for phubbing?	(1) Phubbing is normal acceptable behavior (2) I feel bad to see people phubbing (3) I phubbed when I am bored and not interested in discussion (4) I phubbed to check for important massage (5) I phubbed because I am addicted to smartphone (6) Those who phubbed are uncivilized (7) No rule exists on phubbing behavior.

Research Question 2: What cognitive factors account for phubbing behavior?

This question sought to determine the cognitive motives for phubbing behavior. Analysis of interview data revealed one recurring topic as classification category depicting cognitive motive for phubbing in the study setting (Table 2: Cognitive motives for phubbing). This is explained below:

People engaged in phubbing during classes or when seeking for specific information online: This category comprises narrations revealing instances in which people are engaged in phubbing to get clarifications or further information using their smartphones. One respondent stated that "I always use my smartphone in the lecture room or when I am receiving lectures" Another respondent stated that, "I use it in a lecture hall when I want to search for a specific information" or "during scholarly argumentation in the lecture hall with my friends".

Table 2: Cognitive Motive for Phubbing	
Research Question 2	Emergent categories
What are the cognitive motives for phubbing?	When receiving lectures or when searching for specific information during conversation

Research Question 3: What cultural factors account for phubbing behavior?
In regard to the third research question 2 recurring topics were identified as classification category (Table 3: cultural factors that discourage phubbing) depicting cultural factors that discourage phubbing in the study setting. This are explained.

I do not phub when discussing with my superior. This category provides explanations from participants' about the cultural motives for phubbing. It explains the circumstances preventing people from phubbing. A respondent observed, "I do not phub if I'm discussing with my superiors". In the same another respondent states, "If I'm talking with my boss at work I don't phub"

I do not phub when interacting with parent and elders. This category also contains narratives about the situations that prevent people from phubbing as describes from the following respondents: "If I'm talking with my parents or an elderly person I found it difficult to use my smartphone." Similarly, another respondent notes, "When I am engaged in serious discussion especially with parent or when I am conversing with the aged I do not use smartphone"

Table 3: Cultural factors discouraging phubbing	
Research Question 3	Emergent categories
What are the cultural factors discouraging phubbing?	(1) I do not phub when discussing with my superior (2) When receiving lectures or when searching for specific information

TOWARDS A THEORY OF PHUBBING BEHAVIOR: THEORETICAL PREPOSITIONS AND DISCUSSION

Arising from evidence collected from this study seven theoretical prepositions on techno-snubbing (phubbing) behavior (TofPB) is presented. The seven theoretical prepositions are as presented below together with their corresponding expositions.

Preposition 1:Those who considered phubbing as pervasive are likely to practice phubbing. Individuals are socially motivated to phubbed when they consider phubbing as common. This denote that there is a strong desire by individuals to phubbed when they discovered that peers, relations, acquaintances, family members also practice phubbing. Under this circumstances the individual believes that since everyone else in the community considered phubbing as ubiquitous it is fine for them to do so. In this circumstances individuals believed that taking a moment to peep through one's smartphone during conversation is largely conceived as acceptable.

Preposition 2: Individuals who consider smartphones as conjoined partner are more likely to practice phubbing. Individuals are likely to phubbed if they consider smartphones as a companion that should be carried all the time, all day, and every day. Individuals who believe smartphones as inseparable companions are social and therefore maintaining timely connections with online friends is crucial and indispensable.

Preposition 3: Individuals who consider smartphones as learning device are likely to engage in phubbing. Individuals are likely to phubbed if they consider smartphones as a learning gizmo. They do so by checking emails and short service massages, and by chatting. The main objective of phubbing is primarily cognitive with the intention to seek information considered critical. For this category of individuals, peeping through one's smartphone during communicative action is purely cognitive and done on impulse.
Preposition 4: When individuals are bored/uninterested during conversations they are likely to engage in phubbing behavior. Individuals are likely to phubbed if they are engaged in discussions that is boring and/or uninterested. In this circumstances, individuals are engaged in phubbing principally seeking for exciting information as a means to escape a conversation that is considered bored. For this category of individuals, peeping through one's smartphone during communicative action is deliberate and not necessarily on impulse.
Preposition 5: Individuals who practiced phubbing and considered phubbing as pervasive considered phubbing as uncivilized and therefore do not like to be phubbed. Those who practice phubbing disliked to be phubbed by others, despite the fact that they practice phubbing and they consider phubbing as ubiquitous.
Preposition 6: Individuals are unlikely to engage in phubbing practices when they are conversing with parents, elders, and respected personalities. Those who phubbed are unlikely to do so while they are with parents, elders, and persons they accorded much respect. In this situation smartphone addiction, expecting critical/vital information, or being bored during conversation has no place, because respect for elders, personalities, and parents overshadows cognitive and social benefits of phubbing.
Preposition 7: Those who practice phubbing are not aware of formal or informal rule on phubbing. There is lack of common rule, norms, and value systems in regard to phubbing.

DISCUSSION AND CONCLUSIONS

The seven theoretical propositions of the Theory of Phubbing Behavior (TofPB) discussed above highlights the social, cognitive, and cultural dynamics of phubbing in the contexts of everyday life. However, the 7 prepositions of TofPB should not be understood as an effort to generate a wrong contrast between phubbing in the context of nonwestern culture and western societies because phubbing behavior across culture may be identical in some instances. Generally defined, the proposed theory of TofPB refers to the tendency of individuals to peek at smartphones and other handheld devices during conversation. Consulting smartphones and other handheld devices occur as a result of conversation being bored or uninterested, or the desire to access information that is considered critical. Phubbing also occurs out of the belief that everyone else does it.
Phubbing is associated with differing situations and contexts. For example, in the classroom during learning, with peers during conversations, or with significant others and loved ones. Phubbing behavior is shaped by factors such as the person(s) being phubbed, length of conversation, personality of conversation partners, and the topic of discourse. However, these factors are not solitary to explain phubbing culture. The prepositions of the TofPB attempt to offer broad principles for phubbing culture why it is done, and why it is done in the context of non-western setting.

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Possible Impact of Adopting Information System Management in the States of Under Developing Country of Africa

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ABSTRACT

The local government of Ifako Ijaiye in Lagos state of Nigeria was considered to be a candidate for automation that will implement an information management system. In automating their processes the voluminous records stored in the numerous filing cabinets within its offices shall need to be digitized and made available by using computer based tools. However, during the course of the study several realizations should have been taken into consideration first. It was determined that the area where the local government of Ifako Ijaiye is located does not have the infrastructure needed to successfully implement an information management system. It was also determined that the employees of the local government of Ifako Ijaiye do not have sufficient computer literacy or have any computer training that is at a level required for the successful implementation of an information management system. The survey that was given to the employees of the local government of Ifako Ijaiye revealed the desire of the employees for a better system that would allow them to provide quality customer service to the clients of the local government office. Taking into consideration these factors, an analysis of the deficiency as enunciated by Mr. Dapo Okeniran have been studied. Possible solutions and strategies have also been studied to resolve the issues presented that impede or hinder not only the implementation of an information management system but also the development of Ifako Ijaiye in general.

KEYWORDS. IS Management, Technology Adoption, Under Developing Countries

INTRODUCTION

The the depth and breadth of the proposed Information System Management that will be implemented in Ifako Ijaiye as a representative local government within in Lagos State. An Information System Management has several different components and each component has their own unique impact to the different sectors of the organization where it will be rolled out (Haag & Cummings, 2009). From hardware to the different modules of the sys-tem that will be installed, different reactions emanating from various stakeholders is worthy of an investigation. The same goes with the department that will be tasked to manage the information system's infrastructure.

To illustrate: an Information System Management would include a Process Flow Management System that will automate and track each of the transactions of the individual processes of Ifako Ijaiye's local government's operation. An example is the business permit processing which would include tax mapping of the business, financial assessment and economic impact assessment of the business. Another local government unit pro-cess is the request and release of funds for local project. These processes are actually the ones that generate most if not all of the documents stored in the cabinet of the local government.

An information system management system shall also include the digitization of the documents generated over the years from the various local government units operations. And to be truly paperless, the ISM in fact includes an email system that would enable the various departments of the local government units to communicate with each other. The three systems is a start that will make the operation of the local government of Ifako Ijaiye truly paperless. Further along, to provide Ifako Ijaiye with a good decision support sys-tem an Enterprise Resource Management system with a financial system module capable of handling government accounting can also be installed and used to manage its finances for a more transparent operation.

The impact to the organization comes in several different ways. The psychological impact pertains to the effects on the confidence, motivation and the dynamics or the relationship of each personnel in the organization with each other (Evans & Yen, 2005). Efficiency impacts the process flow itself and the performance of the organization including its service level. Cost impacts the operating expenses related in the maintenance of the Information System Management. It should be noted that the different levels of the organization are also affected at different levels. To illustrate: City or municipal officials are affected differently from that of the ordinary local government employee. The fear of losing a job due to the automation process or the fear of being replaced by a computer is a com-mon fear associated with computerization.

Consequential impact also considered as over-all impact to the organization includes an increase or decrease in the collection of taxes, provisioning of basic services to a wider or narrower constituency likewise deserves attention and investigation. These impacts are emanating from the perception of the clients of the organization. The different permutations and combinations of the above mentioned impacts also affect each level of the organization. The impact is considered myriad because of the different stake and vested interest each level has in the implementation of the Information System Management. The implementation process in itself is categorized as pre-implementation, implementation and post implementation and each category has its own impacts on the organization (Arwidmark & Nystrom, 2010). The process of implementing the information system management also transform the perspective of each employee within the organization thus the dynamics and the relationships of each of the permutation changes above shall also change.

Tallon and Kraemer (2003) in a similar study investigated the relationship between strategic alignment and the benefits there of. An analysis was carried out on sur-vey data from over sixty (60) companies and the study revealed the existence of a significant link between strategic alignment and the benefits from IT irrespective of the company's strategic orientation or the focus of their IT units. The authors also noted that despite the strive for strategic alignment for IT business value, executives have been cautioned to enforce this principle with care as it may lock the organization into inflexibility and will have difficulties in reacting to environmental issues.

This paper shall study the impact of implementing an information system in Ifako Ijaiye particularly the impact to the employees and the local government's clients. By projecting the effects of an automation system to the operation of the local government this paper shall be able to determine the added efficiency that will be achieved by the automated system. Taking into considerations the requirements of having an information system installed, its maintenance and operation also impact the organization.

The adoption and implementation of an Information System will digitize the documents currently stored in the numerous filing cabinets. The system hopefully will lower the turn-around time in the retrieval of pertinent records essential in the operation of the local government departments. Although there will be several technical professional who will be hired to administer and manage the system from an IT perspective. The system will actually be used by the employees themselves, thus retooling the current regular employees is an essential part of the project.

However, the ultimate aim of the Information System is to aid the local government to manage its internal processes and provide all stakeholders (customers) with an improved efficient service. This would translate to the installation of a process flow system that will keep track of all transactions. The changes that will be triggered by the information sys-tem are in the area of customer satisfaction that would include the businesses and the other different department of the government. With this parameter the impact of the proposed changes amongst the employees or to the organization itself shall be assessed and a survey shall be used to determine the impact to the employees. Face to face interviews with questionnaires shall also be used to validate the results.

An assessment of the skill set of the employees will be conducted with the use of surveys. The surveys will ascertain the resiliency of the employees to change, their current ability to accept change and the level of readiness of the employees to change. The sur-vey will be conducted on site. This project will address three areas of concern in implementing an Information Management System. The first area of concern shall be the infrastructure needed in order for an information management system shall prosper. The second area of concern is the actual implementation strategy that will be adopted including the possible systems that could be implemented that will form part-and-parcel of the Information Management Sys-tem Infrastructure (Vengurlekar, Vallath, & Long, 2007). The third and last area of concern is the human factor that will consist of the acceptability and resiliency of the prospective users to change and the new technology. These three areas are the drivers of information management system implementation and without there will be failure in the implementation.

REVIEW OF LITERATURE

Lagos is Nigeria's financial, commercial and industrial centre (Lagos State Government, 2011) boasting of over 2,000 manufacturing industries, more than 200 financial institu-tions (Banks, Insurance companies etc) and the nation's stock exchange, the Nigeria Stock Exchange. The nation's monetary authority, the Securities and Exchange Commis-sion and the Central Bank of Nigeria (CBN) is in Lagos State. The State alone holds 60% of the Federation's total industrial investments including foreign trade while attracting 65% of Nigeria's commercial activities. It equally accounts for more than 40% of all labour tax-es. Various international companies have offices in Lagos State that would include Unile-ver, John Holts, BEWAC/VYB, Leventis, Churchgate, Chevron, Shell and ExxonMobil.

Nigeria particularly Lagos State is in a stage of its economic development that automating the operation of its Local Government would tremendously help its turnaround time in providing local government services to multi-national companies wanting to invest in the area and benefit Lagos State as a whole. However, an in-depth study of the factors that affect automation should be considered since it is dependent on several factors such as the organization's culture, business environment, technology and the type of service (David Skyrme Associatioes, 1999). It is also suggested that in implementing information technology not only should the organization itself desiring to be automated should be examined but rather holistic views should be adopted to determine the organization's inter and intra communication to determine its overall impact (Francalanci, 2010).

It should be noted however, that automation is not a matter of providing a number of programs and a number of computers in the department (Galup, 2009). The automation should start with the examination of all the organization's processes since automation is not only automating the processes for the sake of automating the process (Laudon & Traver, 2009). The automation should also mean improving the processes to make the job of the process owners not only easier but also efficient (Heizer & Render, 2009). The concept of the automation is to ensure that all aspect of the organization is anylzed including its resiliency (Oerlemans, 2005).

In order for the Ifako Ijaiye local government to compete with the rest of its neighbouring local governments in Lagos State, it is imperative that it modernises its operations to en-sure that potential investors will not be discouraged by the slow processing of transac-tions. Nonetheless, before any computerization is commenced, an in-depth study of its feasibility and viability should first be conducted.

Foremost, among the requirements of automation is the infrastructure where the hard-ware that will host the software shall reside. Infrastructures such as clean and reliable power source is an important factor to ensure that the equipment that support the infor-mation management system will not be subjected to adverse condition that will have an impact on its performance. The sensitivity of the equipment cannot be underscored and the energy that provides the power to make the system work at its optimum should be at the very least reliable.

Another factor to consider is a reliable telecommunication infrastructure that will enable the system to communicate to the satellite offices within the local government of Ifako Ijaiye. Most if not all multi-national companies communicate through the internet and not being at par with the technology of these companies would make any office in Ifako Ijaiye isolated. Support for the hardware and more importantly, the software component should also be considered and the presence of the vendors will make the implementation of an information management system feasible.

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DECISION SCIENCES INSTITUTE
Preventive Maintenance Planning Using Group Technology

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ABSTRACT

Preventive Maintenance plays a critical role in any manufacturing environment to avoid any possible machine breakdowns which can lead to serious interruptions in the production and customer dissatisfaction. This research explores the use of similarity coefficient method in Group Technology that considers machines reliability to form virtual machine cells.

KEYWORDS: Maintenance Planning, Group Technology

INTRODUCTION

The competitiveness power of any industry is affected directly or indirectly by the effectiveness of the maintenance strategy they use (Almomani *et al*., 2012). Preventive maintenance is necessary in production since it helps to reinforce machine efficiency and extend the useful life of a system. All types of complex systems, ranging from manufacturing machines to computer network systems need to have prescribed maintenance schedules. A good preventive maintenance program can prevent equipment failures by sensing an imminent failure and fixing the equipment before it causes any damage (Kister and Hawkins, 2006). With the increased use of Flexible Manufacturing and Just-In-Time systems in today's manufacturing, preventive maintenance has become critical issue in the manufacturing environment to avoid any possible machine breakdowns in the production lines or manufacturing cells that can lead to delays and interruptions in the production which will also cause a dramatic increase in the cost and customer dissatisfaction. Preventive maintenance activities generally consist of inspection, cleaning, lubrication, adjustment, alignment, and/or even replacement of components (Moghaddam, 2015).

LITERATURE REVIEW

Several multi-criteria decision-making approaches have been developed in the pursuit of an optimum maintenance strategy, including analytical hierarchy process (AHP) and Technique for Order Preference by Similarity to Ideal Situation (TOPSIS; Sharma *et al*., 2011; Shyjith *et al.,* 2008). Different algorithms and techniques were proposed to schedule preventive maintenance activities. Alardhi *et al.* (2007) used mixed integer programming model, where Sitompul and Aghezzaf (2011) used integrated aggregate production and maintenance planning together. In other models, the system failure probability is integrated with the maintenance cost to determine the time interval between preventive maintenance activities (Kardon and Fredendall, 2002). Talukder and Knapp (2002) created a heuristic method to group equipment for the application of preventive maintenance overhauls within a series system.

The models that uses Group Technology (GT) methods to plan preventive maintenance are very limited in the literature. GT method can be used to form virtual machine cells that contain machines with similar maintenance needs. By performing similar activities of preventive

maintenance on different machines in the virtual cells, one can avoid time wasted in changing from one unrelated task to another and leads to standardization of the maintenance processes, tools and maintenance materials used, and allows the work to be done by a small group of workers which avoids duplication of effort and saves time Abdelhadi *et al.* (2015). Abdelhadi (2010) developed a platform for the planning of preventive maintenance actions that uses the concept of GT to establish preventive maintenance virtual cells for equipment/machines based on the type and/or severity of failures that the equipment/machines encounter. Almomani *et al.* (2012) presented a case study on the use of similarity coefficient method in GT for creating preventive maintenance virtual cells. Abdelhadi *et al.* (2015) studied the impact of applying the GT method for preventive maintenance on stockroom operational costs. They showed that preventive maintenance programs can be enhanced by applying the concept of GT in the formation of the virtual preventive maintenance cells in manufacturing. Abdelhadi *et al.* (2015) also showed that a significant cost savings that can be obtained by applying the GT method to the activity of preventive maintenance using a simulation study based on real-life manufacturing.

GROUP TECHNOLOGY METHOD

GT is a philosophy that identifies and exploits the sameness among the attributes of a set of objects. (Ballakur and Steudal, 1987). This philosophy is used in practice to design Cellular Manufacturing Systems. This requires identification of groups of machines that can produce parts with similar processing requirements. Each dedicated cell with dissimilar machines process a family of parts, in which the parts in each cell are processed with minimum moves into other cells.

Mathematical programming models are mainly used to solve the cell formation problem in GT. NP-hard problems usually take very large amount of computational efforts and time to solve the problem when classical optimization methods are used, especially for large-sized problems (Chung, Wu, and Chang 2011; Jouzdani *et al.* 2014). On the other hand, procedures using the similarity coefficient method (SCM) are more flexible in incorporating various important production data and can be used easily in the computer applications (Alhourani and Seifoddini 2007; Yin and Yasuda 2006). Furthermore, the optimal solution methodology fails to solve larger instances of problems (Islam & Sarker, 2000).

Similarity Coefficient Method in GT

Jaccard's similarity coefficient is the basic similarity coefficient equation that uses 0–1 binary data to calculate the similarity between machines. Jaccard's similarity equation calculates the similarity based on the number of part types that visit the machines. McAuley (1972) defined the similarity between a pair of machines as follows:

$$S_{il} = \frac{A_{il}}{A_{il} + B_i + C_l} \quad (1)$$

Where:

S_{il} similarity coefficient between machines i & l
A_{il} number of part types processed by both machines i & l
B_i number of part types processed by machines i
C_l number of part types processed by both machine l

Almomani *et al.* (2012) used this basic similarity equation to calculate the similarity between machines based on the types of failures that occur in these machines. To the best our knowledge this is the only research that appeared in the literature that utilized the similarity coefficient method in GT to form preventive maintenance virtual cells. Almonami *et al.* (2012) ignored other important production factors such as machines reliability. It is important to consider this factor when forming the virtual machine cells since each machine has a different reliability and therefore, preventive maintenance for each machine is needed at a different times.

NEW SIMILARITY COEFFICIENT CONSIDERING MACHINE RELIABILITY

A common way of dealing with machines reliability concern in the design phase of a manufacturing system is by the evaluation of the quantities of the mean time between failures (MTBF).

Therefore, the above similarity coefficient can be modified to incorporate this important factor:

$$S_{il} = \frac{A_{il}}{A_{il} + B_i + C_l} * R_{il} \qquad (2)$$

R_{il} ratio of the two machines' reliabilities

CLUSTERING ALGORITHM

McAuley (1972) proposed the use of single linkage clustering algorithm (SLINK). It assigns the largest value of the similarity coefficient possessed by a pair of machines from the two groups as the coefficient value for the two groups. SLINK may identify two groups as candidate for the formation of a new group at a certain threshold value, although several machine pairs possess significantly smaller similarity coefficient. This results in ‘‘chaining’’ problem among the groups of machines. Seifoddini (1988) suggested the use of average linkage clustering (ALINK) to reduce the chaining problem. ALINK assigns the average of similarity coefficients for all pairs of machines in the two groups as their similarity. Gupta and Seifoddini (1990) used the complete linkage clustering (CLINK) which assigns the smallest value of the similarity coefficient possessed by a pair of machines from the two groups as the coefficient value for the two groups. CLINK clustering is expected to result in more closely bonded groups due to the fact that each machine pair possesses similarity coefficient higher than the similarity coefficient for the two groups (Gupta & Seifoddini, 1990). Alhourani and Sefoddini (2007), Alhourani (2013), and Alhourani (2016) used their developed similarity coefficient equation to calculate the similarity between the formed machine cell and other machines. Their algorithms do not assign the smallest, largest, or average value (SLINK, ALINK, or CLINK) of the similarity coefficient possessed by a pair of machines.

CONCLUSIONS

Group technology can be used for preventive maintenance planning in the manufacturing environment. Machines can be grouped into machine cells where each machine cell contains machines with similar maintenance needs. Machines reliability should be considered when forming the virtual machine cells. Machines have different reliabilities and therefore their maintenance needs will be different. Incorporating this factor will make the problem more complex but more realistic. Similarity coefficient equation method in group technology is easier

to use and incorporate the important factors than the mathematical programming models that require a lot if computational efforts.

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DECISION SCIENCES INSTITUTE
Principle-Based MBA Course Design

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ABSTRACT

Many of the thousands of MBA courses offered online are developed haphazardly and without reference to learning design principles. This paper describes the challenges encountered by graduate faculty at a public university as it used instructional design principles to develop and implement online, hybrid, and traditional courses in its MBA Program. Adjustments to teaching methods, assignment structures, student interactions, and teaching assistant integration are described, and case studies of fast-paced, large online classroom environments are presented.

KEY WORDS: MBA Programs, Online MBA Programs, Course Design Principles

INTRODUCTION

In 2018, 450 online MBA programs are now offered in the United States. The majority of these programs co-exist with on-the-ground MBA programs, which share the same curriculum and learning goals. However, the growth in scale of MBA programs has raised questions about the instructional quality of online delivery. An examination (Margaryan, Bianco, & Littlejohn, 2015) of a random sample of 76 massive open online courses (MOOCs) indicated that the majority of the courses scored poorly on most instructional design principles. Only organization and presentation of course material of the courses examined received higher ratings. Although the Margaryan, Bianco & Littlejohn (2015) study focused on MOOCs, the results have implications for the design of online MBA programs, as well.

This paper examines the course design characteristics of the launch of an accelerated online MBA program in 2016 in the context of a synthesis of effective contemporary instructional design principles (Merrill, 2002, 2009, 2013; Margaryan, Bianco, & Littlejohn, 2015; Collis, Margaryan, & Amory, 2005; Frick et al., 2010; Gardner, 1999, 2011; Margaryan & Collis, 2005). Between August, 2016 and August, 2018, the number of students in the online version grew exponentially--from 100 students to 620 students. Due to the rapid enrollment growth, class sizes increased from an average of 65 to 245 for approximately one year before structural adjustments could be made to reduce class sizes to a more manageable level.

The paper begins with background on the development of the ten-principle framework for effective course design that was extended from Merrill's "First Principles of Instruction" (2002), and tested and validated by Margaryan, Bianco, & Littlejohn (2015); followed by case studies that detail how this framework was consulted and integrated into the development of courses for the MBA program of interest in this paper.

THEORETICAL BASIS FOR MERIILL'S FIRST PRINCIPLES OF INSTRUCTION

The flourishing of the demand for, and the availability of, online MBA programs presents the challenge of developing courses, methods and materials that are based on relevant instructional design principles. As pointed out in an article by Phan and Hoover (2014), many online MBA programs are put together in a haphazard manner, without consideration for current instructional theories and principles. The importance of theory-based instructional design was also recognized a few years earlier by David Merrill, who developed the First Principles of Instruction after extensive examination of contemporary instructional design theories (Merrill, 2002, 2009, 2013). The First Principles of Instruction include a problem-centered approach, activation of prior knowledge and skills, demonstration of new skills to be developed, and the integration of new skills/knowledge into the learner's skill set. It should be noted that Merrill's work was not specifically focused on online course delivery, but Merrill argued that this set of principles was applicable and valuable in any learning setting. Margaryan, Bianco, & Littlejohn (2015) more recently confirmed the validity and reliability of these principles and their usefulness in evaluating online courses. In developing his First Principles of Instruction, Merrill referenced several prominent instructional design theories, which are briefly described in the following paragraphs.

Vanderbilt learning technology center's star legacy (Schwartz et al., 1999)

(Schwartz et al., 1999) proposes a learning cycle that includes looking ahead to provide a learning context and learning goals; a progression of increasingly challenging problems to be solved; generating ideas that facilitates interaction among learners about their challenge-related experience; and multiple perspectives in which students compare their view of possible problem solutions with that of other students and the instructor. The research and revise phase engages students in the application of various solutions to the problem. Students get feedback on their ideas from others before final sharing of their ideas. Students are then ready to go public to demonstrate their solutions and defend their ideas. Finally, in the reflect back phase, they review the learning activities they have just completed.

4-Mat model (McCarthy, 1987; McCarthy & McCarthy, 2006)

McCarthy (1987; McCarthy & McCarthy, 2006) proposes an explicit learning cycle. She recognizes that, although learners may have preference for various approaches to learning, effective instruction should involve them in the whole cycle of learning activities. The first phase of her theory engages students in sharing information of past experiences and finding meaning in new material. Phase two is the demonstration phase, in which students acquire new knowledge and relate it to their prior knowledge. In phase three, application, students use their new knowledge to make something or develop a new idea. In phase four, they integrate their new knowledge into their knowledge/skill set.

Instructional episodes model (André, 1986, 1997)

According to André, (1997) an instructional episode has three phases. First, the activation phase; then the instructional phase, which includes presentation, discovery, and practice; and third, the feedback phase. André argues that identifying problems, searching for solutions, and presenting results give the learner many opportunities to integrate new knowledge.

Multiple approaches to understanding model (Gardner, 1999)

Gardner's (1999) performance approach to understanding emphasizes understanding content, such as "important questions and topics of the world" (73), rather than problem solving. He argues that evaluating learning must involve demonstrations “that can be observed, critiqued, and improved" (73). Gardner’s theory includes three phases. First, entry points are used to activate students and engage them in a topic, in one or more of the following ways: through narration, or quantitative, numerical, foundational, existential, aesthetic, hands-on, or social activities. In the second phase, telling analogies, students must demonstrate their new knowledge. The third phase, approaching the core, includes demonstrating and applying the new knowledge in a number of ways to show how they have integrated it into their skill/knowledge set.

Collaborative problem solving (Nelson, 1999)

Nelson's (1999) theory emphasizes critical thinking, creativity, and complex problem solving as well as social interaction skills. She presents guidelines that are organized under nine process activities: (1) build readiness, (2) form and norm groups, (3) determine a preliminary problem definition, (4) define and assign roles, (5) engage in an iterative collaborative problem-solving process, (6) finalize the solution or project, (7) synthesize and reflect, (8) assess products and processes, and (9) provide closure.

Constructivist learning environments (CLE) (Jonassen, 1999)

Jonassen's (1999) CLE theory places major emphasis on problem solving, which, he argues, drives learning. “Students learn domain content in order to solve the problem, rather than solving the problem as an application of learning" (218). Jonassen recommends using a progression of problem-solving tasks. "Start the learners with the tasks they know how to perform and gradually add task difficulty until they are unable to perform alone" (235).
He argues that demonstrations/related examples can be used to scaffold students’ existing knowledge by providing representations of new experiences or skills. Experts should demonstrate activities carefully, emphasizing how to perform activities and explaining the reason behind each activity. Students should have opportunities to perform the activities, first by imitating the expert, gradually developing skills, and then exhibiting original use of the skill to show they have integrated it into their skill set. "Coaches should “monitor, analyze, and regulate the learners' development of important skills" (233).

Learning by doing (Schank, Berman, & Macpherson,1999)

Shank, Berman, l Macpherson’s (1999) model is problem-focused and emphasizes the application phase of instruction. In GBSs [goal-based scenarios], students are engaged in learning-by-doing simulations in which they practice target skills and use relevant content knowledge to achieve a goal. A GBS includes seven phases: learning goals, mission, cover story, role, scenario, operations, resources, and feedback. First, a goal is determined, then a background story line establishes the need for the mission to be accomplished, and a role defines whom the student will play within the cover story. Stories provide content that extends

what the student already knows. In the scenario phase, experts scaffold the student through tasks and application, and in the operations phase, students work toward the mission goal, demonstrating integration of new skills in the process.

Categories of learning theory (Gagné, 1985)

Gagné argues that the different types or levels of learning require appropriate instructional goals and procedures. Learning is facilitated when the practice used is consistent with the learning goal. Gagné identifies five major types of learning: verbal information, intellectual skills, cognitive strategies, motor skills and attitudes; and nine instructional events and corresponding cognitive processes that can provide the necessary conditions for learning: (1) gaining attention (reception) (2) informing learners of the objective (expectancy) (3) stimulating recall of prior learning (retrieval) (4) presenting the stimulus (selective perception) (5) providing learning guidance (semantic encoding) (6) eliciting performance (responding) (7) providing feedback (reinforcement) (8) assessing performance (retrieval) (9) enhancing retention and transfer (generalization).

Four-component instructional design model (4C/ID) (van Merriënboer, 1997)

Van Merriënboer's (1997) model provides detailed instructional sequences to use with problem-based approaches, based on current understanding of cognitive processing. His whole-task practice approach includes the use of increasingly complex versions of a skill. "While learners practice simple to complex versions of a whole task, instructional methods that promote just-in-time information presentation are used to support the recurrent aspects of the whole task while, at the same time, instructional methods that promote elaboration support the non-recurrent aspects of the task" (10).

Elaboration theory (Reigeluth, 1999)

According to elaboration theory, the most effective learning occurs when instruction is organized in increasing order of complexity. With each succeeding lesson, the student should be reminded of all versions taught so far. Students should be guided to develop a meaningful context into which subsequent ideas and skills can be assimilated. Elaboration theory proposes seven major strategy components: (1) an elaborative sequence, (2) learning prerequisite sequences, (3) summary, (4) synthesis, (5) analogies, (6) cognitive strategies, and (7) learner control. The elaboration approach has been praised for facilitating more stable cognitive structures, and better retention and transfer of knowledge, increased learner motivation, and the provision of information about the content that allows informed learner control.
Merrill found commonalities among these instructional design theories and models that helped to confirm the integrity of his First Principles of Instruction, which are presented in more detail below.

A TEN-PRINCIPLE FRAMEWORK FOR EFFECTIVE COURSE DESIGN

As stated earlier in this paper, Margaryan, Bianco, & Littlejohn (2015) examined the design and structure of MOOC courses. Merrill's (2002, 2009, 2013) five First Principles of Instruction were used as criteria for rating the courses, and Margaryan & Collis (2005) also included five additional principles from the instructional design literature (Margaryan & Collis, 2005)—the development of collective knowledge, learner collaboration, differentiation of learning activities to fit learner needs, authentic (real-world) resources, and feedback. These additional five criteria were combined with the five First Principles of Instruction to create a ten-principle framework

(See Table 1.), which was validated in more than one hundred online corporate courses to test its ability to measure online course design quality (Margaryan, 2008; Margaryan & Collis, 2005). When employed as criteria of effective instruction in the MOOC study, Margaryan, Bianco, & Littlejohn's (2015) ten principle framework revealed that, except for organization and presentation of course material, the majority of MOOC courses were significantly lacking in all aspects of effective course design and learning environment that were measured, including problem-centered approach, activation of existing experience, demonstration of new skills, opportunities for learners to apply their new knowledge or skill to solve problems, facilitation of learner integration of the new knowledge, development of collective knowledge, collaborative learning, support for the learning needs of diverse learners, real-world course materials, and expert feedback to learners. These results highlight the importance of effective, theory-based online course design.

The following section presents more in-depth descriptions of Merrill's First Principles of Instruction and the five additional principles added by Margaryan & Collis (2005) to create the Ten Principles of Effective Course Design.

Table 1: Ten Principles of Effective Course Design	
First Principles of Instruction (Merrill, 2002, 2009, 2013)	
Problem-Centered	Learners acquire skill in the context of finding solutions for real-world problems that are representative of real-world issues.
Activation	Learning is promoted when learners activate existing knowledge and skills, relate and apply these to what they will learn in the course; and develop mental models and schemes.
Demonstration	Learning is promoted when learners observe a demonstration of the skill to be learned and are shown how to apply it in new situations.
Application	Learning is promoted when learners apply newly acquired skill to solve problems, with scaffolding gradually diminished.
Integration	Learning is promoted when learners reflect on, discuss, and defend newly acquired skills.
Five Additional Principles (Margaryan & Collis, 2005)	
Collective Knowledge	Learning is promoted when learners contribute to, and have access to, the collective knowledge.
Collaboration	Learning is promoted when learners collaborate with other learners.
Differentiation	Learning is promoted when different learners are provided with different avenues of learning, according to their need.
Authentic Resources	Learning is promoted when learning resources are drawn from real-world settings.
Feedback	Learning is promoted when learners are given prompt expert feedback on their performance.

Merrill's first principles of instruction (Merrill, 2002, 2009, 2013):

Problem-centered

Learning is promoted when learners acquire skill in the context of real-world problems. Many contemporary learning theories and instructional models such as constructivism, authentic learning, cognitive apprenticeship, situated learning, problem-based learning, and expansive learning, have as a premise, the idea that humans learn better when they are engaged in solving problems and building knowledge than when they are presented with information they are required to memorize. Problems refer to 'a wide range of activities, the most critical characteristic being that the activity is a whole task rather than only components of a task. and that the task is representative of those the learner will encounter in the world following instruction (Merrill, 2002, 45). In contrast to topic-centered instruction, where a subject is taught in isolation from the real-world tasks, problem-based instruction focuses on working through a progression of interrelated tasks, from the least difficult to the most difficult, that reflect the complexity of real-world settings.

Activation

Learning is promoted when learners activate existing knowledge and skill as a foundation for new skill. Instructional effectiveness of a course will increase if the course includes learning activities that help learners to recall and describe their relevant previous experiences, and to relate and apply these to what they will learn in the course. If learners have not had relevant experience, a course should begin by helping learners acquire such experience by, for example, providing real-world or simulated examples that learners can use as a foundation for their new learning. However, activation requires more than enabling learners to recall or build relevant experience; activation also requires learning activities that stimulate the development of the mental models and schemes that can help learners to incorporate the new knowledge or skill into their existing knowledge.

Demonstration

Learning is promoted when learners observe a demonstration of the skill to be learned. This principle highlights the importance of showing learners what they could do to apply the new information or skill in new situations rather than merely presenting them information about what to do. Effectiveness of a course is enhanced, firstly, when learners are shown examples of both poor and good practices; secondly, when the demonstration is consistent with the type of knowledge or skill being taught; and, thirdly, when learners are guided to relate general information or an organizing structure to specific instances of the knowledge or skill being taught.

Application

Learning is promoted when learners apply their newly acquired skill to solve problems. There is widespread agreement among contemporary learning theories that applying new knowledge or skill to real-world tasks is a necessary condition for effective learning. This principle emphasizes that applying knowledge to a single problem is insufficient for learning and that a course must provide multiple opportunities for learners to apply their new knowledge or skill to a wide range of real-world problems. A key corollary to the application principle is appropriate learner guidance, through diminishing coaching or 'scaffolding'. The basis to this corollary is the observation shared by many learning theories that while in the early stages learners may need considerable support, as learners progress this support is gradually taken away, with more control shifted to the learner to help build their independence. A key mechanism of scaffolding is feedback and most learning theories have long recognized feedback as the most important form of learner guidance.

Integration

Learning is promoted when learners reflect on, discuss, and defend their newly acquired skill. Learners have integrated new knowledge and skill into their everyday life when they are able to demonstrate change in behavior or modification of their existing mental models and, when challenged, are able to defend their new knowledge or skill. Therefore, the effectiveness of a course is enhanced when, first, learners are provided with opportunities to reflect on what they have learned in order to revise, synthesize, recombine and modify their new knowledge or skills; and, second, when learners are required to demonstrate and defend their new knowledge or skill to peers and others.

A meta-review (Merrill, 2002, 2013) indicated that these fundamental principles underpin all contemporary instructional design models and theories. Several aspects of the above five principles are worth noting. First, they are "relationships that are always taken to be true under appropriate conditions, regardless of program or practice" (Merrill, 2002, 43). Second, they "can be implemented in any delivery system or using any instructional architecture" (Merrill, 2002, 44). Third, "learning from a given program will be promoted in direct proportion to its implementation of these principles" (Merrill, 2002, 44). Fourth, the principles are "design-oriented and prescriptive, rather than learning-oriented or descriptive - they relate to creating learning environments and products rather than describing how learners acquire knowledge and skills" (Merrill, 2002, 44).

Additional principles of instructional design in the framework (Margaryan & Collis, 2015)

The five items below are additional principles of instructional design which Margaryan & Collis (2005) gleaned from the literature and included in the Ten-Principle Framework.

Collective knowledge

Learning is promoted when learners contribute to, and have access to, the collective knowledge. The interactive process of collective knowledge construction occurs when a group of individuals creates new knowledge by recombining the contributions of others to form new insights (Lave & Wenger, 1991). As a result, a group of learners as a whole develops and constructs new knowledge, and participants also individually advance and refine their own knowledge (Kimmerle, et al., 2015).

Collaboration

Learning is promoted when learners collaborate with other learners. Educators have long recognized the crucial role of dialogue and social interaction in learning (Vygotsky, 1978; Lave & Wenger, 1991). The collaboration that is part of learning in an online course facilitates the development of critical thinking skills, co-creation of knowledge and meaning, reflection, and transformative learning (Vygotsky, 1978; Lave & Wenger, 1991).

Differentiation

Learning is promoted when learners are provided with different avenues of learning, according to their need. Educators and instructional designers must be aware of students' individual differences, such as cognitive and learning styles, prior knowledge, and cultural differences. Field dependent learners and learners with low prior knowledge may need more attention and support from instructional designers, while other learners may be able to work independently in web-based learning systems. Adaptability is important in the design of web-based learning

systems to enable a variety of individuals to use the system successfully in learning environments (Alomyan, 2003).

Authentic resources

Learning is promoted when learning resources are drawn from real-world settings. Applications of theoretical material in real-life situations make content more relevant and easier to understand. Recent literature on brain function and learning indicates that existing knowledge forms the foundation for incorporating new information into more complex and sophisticated schemas (Theall, 1999; Keller, 2008).

Feedback

Learning and student engagement are promoted when learners are given expert feedback on their performance. In order to be beneficial to learners, feedback must enhance learning, be timely, clearly communicated to students, consistently delivered, and have consistent quality. (Black & William, 1998; Falchikov, 2001; Gibbs & Simpson, 2004).

DESIGN OF ONLINE MBA COURSES BASED ON THE 10-PRINCIPLE FRAMEWORK

With a commitment to developing courses which reflect the best practices of instructional design identified in the ten-principle framework, the administrators and faculty responsible for the online MBA described in this paper consulted the framework and employed principles from it to guide the development of the two courses described below.

Case Study #1: CIS 601: information systems and technology

Course description

CIS601 is the information technology-focused course offered in the MBA. This course concentrates on the strategic use of information systems, with emphasis on the Information Systems Strategy Triangle, which relates business strategy with IS strategy and organizational strategy. The underlying theme of this course is that, with information systems at the heart of virtually every business interaction, process, and decision, managers can no longer abdicate participation in decisions regarding their company's use of information systems. Managers must become knowledgeable participants in information system decisions. CIS601 is designed to build the knowledge and skills business managers need to make strategic decisions about information technology, as well as to introduce them to the use of digital visualizations with software like Tableau. Course topics include the Information systems strategy triangle, strategic use of information resources, organizational strategy and information systems, digital systems and the design of work, information systems and business transformation, architecture and infrastructure, security, the business of information technology, governance of the information systems organization, information systems sourcing, managing information technology projects, business intelligence/knowledge management/analytics, and privacy and ethical considerations in information management.

Adaptation of CIS 601 for online delivery

CIS601 had been offered for many years as a face-to-face course, but the growing digital presence of the RCOB's MBA necessitated offering the course online. The course was offered online for a couple of years, serving mostly local and area students. All assignments were

posted and submitted online. Students were required to take exams on campus, or to arrange for an approved local proctor to administer the exam to them.

With the move to a totally online MBA, the course now serves an unlimited number of students, with enrollments from around the world and around the nation. The spring, 2018 the course had an enrollment of 250 students. This newly increased enrollment necessitated major changes in how the course is run. First, the MBA Program is now working with Instructional Connections, LLP, which provides instructional support services to colleges and universities that offer online programs (http://instructionalconnections.com/). Instructional Connections supplies well-qualified academic coaches to support the instructor and the students. For a class with 250 students, for example, the resumes of potential academic coaches are offered, and the instructor can determine how many coaches are needed as well as which coaches have the most appropriate background for a particular course. The instructor provides detailed instructions to the coaches, regarding assignments, projects, procedures, and grading rubrics, as well as a table of responsibilities—those of the instructor, the coaches, and the students. For this eight-week course with an enrollment of 250 students, four coaches were assigned, with each coach being responsible for a portion of the students. The coaches provide updates to the students, reminders of due dates, and encouraging messages to them. They also grade assignments and projects, using guidelines and rubrics provided by the instructor, and in close consultation with the instructor. Throughout the course, when a student has a question about course content or other issue that the coaches believe can be better and more thoroughly answered by the instructor, the coaches forward the questions to the instructor. All questions are answered immediately or as soon as possible.

Consideration of psycho-social factors of online learning

The expanded enrollment has also necessitated consideration of several psycho-social factors related to student learning online that are relevant to large enrollment courses. These factors are widely discussed in the MOOC (massive open online course) literature, and many of them are relevant to large enrollment courses in general. As the following discussion points out, these factors are consistent with the ten criteria for effective instruction based on key instructional design theories and models[i] (Merrill, 2002, 2009, 2013; Margaryan & Collis, 2005) that were discussed above.

First, research has found that most online learners need to feel “teacher presence” throughout a course in order to feel confident and able to succeed in a course (Garrison & Anderson, 2003). This factor is addressed in CIS601 by the use of academic coaches, each of whom is assigned a portion of the students to manage, and by the prompt addressing of issues and questions by the instructor, updates and deadline reminders, and other encouraging emails. Prompt, consistent feedback to students (Margaryan & Collis, 2005) provides scaffolding that supports the learning experience and builds students’ confidence in the application of new knowledge (Merrill, 2002, 2009, 2013).

Second, online learners can differ across many dimensions, such as skills (digital and participatory), preferences, learning styles, motivation, engagement, and the context of learning (Terras & Ramsay, 2014). To the extent possible, an online course should address learner differentiation (Margaryan & Collis, 2005) and diversity and provide structure that facilitates a high-quality learning experience for diverse learners. CIS601 addresses individual differences in background/experience/preferences by, to the extent possible, giving students choices in project topics. All assignments are problem-centered and require students to analyze and develop solutions to real-world issues (Merrill, 2002, 2009, 2013; Margaryan & Collis, 2005). A project that focuses on the impact of new IT initiatives includes the choice of either writing about an on-the-job project or about a fictitious IT initiative. A second project, an article review, gives students the choice of a number of different articles from prominent journals, each related to a

particular chapter in the text. Students can choose an article, based on interest or relevance to their experience, thus underscoring the importance of activation, in which students activate existing knowledge and skills as a foundation for new skills. The coursework also includes a hands-on component, in the form of two projects that involve students in learning the rudiments of Tableau software. The goal is to introduce them to data visualization and provide practice exercises that build their skills and confidence and demonstrate how powerful and insightful data visualizations can be. It should be noted that some students had difficulty using Tableau on their particular computer systems. In the few cases in which students found it impossible to complete the Tableau exercises, an alternative assignment was given which involved reviewing an article about Tableau and detailing how the student believes that data visualizations could be useful in his/her given field/position.

Third, another aspect of online learning that is relevant to online MBA courses is the finding that discussion and interaction with others are paramount to achieving higher-level learning (Ferschke et al., 2015). This issue is important for MBA students, who, one can assume, are mature and deal with complex, real-world issues daily. Weekly discussion board assignments involve CIS601 students in sharing their opinions and commenting on the postings of other students. This process widens their horizons as they share their own ideas and peruse the experiences and perspectives shared by a diverse group of learners. Students have an opportunity to get to know each other through the first week of the course's discussion board, which requires them to share their educational and work experience, and how they feel information technology fits into their current work and future career goals. These activities involve application of newly acquired skills and the integration of new skills through reflecting on, discussing, and defending newly acquired skills (Merrill, 2002, 2009, 2013).

Fourth, active engagement of students in the learning process is also key to a successful learning experience (Harasim, 2012). The table of responsibilities of instructor, academic coach, and students that is listed on the class syllabus provides students a clear idea of their role in the course. Students are also engaged through weekly discussion board interactions with other students, in which many assignments call for their opinions on various topics and they are required to respond in detail to the opinions of other students on the same topics.

The author has found that the eight-week format for the online course significantly limits the depth into which it is possible to go on the many important topics included. Going forward, CIS601 will be offered in fall, 2018, in a semester-long face-to-face format as well as the eight-week online format. The decision to offer two formats addresses the issue of learning preferences and learning styles, as some students, depending on their geographic location and work schedule, will have the option of choosing the format that best fits their learning style and preferences. The face-to-face format will also make it possible for the instructor to go into greater depth on the Tableau data visualization portion of the course and to offer hands-on experiences with SAP/ERP/Sim software.

Management 611: leadership skills and innovation online

Course overview

Management 611: Leadership Skills and Innovation is an MBA course that addresses leadership in the business context to prepare students for a future of rapid change and increasing complexity. The skills developed in this course include project management, change management, critical thinking, effective decision-making, developing others to improve work engagement, disciplined execution, developing business models, conducting a leadership audit, conducting an innovation audit, and pitching an idea. This course has been taught on campus full-term, hybrid full-term, and online full-term, but the most profound learning curve occurred in delivering this broad scope of topics in an online accelerated (8-week) term to 235 students.

Teaching a large section of an online MBA course can profoundly impact instructional effectiveness both in the classroom and online because it forces examination of three important course elements: content, design, and feedback.

Course content

Most college faculty maintain the intellectual and interpersonal abilities to gain the affection and admiration of their students in the classroom regardless of their teaching skills. However, students taking MBA courses online are primarily concerned with how the content of the course will help them be more effective in their careers. The intellectual prowess of the instructor is far less important than the extent to which the topics covered in the course are practical, engaging, and valuable. Therefore, these three criteria were the lens through which course topics were selected.

As this course is in the core of the MBA program, there is great diversity among the students in the course in terms of background, profession, and years of experience. Students did not self-select into the course based on experience or interest, but rather were required to take it for the degree which poses quite a challenge for faculty teaching courses in the MBA core. In light of this, the chosen course topics were broadly applicable across industry segments and levels of career experience. While each topic was not expected to appeal to every student given the population diversity, carefully selecting broadly applicable content was an essential element to appeal to a majority of the students.

Once the course topics were identified, the same criteria (i.e., practical, engaging, and valuable) were used for content selection, which was vastly underwhelming, as the experiential methodology is nascent relative to the discipline. As a result, custom materials (e.g., readings, simulations, and videos) were curated and/or created to accomplish the course objectives and appeal to the student population. In addition to content, customized presentations, quizzes, and assignments were created for each module. The upfront workload of this approach was high, but the reward paid excellent dividends in student experience and engagement. The results from a survey from 221 students in the online accelerated section of this course indicated that 90.95% felt the course was very practical, 89.59% felt the course was engaging, and 87.78% felt the course was valuable. Furthermore, 91.39% indicated this course was intensive so the rigor of the course was very high from the students' perspective and numerous favorable comments were offered with regard to course quality and impact.

Course design

The format of a course (i.e., online or in-person) should never dictate the learning objectives, but almost always influences the course design. When dealing with large online class sizes, there are several practical course design elements to maintain consistency and improve effectiveness. Practices that were valuable in building a scalable course include: 1) creating grading rubrics in the learning management system (e.g., blackboard) for each assignment to assist with grading consistency, 2) organizing content into modules rather than task type, 3) outlining the module learning objectives on each module folder in the LMS, 4) using thread box via voice thread to facilitate connections and build a sense of community among students, 5) using online video conference office hours via zoom, and 6) organizing module folders consistently (e.g., module instructions and attached documents - module presentation – quiz to assess content coverage – submission folder for assignment documents).

While some of these practices apply to all course formats, they become profoundly more important for large online courses. 100% of survey respondents indicated the LMS site was easy or very easy to navigate, and the module requirements were easy to understand.

Furthermore, while consistency is key in LMS formatting, differentiating assignment types (Merrill, 2002) engages different student strengths and provides diverse pathways for success. Because online MBA students are keenly sensitive to how their learning will impact their life, course assignments were designed to help them discover how much they need the information before they receive it. For example, when students ran simulations in the course, they first completed a practice run with only instruction on the mechanics of the simulation. Because they were taking actions without a conceptual framework or understanding the theory behind making effective decisions, their performance quickly illustrated their need for knowledge they did not maintain. The subsequent debrief covered content relevant to the simulation as well as reflection on how that information would alter their decisions in the simulation. Students then ran the simulation again and achieved profoundly better results.

This approach is consistent with the *problem-centered* criterion for effective instruction (Merrill, 2002) as it focuses students' attention on solving the problem at hand, rather than memorizing information for an ambiguous situation they may encounter at some point in their life. This approach has been more effective than simply telling students why the topics they study are important because once they are hungry for the information, they place value on it and receive it with excitement. They see it as keys to success rather than information to be memorized for an assignment or exam.

The *application* criterion for effective instruction (Merrill, 2002) was built into each module assignment as students applied the content to a scenario in their work-life. This facilitated the transfer of training and made the material high-touch in a real and experiential way. This reflection/application component highlighted the impact the content had on students' lives and helped integrate them as co-creators in the learning process.

This course design was adapted from the scaffolding model which follows an I do – We do – You do approach that helps learners perform a task that would be difficult independently (Gašević, et al., 2015). The scaffolding methodology facilitates experiential learning without overburdening the instructor because students have a frame-of-reference to reflect on when applying the content to themselves or a situation. This approach emphasized the *demonstration* component of effective instruction (Merrill, 2002) as examples of unsatisfactory, satisfactory, and excellent performance were presented as well as the assignment instructions and completion process for each assignment.

Course feedback

Social presence (i.e., the ability of students to share their personal characteristics and present themselves to others as real people) has been found to relate positively to the ability to construct meaning from course interactions (Lee, 2014). Voice thread boxes were effective tools to elicit social presence as students shared presentations and ideas with peers and received feedback from them. This built a sense of community to help them feel connected to one another, the university, and the instructor. Students in this course introduced themselves by posting their leadership journey in a thread box which accomplished two things: (1) eliciting social presence, and (2) creating student awareness that they have a foundation on which to build with this course material, which aligns with the *activation* component of effective instruction (Merrill, 2002). Furthermore, the expert feedback (Merrill, 2002) they receive from emails and graded assignments allows students to experience high teacher presence as well. With large sections, clarifying responsibilities of faculty, teaching assistants, and students was also very helpful way to convey teacher presence and elicit higher-level learning.

Course feedback in this online course appeared superior to on campus sections in some ways. For instance, communication is an essential leadership skill and presenting to peers provides valuable practice for the learner. However, audience feedback during live student presentations is limited by class time, but this constraint does not exist online. Online presentations can be

paused, restarted, and watched again so feedback can be deeper and more constructive. Similarly, peer engagement in online discussion boards is often greater than in-class discussions due to higher perceptions of psychological safety which allows for a free-flowing exchange of ideas. Furthermore, student interactions in this course aligned with the *integration* component of effective instruction (Merrill, 2002) as students reflected on, discussed, and defended their acquired skills which elicited social presence and provided valuable feedback to the learner.

Online education is not ideal for every instructor or learner, but selecting content relevant to the student population, using a scalable/appropriate design, and creating feedback interactions which contribute to social and teacher presence are excellent ways to appeal to this segment of learners.

DISCUSSION AND CONCLUSIONS

Table 2 presents a summary of ways in which design elements in MBA courses CIS601 and MNGT611 have addressed the ten principles of effective course design developed by Merrill (2002, 2009, 2013) and expanded by Margaryan and Collis (2005).

The goal of this paper was to use these principles as a guide in the development of MBA courses that reflect the best practices of instructional design and provide a means of evaluating the achievement of this goal. Adjustments to teaching methods, assignment structures, student interactions, and teaching assistant integration were made to facilitate fast-paced, large online classroom environments.

This paper is limited, of course, by the inclusion of only two courses. Further research will expand to include all MBA courses in the college's MBA Program. A tool will be developed to evaluate MBA courses on their implementation of the ten principles, based on the tool used by Margaryan and Collis (2005). An additional tool will be developed to measure student perception of the course's coverage of the ten principles, using Margaryan and Collis' (2005) tool as a starting point. Both tools will be administered for several semesters/years to determine trends; and based on the results, any needed adjustments will be made to courses.

Meanwhile, efforts will be made to provide both synchronous and asynchronous communication channels for students in all courses, in order to facilitate student-to-student and student-instructor interaction. Additionally, to facilitate knowledge sharing, an area will be provided where assignment answers can be shared, after the due date has passed. More provisions will also be made to accommodate the needs of diverse learners. According to Rolfe (2015), when an online course is available to learners around the world, it is important to address the needs of a geographically, culturally, and academically diverse participant group, as well as special needs students. This is particularly important for the MBA Program discussed in this paper, which has students in remote locations, international students, and special needs students.

Table 2: Coverage of the ten course design principles in CIS601 and MNGT611		
Course Design Elements	**CIS601**	**MNGT611**
Problem-Centered	Real-world case analyses and article reviews	Problems introduced first to set the stage for material
Activation	Students use prior experiences to analyze new information and build on these to develop new skills.	Students use prior experiences to analyze new information and build on these to develop new skills.
Demonstration	Cases and articles demonstrate both best practices and challenges.	Scaffolding methodology is used to teach material and clarify assignments.
Application	Students are required to apply new skills to real-world situations.	Assignments exclusively use real-world scenarios.
Integration	Students required to demonstrate new knowledge and understanding.	Students required to demonstrate new knowledge and understanding.
Collective Knowledge	Students share ideas in discussion boards.	Students share ideas in voice threads and discussion boards.
Collaboration	Students critique and learn from each other.	Collaboration occurs via voice thread presentations and discussion boards.
Differentiation	Assignment options provide diverse pathways for success.	Assignment options provide diverse pathways for success.
Authentic Resources	Exclusive use of real-world scenarios.	Exclusive use of real-world scenarios.
Feedback	Coaches instructor, peers provide prompt feedback.	Occurs via peers, academic coaches, and instructor.

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DECISION SCIENCES INSTITUTE

Public acceptance of commercial drone deliveries:
A case study in developing a marketing research measure with the Rasch model

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ABSTRACT

This paper will detail the development of a measurement scale designed to profile the extent to which the public would be willing to accept commercial deliveries by drones. The survey items for this instrument were generated through the use of focus groups, guidance from experts of the technology, backward translation and extensive piloting and calibration using the Rasch model.

KEYWORDS: Drones, drone delivery, Rasch, acceptance survey, survey development, focus groups, backward translation

INTRODUCTION

Drones are a hot topic. They are in the news, shown in movies, given as toys for children, used by hobbyists for shooting videos and the government for surveillance. They are becoming part of our culture. Some are eager to find new commercial applications for drones, and the most obvious possibility would be for package delivery. Yet, as with all changes in culture, there is resistance – particularly when it comes by way of a new technology. Those that are less eager ask if these changes are happening too rapidly. The online retailer Amazon.com doesn't think so. They, and other firms, have spent untold millions of dollars developing such programs, and to them, it's merely a matter of time.

Strangely, very little academic research has been devoted to business models involving drones. Most of the material discussing drones has been published in trade journals, or as news articles related to some specific development - nearly all of which focuses on either the feasibility or inevitability of drone package delivery. Almost no one is asking if potential customers would actually want such a service. This paper details the development of an instrument for the measurement of public acceptance of drone deliveries.

The method used in this development is centered around the use of the Rasch model. While the Rasch model is used extensively in educational and psychological research, it is rarely used to explore business related issues. This is truly unfortunate as many areas of business research rely upon psychographic data gathered largely through surveys. The data from surveys is typically categorical, or at best ordinal, and difficult to analyze without a number of dubious assumptions. The Rasch model (or simply Rasch) was designed specifically to analyze such data and would be extremely useful to business researchers – particularly in marketing. Therefore, this paper has two purposes. The details behind the development of the proposed measure are presented not only to demonstrate the application of specific methodology, but also to serve as an ambassador for Rasch to business academia.

The paper begins with a brief overview of the publications related to drone delivery. The theoretical framework suggested in the literature serves as valuable guidance for the generation of survey items in this study. The development itself is broken into process sections. The pre-pilot section discusses how the initial ideas for survey items were generated and tested with Rasch. The focus group section introduces a more structured approach to refining survey

items. The primary testing section details a large scale test of the proposed measurement instrument. The Rasch analysis section discusses a few difficulties encountered during the analysis. A final section offers advice for the deployment of the measure as a market research tool.

LITERATURE REVIEW

As of this writing, there are only two publications of academic value directly related to public acceptance of drone deliveries. In October of 2016, the Office of Inspector General for the United States Postal Service published "Public Perception of Drone Delivery in the United States". This report details the results from a nationwide online survey in which participants were asked how they might prefer to receive their mail. The survey also gathered a great deal of demographic information through which a number of conclusions were drawn. They divided the respondents by generations of Millennials, Generation X, and Baby Boomers. Millennials were found to be significantly more knowledgeable, open, and positive towards the idea of drone delivery than older generations, though all generations seemed to feel that it may be "too soon" for drone delivery.

According to this report, men were more aware of the idea of drone delivery and more accepting of the prospect. They also observe that those who rely primarily on postal deliveries would feel less positive towards the USPS if it offered the service today compared with those who frequently use ecommerce channels. There appeared to be no significant difference in awareness of the drone delivery concept across geographic regions. The concept was viewed most positively by Western residents and least liked by Midwestern residents, with Southern and Northeastern residents somewhere between.

Surprising for a government report, a relatively detailed description of their methodology was included along with a list of the questions posed. One limitation noted by the authors was the use of quota sampling. Strictly speaking, this non-probabilistic method restricts the generalizability of the findings, though they point out that it is used extensively in marketing research. They also note that rural residents were overrepresented in the sample.

The biggest limitation in the USPS report was in the design itself. The questions posed were largely written in the context of mail delivery. Respondents were asked how they felt about the USPS in comparison to other commercial entities such as FedEx or Amazon, and while these other firms are prohibited from delivering mail, it was clear that the focus was to gauge the public attitude toward the prospect of the USPS entering the future ranks of drone-capable delivery services. In fact, an internal memorandum from the vice president of operations attached to the report notes the importance for the USPS to remain competitive. This is noted here as a limitation because the conclusions drawn by the report were tailored very specifically for the USPS, and while they may be interesting, they are not likely to be of direct use by private firms.

The other relevant publication was a 2017 article by Ramadan, Farah and Mrad entitled "An adapted TPB approach to consumers' acceptance of service-delivery drones". In this article, the authors attempt to draw a parallel between consumer acceptance of other business-to-customer technologies (such as ATMs) and drone deliveries through a framework based on the Theory of Planned Behavior (TPB). Similar in structure to the Technology Acceptance Model, though the TAM antecedents *perceived usefulness* and *perceived ease of use* are generalized to the TPB variables *functional benefits* and *relational attributes*. In this conceptual article, these proposed variables, along with *risks*, are antecedents to *attitude toward using drones*, which in turns leads to *intention to use drones*. The authors offer propositions that link perceived risk, drone performance and "personification" with the likelihood of acceptance.

The inclusion of perceived risk and drone performance are certainly reasonable (and somewhat obvious), though the notion of personification is quite interesting. By this, the authors refer to the "consumer's need for human interaction". While noting that this need has often been an inhibitor of acceptance for other technologies, the possibility that a single firm (such as Amazon.com) might gain enough of a lead in the implementation of drones that the service itself may become part of their brand identity. This brand-consumer relationship, along with the sheer novelty of the drones, may lead to some level of anthropomorphic attachment. No empirical evidence was offered, but the linkages between benefits, risks and intentions were set on a firm theoretical foundation.

The primary idea behind TPB is that an individual's perception of the outcomes of performing a certain behavior influences their attitude towards the related behavior (Fishbein and Ajzen, 1975). By extension, TAM argues that the *perceived usefulness* of a technological adoption is relevant in terms of improving one's job performance and thereby may influence attitudes towards the intention to use the technology (Davis, Bagozzi, and Warshaw, 1989; Porter and Donthu, 2006). TAM also suggests that the *perceived ease of use* of technology influences the decision regarding how and when the technology might have the greatest impact. While TAM was intended to model workplace behavior, Ramadan, Farah and Mrad (2017) would argue that issues such as concerns over privacy, susceptibility to subversion or mere malfunctions are legitimate risks in the eyes of potential users and thereby would have the same impact on their intention to choose drone delivery.

OVERVIEW OF THE RASCH MODEL

To motivate the use of the Rasch model, consider how most empirical research is conducted in business academia. The point of most empirical models is to establish a causal relationship between higher order latent constructs. Each of the underlying first order constructs would be defined by a number of survey items – each of which would be related to a particular aspect. In terms of measurement, having a single survey item to measure an idea would be analogous to a ruler with a single tick mark. If the research objective is merely to establish relationships between constructs, then the true degree of covariation between items may not be as important as the specification of the model itself.

On the other hand, if the research objective is to develop a rigorous measure of a latent construct through the gathering of psychographic data, a ruler with more than one tick mark is needed. This would certainly be the case in marketing research, in which researchers wish to generate a demographic profile of attitudes toward a product or brand. The Rasch model is ideal for the development of such measurements.

The primary idea behind using multiple survey items to build a single measurement scale is based on the notion that each question should present a different level of difficulty for someone of a set view to agree. For example, imagine a respondent that is positively disposed toward, but not completely in agreement with the idea of drone delivery. Such a person might readily agree that drones would work well in situations of low-risk with packages of minimal value. However, as the concerns increase, this person might find it harder to agree with the assertion that drones would work well. In this way, a carefully crafted series of questions that spanned the range of benefits and concerns could gauge the extent to which a respondent would be willing to accept the idea of drone package delivery.

The difficulty lies in developing survey items that, as a whole, are unidimensional, adequately cover the extremes (easy to agree and hard to agree) of the range, and form a coherent narrative from which a marketing profile might be inferred.

DEVELOPMENT OF THE PRE-PILOT SURVEY INSTRUMENT

The Initial Brainstorming Session

The initial survey items were developed during a classroom discussion of new product development in an undergraduate operations management course. Though the discussion was not specifically intended to be part of a research project, a number of interesting insights were revealed regarding the concerns over drone package delivery. By the end of the class period, a number of specific survey items were proposed. Appendix 1 contains a list of these initial questions. From these questions, three primary themes emerged: impact, benefits and trust. While the survey items are not ordered according to these themes, they could be grouped as follows:

The general idea behind the theme of impact is to measure how respondents view the effect of drones on the welfare of society. Items 4, 5, 6, 7, and 16 were intended to address this issue. Because of the very general nature of such questions, it was decided to ask about societal impact and the impact on families in both positive and negative forms. Reasoning that the absence of a threat does not imply a benefit, Item 7 was given as the negation of Item 5. Similarly, Item 6 is the negation of Item 16.

The theme of benefits is fairly straightforward. The focus group identified speed and potentially lower costs as the primary incentives to request drone delivery. Items 21, 23, and 24 were included to address these features.

The benefit theme was also intended to explore the limitations of drone technology. It has been suggested that a delivery drone may not be able to reach all residents. For example, a customer may live in a high-rise apartment building with no suitable drop zone. In such cases, a customer may have to retrieve their package from a common drop point. Item 10 was included for this purpose.

Further concerns regarding the limitations of drones include the impersonal nature of the system and the worry that a drone might drop their package in the wrong location. Items 20 and 26 were intended to address these concerns. The inclusion of such items may serve to identify possible deficiencies that may need to be addressed. For example, if a large enough percentage of respondents answered strongly agree to Items 20 and 26, retailers might consider a new marketing campaign to change public perception.

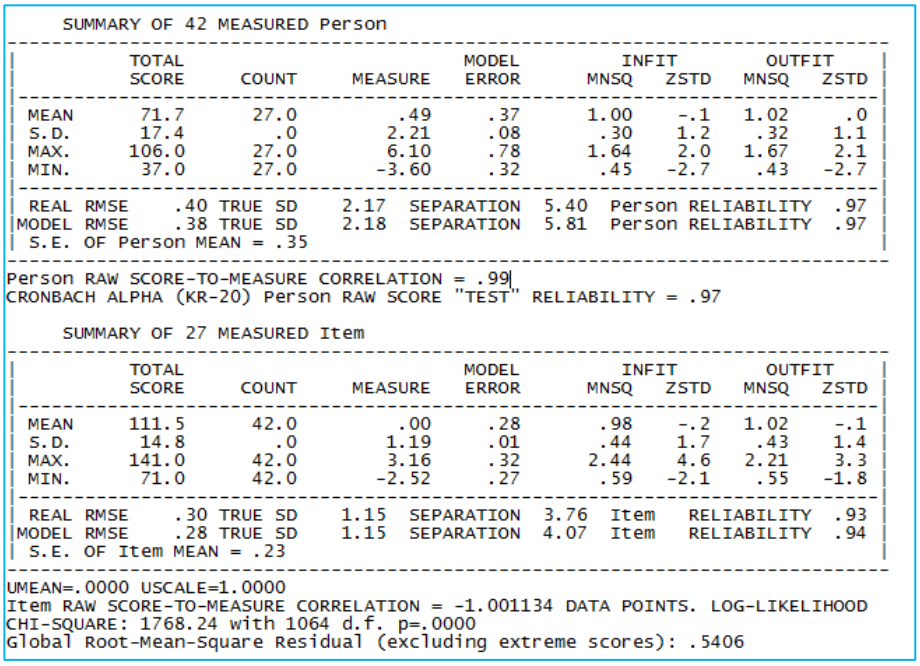
Given the historical use of drones, the bulk of the items were related to trust. The focus group identified a number of possibilities related to trust. Chief among these issues is safety. Items 1, 9, 15, 17, 18, and 19 address the specific concerns discussed.

In addition to personal safety, concerns were also raised regarding the safety of the cargo. Item 3 is related to the fragility of packages, while Items 2 and 13 are related to valuable or confidential cargo.

The small remainder of items are all related, if somewhat tangentially, to one or more of these themes. For example, Item 12 touches onto issues of trust and benefit. To date, no grocer has expressed interest in pursuing drone delivery, if perishable food were ever to be delivered by drone, pizza would likely be the first to fly.

Rasch Analysis of the Pre-pilot survey

The items proposed in Appendix 1 were assembled into a pre-pilot instrument and tested on a different class section with 42 students. The characteristics of the survey instrument fits the Rasch rating scale measurement model, and was analyzed with the Winsteps program (version 3.74.0). The analysis and consequent revisions were arranged in the order of scale, dimensionality, item, and people. The initial results are shown in Figure 1.



SUMMARY OF 42 MEASURED Person

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	71.7	27.0	.49	.37	1.00	-.1	1.02	.0
S.D.	17.4	.0	2.21	.08	.30	1.2	.32	1.1
MAX.	106.0	27.0	6.10	.78	1.64	2.0	1.67	2.1
MIN.	37.0	27.0	-3.60	.32	.45	-2.7	.43	-2.7

REAL RMSE	.40	TRUE SD	2.17	SEPARATION 5.40	Person RELIABILITY .97
MODEL RMSE	.38	TRUE SD	2.18	SEPARATION 5.81	Person RELIABILITY .97
S.E. OF Person MEAN = .35					

Person RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .97

SUMMARY OF 27 MEASURED Item

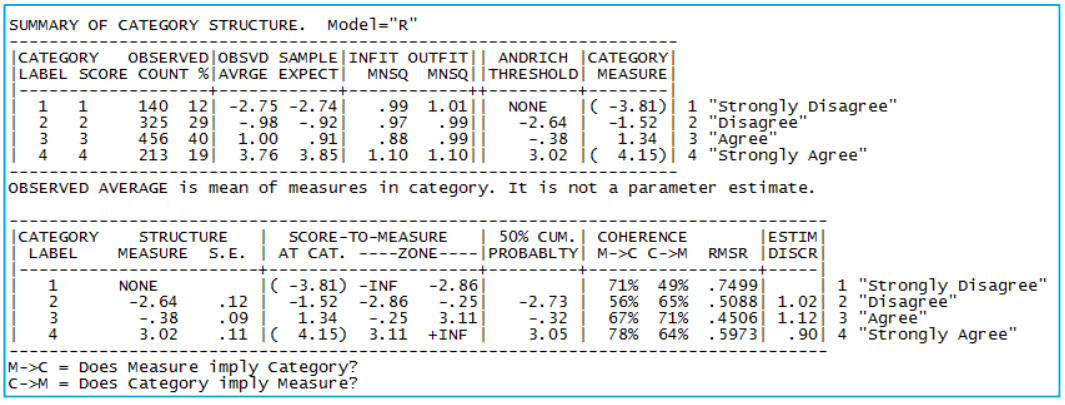
	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	111.5	42.0	.00	.28	.98	-.2	1.02	-.1
S.D.	14.8	.0	1.19	.01	.44	1.7	.43	1.4
MAX.	141.0	42.0	3.16	.32	2.44	4.6	2.21	3.3
MIN.	71.0	42.0	-2.52	.27	.59	-2.1	.55	-1.8

REAL RMSE	.30	TRUE SD	1.15	SEPARATION 3.76	Item RELIABILITY .93
MODEL RMSE	.28	TRUE SD	1.15	SEPARATION 4.07	Item RELIABILITY .94
S.E. OF Item MEAN = .23					

UMEAN=.0000 USCALE=1.0000
Item RAW SCORE-TO-MEASURE CORRELATION = -1.001134 DATA POINTS. LOG-LIKELIHOOD
CHI-SQUARE: 1768.24 with 1064 d.f. p=.0000
Global Root-Mean-Square Residual (excluding extreme scores): .5406

Figure 1

The analysis shows a 5.81 separation between people (potentially 7 distinct groups), and a 4.07 separation between items (5 or 6 groups). The survey also appears to exhibit a high level of reliability, but as with the other statistics, a word of caution is advised. The same group that helped write the survey also served as the sample for this pilot study. Hence, this may constitute a significant bias. This type of convenience sample may not be as much of a problem for the pilot study, but this limitation must be kept in mind throughout the evaluation process.



SUMMARY OF CATEGORY STRUCTURE. Model="R"

CATEGORY LABEL	SCORE	OBSERVED COUNT	%	OBSVD AVRGE	SAMPLE EXPECT	INFIT MNSQ	OUTFIT MNSQ	ANDRICH THRESHOLD	CATEGORY MEASURE	
1	1	140	12	-2.75	-2.74	.99	1.01	NONE	(-3.81)	1 "Strongly Disagree"
2	2	325	29	-.98	-.92	.97	.99	-2.64	-1.52	2 "Disagree"
3	3	456	40	1.00	.91	.88	.99	-.38	1.34	3 "Agree"
4	4	213	19	3.76	3.85	1.10	1.10	3.02	(4.15)	4 "Strongly Agree"

OBSERVED AVERAGE is mean of measures in category. It is not a parameter estimate.

CATEGORY LABEL	STRUCTURE MEASURE	S.E.	SCORE-TO-MEASURE AT CAT.	----ZONE----		50% CUM. PROBABLTY	COHERENCE M->C	C->M	RMSR	ESTIM DISCR	
1	NONE		(-3.81)	-INF	-2.86		71%	49%	.7499		1 "Strongly Disagree"
2	-2.64	.12	-1.52	-2.86	-.25	-2.73	56%	65%	.5088	1.02	2 "Disagree"
3	-.38	.09	1.34	-.25	3.11	-.32	67%	71%	.4506	1.12	3 "Agree"
4	3.02	.11	(4.15)	3.11	+INF	3.05	78%	64%	.5973	.90	4 "Strongly Agree"

M->C = Does Measure imply Category?
C->M = Does Category imply Measure?

Figure 2

The results in Figure 2 suggest that the 4-point Likert scale chosen for the survey performed well. The rating scale structure, parameterized with the Andrich Threshold, is monotonic and increasing with threshold separations of at least 1.4. Likewise, the category probability plot in Figure 3 exhibits a strong relationship between a person's logit score and the difficulty of the item.

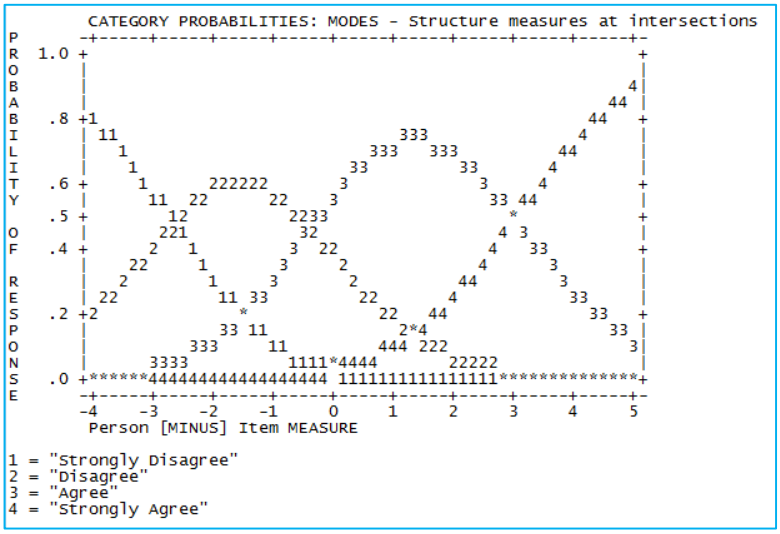


Figure 3

Sometimes, the appearance of perfection disguises problems. Without any revisions, the survey instrument already exhibits large threshold separation. This may suggest that the category structure may be "too broad" – that is, a scale with more categories might have captured more information. Through this analysis, scale can be collapsed, but not expanded. This issue will be revisited after the revisions are made.

The output shown in Figure 3 suggests that the instrument is reasonably unidimensional. The raw empirical variance explained by measures should exceed 60%. The percentage found in the initial analysis estimate the percentage to be 65.6%. Furthermore, no contrast contributed unexplained variance greater than 3.6% - well below the standard of 5%. The items with loadings outside of the (-0.4, 0.4) interval did not appear to be grouped in any particular pattern.

Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)

		-- Empirical --		Modeled
Total raw variance in observations	=	78.4 100.0%		100.0%
Raw variance explained by measures	=	51.4 65.6%		64.7%
Raw variance explained by persons	=	32.1 41.0%		40.4%
Raw Variance explained by items	=	19.3 24.6%		24.2%
Raw unexplained variance (total)	=	27.0 34.4%	100.0%	35.3%
Unexplned variance in 1st contrast	=	2.8 3.6%	10.5%	
Unexplned variance in 2nd contrast	=	2.7 3.5%	10.1%	
Unexplned variance in 3rd contrast	=	2.3 2.9%	8.3%	
Unexplned variance in 4th contrast	=	2.1 2.6%	7.6%	
Unexplned variance in 5th contrast	=	1.9 2.5%	7.2%	

Figure 4

The item analysis begins with an examination of the misfit order rankings in Figure 5. Item 11 exhibits large infit and outfit statistics, as well as a low point-biserial estimate. Perhaps this is not surprising as it was the only item to which no respondents chose *strongly disagree*. Acceptable infit and outfit statistics should fall within a range of 0.6 to 1.4. The point-biserial should be positive, and preferably above 0.3. When these statistics do not agree, the point-

biserial is considered to be more predictive. At this point, item 11 is the only item with a point-biserial below 0.3 and is a good candidate for removal.

Item STATISTICS: MISFIT ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
11	141	42	-2.52	.32	2.44	4.6	2.21	1.8	A .28	.66	59.5	70.7	11 Open to New Tech
25	114	42	-.15	.28	1.98	3.6	1.91	3.0	B .65	.76	33.3	62.7	25 SmartPhone App
9	101	42	.82	.27	1.82	3.2	1.90	3.3	C .67	.77	50.0	62.8	9 Safer than Truck
5	116	42	-.31	.28	.81	-.9	1.59	2.0	D .65	.75	69.0	63.4	5 Bene to Society
4	127	42	-1.21	.29	1.21	.9	1.52	1.4	E .63	.72	66.7	68.0	4 Medical Supplies
21	94	42	1.34	.27	1.21	1.0	1.25	1.1	F .74	.78	69.0	62.4	21 Exp but Fast
15	134	42	-1.84	.31	1.15	.7	.98	.1	G .77	.70	66.7	69.6	15 Tech is Risky RC
20	111	42	.08	.28	1.15	.7	1.05	.3	H .79	.76	52.4	62.2	20 Impersonal RC
12	127	42	-1.21	.29	.68	-1.5	1.08	.4	I .79	.72	73.8	68.0	12 Pizza
16	112	42	.00	.28	1.07	.4	1.04	.2	J .79	.76	50.0	62.4	16 Bene to Family
19	103	42	.68	.27	.94	-.2	1.04	.2	K .73	.77	66.7	62.5	19 Collision RC
10	113	42	-.07	.28	1.00	.1	1.00	.1	L .69	.76	61.9	62.3	10 DropOff Area
17	105	42	.53	.27	.89	-.5	.82	-.8	M .82	.77	61.9	62.8	17 No Night Fly RC
1	105	42	.53	.27	.86	-.6	.85	-.6	N .83	.77	66.7	62.8	1 Tech is safe
23	113	42	-.07	.28	.81	-.9	.85	-.5	m .79	.76	66.7	62.3	23 Cheaper
3	98	42	1.04	.27	.83	-.8	.83	-.8	l .84	.78	66.7	62.5	3 Trust fragile
27	119	42	-.55	.28	.81	-.8	.76	-.8	k .85	.75	64.3	64.6	27 Willing to Try
14	100	42	.90	.27	.78	-1.0	.80	-.9	j .83	.77	61.9	62.8	14 Not Home
7	132	42	-1.66	.30	.78	-.9	.71	-.6	i .72	.70	66.7	69.1	7 Threat to Soc RC
2	95	42	1.26	.27	.71	-1.5	.75	-1.1	h .83	.78	73.8	62.5	2 Trust Valuable
24	104	42	.60	.27	.75	-1.2	.75	-1.1	g .87	.77	66.7	62.6	24 Faster
8	100	42	.90	.27	.71	-1.4	.68	-1.6	f .84	.77	76.2	62.8	8 Exclusive Use
26	113	42	-.07	.28	.64	-1.8	.68	-1.4	e .77	.76	66.7	62.3	26 Wrong Place RC
13	71	42	2.16	.30	.67	1.6	.60	1.1	d .84	.77	76.2	68.6	13 Confidential

Figure 5

Further examination of misfit order is shown in Figure 6. The measures of average ability should be monotonic, yet items 4, 11, 21 and 25 are not. In themselves, these estimates are not necessarily cause for removal, but upon closer review, each of these items appear to be mismatched in the context of the whole survey. The double-barreled nature of item 21 ("*I would choose drone delivery if it was more expensive, but much faster, than conventional delivery*") is likely causing a misfit and was later removed.

Item CATEGORY/OPTION/DISTRACTOR FREQUENCIES: MISFIT ORDER

ENTRY NUMBER	DATA CODE	SCORE VALUE	DATA COUNT	DATA %	AVERAGE ABILITY	S.E. MEAN	OUTF MNSQ	PTMEA CORR.	Item	
11	A 2	2	5	12	.33	.49	4.1	-.03	11 Open to New Tech	2 "Disagree"
	3	3	17	40	-.47*	.34	1.0	-.36		3 "Agree"
	4	4	20	48	1.34	.61	2.2	.37		4 "Strongly Agree"
25	B 1	1	7	17	-1.80	.61	1.7	-.46	25 SmartPhone App	1 "Strongly Disagree"
	2	2	9	21	.16	.39	2.1	-.08		2 "Disagree"
	3	3	15	36	-.05*	.41	1.6	-.18		3 "Agree"
	4	4	11	26	2.96	.56	1.4	.66		4 "Strongly Agree"
9	C 1	1	10	24	-1.08	.42	1.7	-.40	9 Safer than Truck	1 "Strongly Disagree"
	2	2	13	31	-.31	.58	3.1	-.24		2 "Disagree"
	3	3	11	26	.74	.34	.9	.07		3 "Agree"
	4	4	8	19	3.41	.62	1.7	.64		4 "Strongly Agree"
5	D 1	1	2	5	-3.52	.08	.3	-.41	5 Bene to Society	1 "Strongly Disagree"
	2	2	8	19	-1.08	.42	.8	-.35		2 "Disagree"
	3	3	30	71	.91	.35	2.8	.30		3 "Agree"
	4	4	2	5	4.55	.35	.1	.41		4 "Strongly Agree"
4	E 1	1	2	5	-1.74	.90	1.9	-.23	4 Medical Supplies	1 "Strongly Disagree"
	2	2	5	12	-2.16*	.64	.6	-.44		2 "Disagree"
	3	3	25	60	.37	.32	2.1	-.07		3 "Agree"
	4	4	10	24	2.57	.73	1.4	.53		4 "Strongly Agree"
21	F 1	1	9	21	-1.64	.49	1.0	-.50	21 Exp but Fast	1 "Strongly Disagree"
	2	2	20	48	-.14	.25	.8	-.27		2 "Disagree"
	3	3	7	17	3.08	.69	1.0	.52		3 "Agree"
	4	4	6	14	2.78*	.76	2.7	.42		4 "Strongly Agree"
15	G 1	1	2	5	-2.83	.76	1.1	-.34	15 Tech is Risky RC	1 "Strongly Disagree"

Figure 6

After a number of successive trials, a total of five items were removed from the survey.

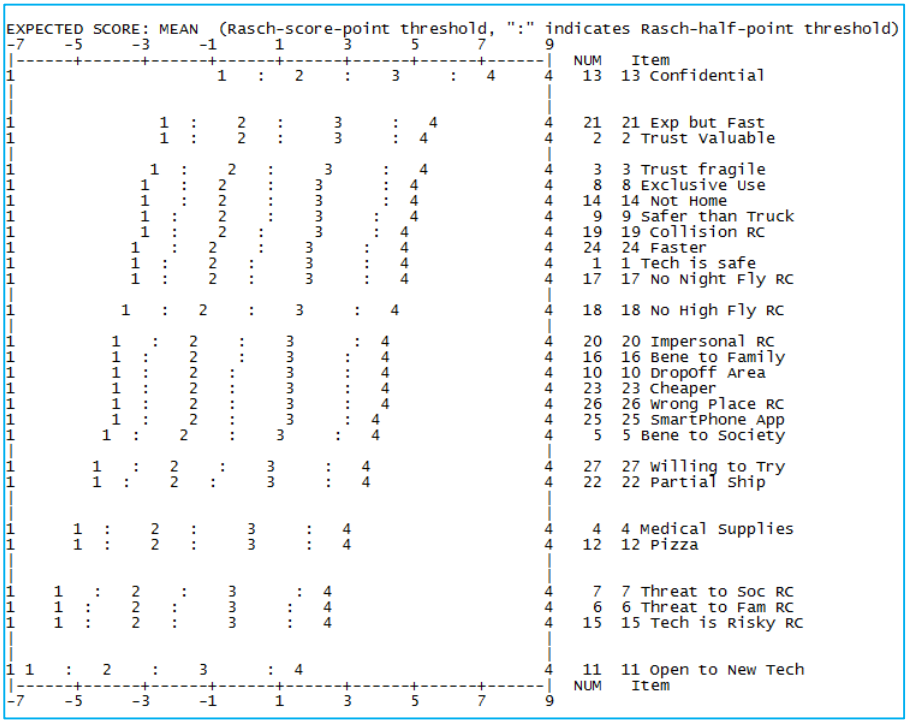


Figure 7

The *diagnostic keyform* table in Figure 7 appears to show significant "stacking" in the center of the item distribution. Ideally, a truly linear measure would disperse the items evenly throughout the domain, though the sort of distribution shown in Figures 7 and 8 are not uncommon.

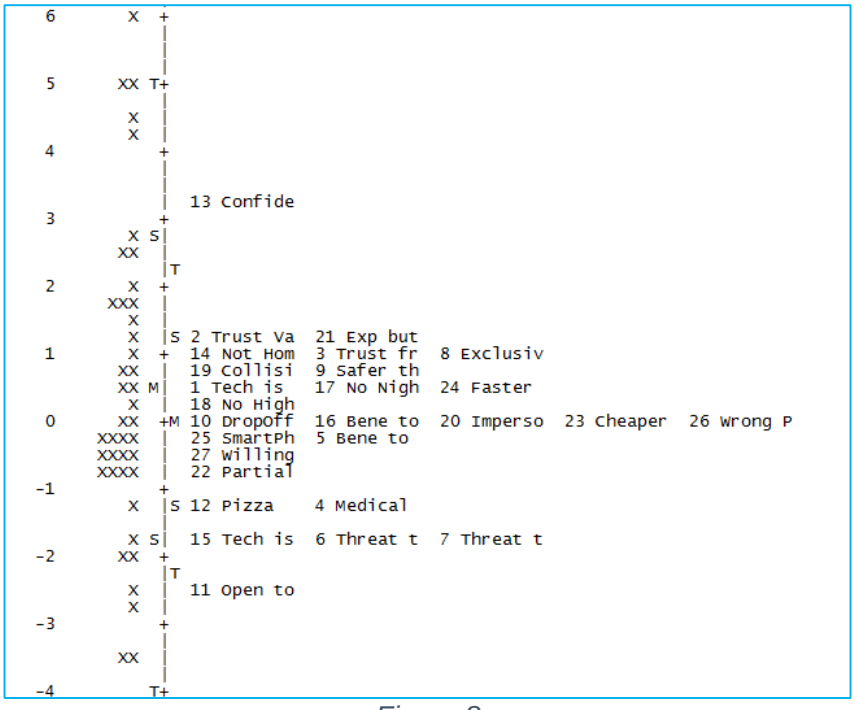


Figure 8

Figure 8 shows why this lack of dispersion may be a problem. While the distributions of items and people may be evenly centered, there is little to measure respondents with "extreme" logit scores – particularly at the higher end. This might suggest that some of the respondents were excited about the possibility of drones beyond that which was prompted by the survey items. This may not be surprising. Consider the sample. Youngsters in American society tend to be very "gadget-focused" and therefore might have answered positively to almost anything. But that is an inference of intuition. From a purely measurement view, the instrument scale should be able to account for these individuals.

The analysis of people begins with the output shown in Figure 9. In this figure, the misfit order of people suggests that persons 2, 35 and possibly 6 may be a problem. The standards for infit, outfit and point-biserial statistics are the same as they were for items, and all of these respondents exhibit high outfit statistics. Most striking is the point-biserial for person 2. It is hard to say exactly why person 2 would have this score - except to say that he or she was *moving in another direction*, as it were. This person was removed from the sample.

Person STATISTICS: MISFIT ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
2	87	22	7.65	1.13	1.56	.8	3.74	1.6	A -.08	.33	95.5	95.5	02
35	85	22	6.13	.70	.94	.1	2.72	1.5	B .31	.42	90.9	89.1	35
6	70	22	2.49	.45	1.82	2.1	1.96	2.4	C .43	.58	72.7	72.8	06
3	73	22	3.08	.45	1.62	1.9	1.60	1.8	D .50	.56	63.6	69.5	03
25	37	22	-2.99	.40	1.45	1.6	1.59	1.6	E .41	.55	59.1	62.2	25
7	62	22	.96	.42	1.46	1.4	1.57	1.6	F .75	.57	45.5	67.8	07
36	82	22	5.05	.53	1.45	1.4	1.20	.5	G .18	.47	63.6	77.1	36
33	50	22	-.99	.39	1.44	1.4	1.40	1.3	H .49	.59	50.0	65.4	33
32	28	22	-4.77	.52	1.34	1.0	1.04	.3	I .42	.46	72.7	79.4	32
41	37	22	-2.99	.40	1.33	1.2	1.28	.9	J .47	.55	45.5	62.2	41
26	29	22	-4.51	.49	1.25	.8	1.30	.6	K .24	.48	68.2	77.0	26
12	63	22	1.14	.43	1.22	.8	1.25	.8	L .72	.57	59.1	68.7	12
15	61	22	.78	.42	1.18	.7	1.24	.8	M .41	.57	54.5	66.5	15

Figure 9

While statistics for persons 35 and 6 were suspicious, their removal was shown to have no positive effect on the reliability of the instrument, and were left in.

While the resulting instrument exhibited a number of positive characteristics, it was also clear that a further grounding in theory might serve to improve the unidimensionality of the measure. However, to do this, a more structured approach toward item development needed to be adopted. The pre-pilot described above, aligned well with the propositions offered in Ramadan, Farah and Mrad (2017), though the issue of personification was not fully explored.

USE OF FOCUS GROUPS FOR SURVEY ITEM DEVELOPMENT

Using insights gained in the development of the pre-pilot, a series of structured discussion points were assembled for use with a number of focus groups. Greenbaum (1988) was used extensively in the design and execution of this phase of the project. A general outline of the methodology is as follows:

- Define the data-gathering objectives
- Define the parameters of the situation, stimuli to be used, and discussion points
- Define the group composition
- Arrange for a suitable location
- Prepare for unexpected group dynamics

In the USPS report, a great deal of attention was paid to demographics. If the ultimate objective of the project was to develop a demographic profile of likely acceptance of drones, then the group composition should be stratified as specified in the report: by generation and gender. In this way, the specific objective of the groups would be to assemble a series of survey items that accurately reflected the perceived benefits and concerns of commercial drone delivery.

The program for the focus group would proceed as follows. First, group members would be shown four still pictures of drones: a military drone, a surveillance drone, a hobbyist's drone equipped with a camera, and a small toy drone being operated by a child. Members would be asked to write down four words to describe their reaction to these images. These responses would then be discussed.

Next, an early commercial produced by Amazon.com would be shown to the members. This video contains no dialogue, but follows a buyer placing an order online, the items being picked in a distribution center and loaded onto a drone, and the arrival of the package at the buyer's home. This time, members would be asked to write down three positive words to describe what they viewed and two negative words. This would be followed by a discussion in which members would be asked to imagine that they were part of a marketing team that wanted to debut the new service. They would then be asked about specific concerns that they might need to address.

Finally, a second Amazon.com video would be shown to the group members. This video was a humorous, fully-fledged commercial intended to highlight the benefits of the service. This time the members would be asked to write down two positive words and three negative words in reaction to the video. The final discussion would ask the members to suggest possible survey items.

The original plan was to hold seven separate focus group sessions with the following compositions. Each group would consist of eight members. Three session of millennials – one all girl, one all boy, and one mixed. Two groups of Baby Boomers – one all women, one all men. Finally, there were to be two additional Baby Boomer groups with mixed genders, but arrangements could not be made within the time allotted.

The primary concern in screening the potential group members was to ensure that friends were not in the same group. The idea is to encourage all members to speak freely, and this become more difficult when there are such preset subgroups. Likewise, the moderator had to be prepared to handle members that dominated the discussion or those that were reluctant to speak at all. Fortunately, having taught a number of undergraduate courses in business, the moderator was well-aware of these issues of group dynamics and was prepared.

In total, five focus groups were assembled and the program was executed perfectly during the month of March, 2018. The Millennial groups were assembled from volunteers at the University of Toledo and the Purdue Fort Wayne campus. The Baby Boomer groups consisted of volunteers from various administrative departments from Purdue Fort Wayne.

During these sessions, the idea of personification was explored in terms of brand recognition. Both videos were produced by Amazon.com and they have managed to dominate much of the discussion regarding the future of drone use. Yet, only a single group member expressed any tendency to associate this new service with any vendor.

Backward Translation

The questions listed in Appendix 2 were assembled after careful review of the group recordings. A number of the questions from the pre-pilot were close enough to what had been suggested in the group sessions that the wording survived the revision.

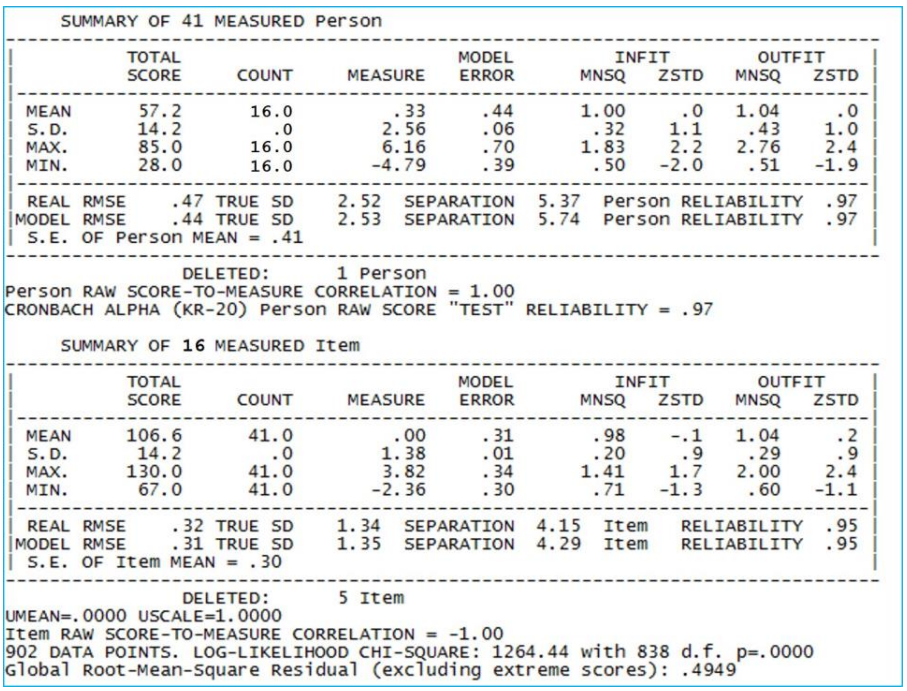
A technique called *backward translation* was used to ensure that the questions retained their intended meaning when read by respondents of differing cultural contexts. A list of

proposed questions was given to a student at Purdue Fort Wayne that was fluent in German for written translation. The German text was given to a graduate student at the University of Toledo to translate back into English.

Of the 16 questions translated, none had lost their original meaning. The grammatical structure of three sentences were altered, though this did not change the intended message. In all three cases, the questions were shortened and given back to the second translator. In each case, the reduced length returned the structure to its exact original form.

RASCH ANALYSIS OF THE PRIMARY SURVEY INSTRUMENT

The summary statistics for the revised survey instrument included in Figure 10. Of particular interest is the Person Separation value of 5.74. In Rasch, *separation* suggests the extent to which one set of parameters of a group can be estimated separately from another. Person Separation implies the number of distinct groupings of respondents with commonalities (Bond and Fox, 2015). Here, a value of 5.74 suggests that the analysis found six distinct groups within the sample. Often such analyses find only three or four. Finding more than four is very encouraging for this sample size.



SUMMARY OF 41 MEASURED Person

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	57.2	16.0	.33	.44	1.00	.0	1.04	.0
S.D.	14.2	.0	2.56	.06	.32	1.1	.43	1.0
MAX.	85.0	16.0	6.16	.70	1.83	2.2	2.76	2.4
MIN.	28.0	16.0	-4.79	.39	.50	-2.0	.51	-1.9

REAL RMSE	.47	TRUE SD	2.52	SEPARATION 5.37	Person RELIABILITY .97
MODEL RMSE	.44	TRUE SD	2.53	SEPARATION 5.74	Person RELIABILITY .97

S.E. OF Person MEAN = .41

DELETED: 1 Person

Person RAW SCORE-TO-MEASURE CORRELATION = 1.00

CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .97

SUMMARY OF 16 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	106.6	41.0	.00	.31	.98	-.1	1.04	.2
S.D.	14.2	.0	1.38	.01	.20	.9	.29	.9
MAX.	130.0	41.0	3.82	.34	1.41	1.7	2.00	2.4
MIN.	67.0	41.0	-2.36	.30	.71	-1.3	.60	-1.1

REAL RMSE	.32	TRUE SD	1.34	SEPARATION 4.15	Item RELIABILITY .95
MODEL RMSE	.31	TRUE SD	1.35	SEPARATION 4.29	Item RELIABILITY .95

S.E. OF Item MEAN = .30

DELETED: 5 Item

UMEAN=.0000 USCALE=1.0000

Item RAW SCORE-TO-MEASURE CORRELATION = -1.00

902 DATA POINTS. LOG-LIKELIHOOD CHI-SQUARE: 1264.44 with 838 d.f. p=.0000

Global Root-Mean-Square Residual (excluding extreme scores): .4949

Figure 10

The effect of the revisions on these statistics was marginal, but interesting. The item separation increased from 4.07 to 4.29, and the item reliability increased from 0.94 to 0.95. A hit was taken on person separation (decreased from 5.81 to 5.74), but as seen in Figure 11, there was an improvement in dimensionality. The raw empirical variance explained by measures increased from 65.6% to 69.1%.

```
    Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)
                                              -- Empirical --    Modeled
Total raw variance in observations     =         71.1 100.0%          100.0%
  Raw variance explained by measures   =         49.1  69.1%           68.5%
    Raw variance explained by persons  =         33.1  46.5%           46.1%
    Raw variance explained by items    =         16.0  22.5%           22.4%
  Raw unexplained variance (total)     =         22.0  30.9% 100.0%    31.5%
    Unexplned variance in 1st contrast =          2.7   3.8%  12.2%
    Unexplned variance in 2nd contrast =          2.5   3.5%  11.4%
    Unexplned variance in 3rd contrast =          2.2   3.0%   9.8%
    Unexplned variance in 4th contrast =          1.8   2.6%   8.4%
    Unexplned variance in 5th contrast =          1.7   2.4%   7.7%
```

Figure 10

However, Figure 12 shows that the concern regarding the category structure may have been justified.

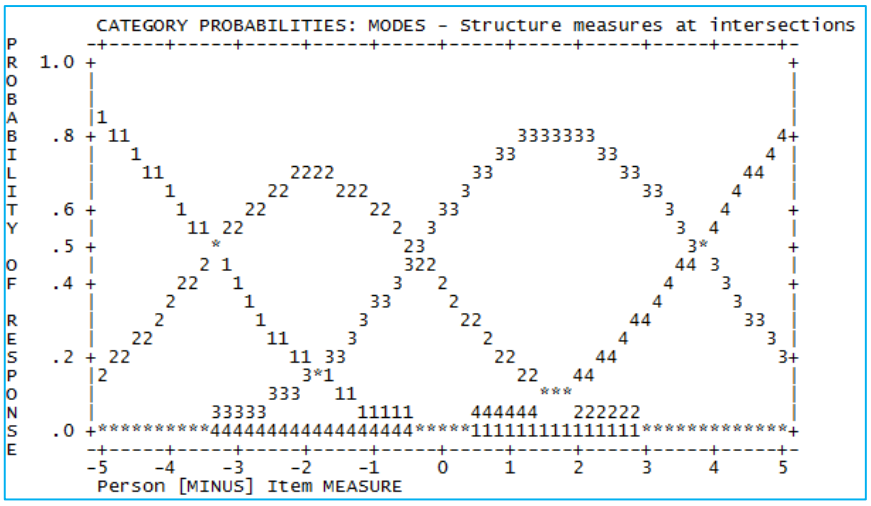


Figure 11

The structure shows Andrich threshold separation of roughly 3 with the probability curves at or approaching 80%. In retrospect, the scale could have included more categories. The decision to use a 4-point scale was based on the agree/disagree nature of the scale. If an odd-numbered scale is to be avoided, how would a 6-point scale be worded?

Strongly Disagree	Disagree	Mildly Disagree	Mildly Agree	Agree	Strongly Agree

This scale seemed likely to cause confusion as respondents might not be able to distinguish between the pairs on either side of the middle.

Person STATISTICS: MISFIT ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
35	85	22	6.16	.70	.95	.1	2.76	1.5	A .31	.43	90.9	89.2	35
6	70	22	2.50	.45	1.83	2.2	1.97	2.4	B .43	.58	72.7	72.8	06
3	73	22	3.10	.45	1.63	1.9	1.61	1.8	C .50	.57	63.6	69.6	03
25	37	22	-3.00	.40	1.46	1.6	1.59	1.6	D .41	.55	59.1	62.4	25
7	62	22	.96	.42	1.47	1.5	1.58	1.7	E .74	.57	45.5	67.8	07
36	82	22	5.08	.53	1.47	1.5	1.20	.5	F .18	.47	63.6	77.1	36
33	50	22	-1.00	.39	1.45	1.4	1.40	1.3	G .49	.60	50.0	65.5	33
32	28	22	-4.79	.52	1.35	1.0	1.05	.3	H .42	.46	72.7	79.4	32
41	37	22	-3.00	.40	1.33	1.2	1.28	.9	I .47	.55	45.5	62.4	41
26	29	22	-4.53	.49	1.26	.8	1.32	.7	J .24	.48	68.2	77.1	26
12	63	22	1.14	.43	1.22	.8	1.25	.8	K .73	.57	59.1	68.7	12
15	61	22	.79	.42	1.19	.7	1.25	.8	L .41	.57	54.5	66.6	15
1	84	22	5.72	.62	1.06	.3	1.24	.5	M .35	.45	86.4	85.2	01
4	71	22	2.70	.45	1.18	.7	1.21	.7	N .33	.58	63.6	72.0	04
40	52	22	-.69	.40	1.18	.7	1.09	.4	O .57	.59	54.5	64.6	40
16	50	22	-1.00	.39	1.13	.5	1.13	.5	P .54	.60	59.1	65.5	16
28	82	22	5.08	.53	1.08	.4	1.06	.3	Q .38	.47	81.8	77.1	28
13	62	22	.96	.42	1.04	.2	1.07	.3	R .48	.57	63.6	67.8	13

Figure 12

As mentioned, it was decided that persons 35 and 6 were not to be removed. This decision is bolstered by the results shown in Figure 13. After the removal of person 2, person 35 was still suspect, but made little difference.

Lastly, an advantage of Rasch over traditional methods is the manner in which the analysis can be used to address how the construct being measured speaks to the underlying theory. Using a more structured, theoretical approach made significant improvements in the performance statistics of the survey instrument.

DISCUSSION AND CONCLUSIONS

Iacobucci and Churchill (2015) draw a distinction been *marketing* research and *market* research. The former establishes the relationship between specific potential customers (often in terms of demographics) and product concepts. An important end product of marketing research is a customer profile by market segmentation. This profile serves as a basis to project likely market reaction (and sales) to a given product. The data used in marketing research is nearly always through primary means (surveys, focus groups, etc.) and is typically proprietary. Whereas, market research looks at specific markets (typically geographic locations) through secondary data. A customer profile can then be applied to the market in question to predict likely sales. The measurement instrument developed here was specifically intended to help firms generate customer profiles by gender and generation.

Unlike surveys intended to support a theoretical model with a series of hypotheses, the instrument developed here is a pure measurement tool. Just as the Wechsler Adult Intelligence Scale is used by researchers in psychology, this measurement of drone acceptance could be used in the analysis of a specific market. Where customer satisfaction measurements (such as the CSAT or NPS) are more general tools, this measurement scale is tailored specifically on a single issue and was intended primarily for primary market research.

The revised survey instrument appears to function reasonably well, but cannot be rigorously validated until certain issues are addressed. First, a much wider sample must be taken. One possible method might be through the use of Amazon's Mechanical Turk program. This program was designed to survey customers after they have made a purchase. The reported response rates from this program are claimed to be "much higher than traditional survey methods". Every survey is different, and it's hard to see how such a claim could be

made. However, this method has the advantage of reaching the very audience intended in the first stage of this study.

Second, consider expanding the category structure. To stay with the rating scale model, each step difficulty would have to be the same – otherwise the model would have to switch to a partial credit or ranks model. Therefore, it would be best to use the same category structure throughout the survey, but it need not be in the form of *agree*/*disagree*. An alternate structure might take the *too little*/*just right*/*too much* form.

Finally, items should be developed to fill the gaps in the measurement scale. It was postulated that some respondents may be so willing that they'd agree to *anything*. If this is true, it might be well to exclude these individuals from a subsequent sample. They might be included in a report of counts, but their inclusion in the analysis does not further the research interest at issue. They were not excluded from this pilot study, in part, due to the limited sample size.

APPENDIX 1

Pre-pilot Survey Questions

Respondents were asked to indication the extent to which they agreed or disagreed with the following statements:

1. This technology is safe.
2. I would trust a drone to carry something of value.
3. Drones are no more likely to damage fragile packages than a delivery truck.
4. Drones would be a good way to deliver emergency medical supplies.
5. This technology is beneficial to society.
6. This technology is threatening to my family and me.
7. This technology is threatening to society.
8. I would be willing to order from a company that exclusively used drones for deliveries.
9. This technology is as safe, or safer, than other technologies that perform the same task.
10. I would be willing to go to a designated drop-off area.
11. I am open to new technologies.
12. I would have a drone deliver a pizza.
13. I would trust a drone to carry confidential information.
14. I would be willing to have a drone deliver a package when I am not home.
15. This technology is risky.
16. This technology is beneficial to my family and me.
17. Drones should be restricted from flying at night.
18. Drones should not be allowed to fly above a certain height.
19. If delivery drones became very popular, then dangerous collisions would be likely.
20. Delivery drones would be too impersonal.
21. I would choose drone delivery if it was more expensive, but much faster, then conventional delivery.
22. If a drone could only carry part of my order (other parts were too heavy), I would still prefer drones to deliver as much as they could.
23. I would choose drone delivery if it was cheaper than traditional delivery.
24. I would choose drone delivery if it was faster than traditional delivery.
25. All drone deliveries should work with a smart phone app.
26. I am concerned that the drone would deliver my package to the wrong place.
27. I would be willing to try drone delivery.

APPENDIX 2

Primary Survey Questions
Respondents were asked to indicate the extent to which they agreed or disagreed with the following statements:

1. Drones would be fast.
2. I would trust a drone to carry something of value.
3. Drones should be restricted from flying at night.
4. Drones would be safe.
5. Drones should not be allowed to fly above a certain height.
6. Deliveries would be environmentally friendly.
7. Drone deliveries would be worth an extra expense.
8. Drones might be used in a way that invades my privacy.
9. Drones would give me more control over where I receive my package.
10. Drones would have no place to land at my residence.
11. Drone might deliver my package to the wrong place.
12. The package it's carrying might be stolen.
13. Drones might malfunction and damage the package they're carrying.
14. Drones would give me more control over when I receive my package.
15. I would be willing to have a drone deliver a package when I am not home.
16. I would be willing to go to a designated drop-off area.

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Quantitative Models of Supply Chain Risk Management: A Systematic Review of Literature

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ABSTRACT

This paper is aimed at reviewing the literature in the domain of quantitative models in supply chain risk management. Screened papers from 2008 to 2018 are analyzed and classified based on the nature of modeling technique being used and the key dimension of supply chain being discussed. We found out that stochastic models are used widely to explain demand uncertainties whereas simulations are used in various manners to explain supply chain network designs. This paper provides a methodical review of journal articles in the domain of quantitative models in supply chain risk management.

KEYWORDS: Supply Chain Risk Management, Modeling Techniques, Supply chain strategy

INTRODUCTION

Academic and industry practitioners have become seriously interested in supply chain risk over the past decade, attributed to supply chain disruptions caused by natural disasters or intentional or unintentional human actions (Snyder et al., 2016). Supply chains, globally are becoming more vulnerable with large unanticipated events (Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007). Supply chain disruptions have deeply impacted firms' performance in recent years (Ho, Zheng, Yildiz, & Talluri, 2015). A number of broad models have been suggested for recognizing and weighing supply chain risks including cause and effect diagrams, social network theory, interpretative network modeling, FMEA, identifying interdependent enablers of risk mitigation and Risk Priority Number analysis (Kim, Choi, Yan, & Dooley, 2011; Lin & Zhou, 2011; Nishat Faisal, Banwet, & Shankar, 2006; Pfohl, Gallus, & Thomas, 2011; Tuncel & Alpan, 2010). Some quantitative and sophisticated models include analytical models (deterministic and stochastic), simulations, AHP, fuzzy set theory, multi-echelon, Linear programming and Integer linear programming models.

In the last decade, four articles were published on supply chain risk management review. 55 articles published between 1994 and 2010 were reviewed by Colicchia and Strozzi (2012) revealed the trend and evolutionary patterns in the field of SCRM. Rao and Goldsby (2009) reviewed 55 journal articles and established a typology of various risk factors. O. Tang and Musa (2011) reviewed 138 journal articles and identified and classified various risks associated with information, financial and material flows. Sodhi, Son, and Tang (2012) formulated their own perception of diversity in SCRM by reviewing 31 journal articles.

Earlier research works have primarily focused on particular topics of SCRM such as risk classification or risk factor analysis or risk gap identification. None of the earlier research works have discussed categorization of quantitative modeling in supply chain risk management. In order to fill this gap, this paper presents a comprehensive review of all quantitative articles from specified journals published between 2008 and 2017 undertaking a classification scheme.

Classical categories of supply chain risk have been proposed by Beamon (1998). He makes a distinction between deterministic analytical, stochastic analytical, economic and simulation models. Another classification scheme provided by R. S. Gaonkar and Viswanadham (2007) focused on the dimensions of supply chain risk based on deviations in sourcing strategies, demand uncertainties and supply chain network.

We will be using these baseline classification schemes to categorize various supply chain risk management models in the literature.

LITERATURE REVIEW

In supply chain risk management literature, the differentiation between risk and uncertainty is not clear. Supply chain risk can be referred to the events that have small possibility but may occur abruptly and such events can have substantial negative consequences on the system (O. Tang & Musa, 2011). Supply chain risk can occur at any stage in the whole supply chain. Supply chain is a complicated production system. It is an integration of different processes instead of individual functions. Issues of supply chain risk are evident at sourcing, operations and customer service levels in a typical supply chain.

Sourcing strategies have gained importance, since the supply chains have become globally dispersed. Supply chains, globally are becoming more vulnerable with large unanticipated events (Craighead et al., 2007). Snyder et al. (2016) explained that academic literature on supply chain disruptions has increased significantly since 1994. The interest of academics in supply chain risk has amplified based on a number of reasons. First, several high-profile events like September 11 attack, hurricanes like Katrina in 2005, Tsunami in 2004, Thai flood in 2011 have aggravated the need of literary work in supply chain risk management. Another reason for growing importance of supply chain risk is the phenomena of global supply chain. Firms' supply chain partners are located across the world and increased lead times have raised issues in supply chain risk. Even a small disruption in supply chain can have devastating impact throughout the supply chain for example, in 1998, 100 part plants were shut down as a result of knock on effect of strikes at two parts plants at General Motors. It further led to closure of 26 assembly plants, leaving dealers vacant for months (Simison, 1998). The examples just discussed show that supply disruptions could result from major event but might also be attributed to less severe, less global events. There are different studies that have evaluated the performance of various sourcing strategies to counter disruption. For instance, Berger, Gerstenfeld, and Zeng (2004) modeled a decision making process of identifying number of suppliers in the presence of risk. Ruiz-Torres and Mahmoodi (2007) proposed a deterministic model where probability of failure of suppliers in delivering the product is tested. Meena, Sarmah, and Sarkar (2011) developed and tested a stochastic model to determine optimal number of suppliers considering different failure probability, capacity and compensation. Multi-sourcing is a better strategy than single or dual sourcing under supply chain disruptions (Meena et al., 2011). Anupindi and Akella (1993) developed a model when demand is stochastic and continuous distribution. There are numerous studies that model sourcing in different analytical ways.

While sourcing is important to manage depending on supply chain risk, demand uncertainties can affect customer service levels. The complex a supply chain is, the more difficult it becomes to cope with uncertainties. Schmitt (2011) modeled a multi-echelon system where disruption can occur at any stage and they evaluate multiple strategies to protect customer service if in any case disruption occurs. They found out that a two-stage multi-echelon system is the simplest of all. Such type of system was used by Bollapragada, Rao, and Zhang (2004) and Qi, Shen, and Snyder (2009) to consider uncertain lead time due to capacitated supply and maintain focus on service levels in the network. Inventory was allowed to be held on lower echelon and disruptions are allowed at other locations. A close form solution was developed approximating the cost function.

Covering the above discussed ends of supply chain i.e., sourcing and customer service level, supply chain network also encompasses manufacturing sub-systems. SC network design is the basic decision of supply chain management. Operational decisions, such as operational

inventory holding and transportation costs are the key decisions in supply chain network design. Baghalian, Rezapour, and Farahani (2013) advanced a stochastic mathematical formulation to design a supply chain network of multi-product supply chains spanning different production facilities, distribution centers and retailers under uncertainty.

THEORETICAL DEVELOPMENT/MODEL

The purpose of literature reviews is to aim and map body of literature focusing on potential research gaps and highlighting boundaries of knowledge (Tranfield, Denyer, & Smart, 2003). Systematic literature reviews ae completed through an iterative process of identifying the appropriate literature through keywords (Saunders, Lewis, & Thornhill, 2007). We used the key terms “Supply chain risk”, “Quantitative models in supply chain risk” and “techniques in supply chain risk management”. Various academic databases were explored like emerald, Taylor and Francis, ScienceDirect, Springer, IEEExplore and Wiley. The key words returned a total of 324 articles. Trend showed that over the past decade, the supply chain risk management has been an area of interest for the researchers.

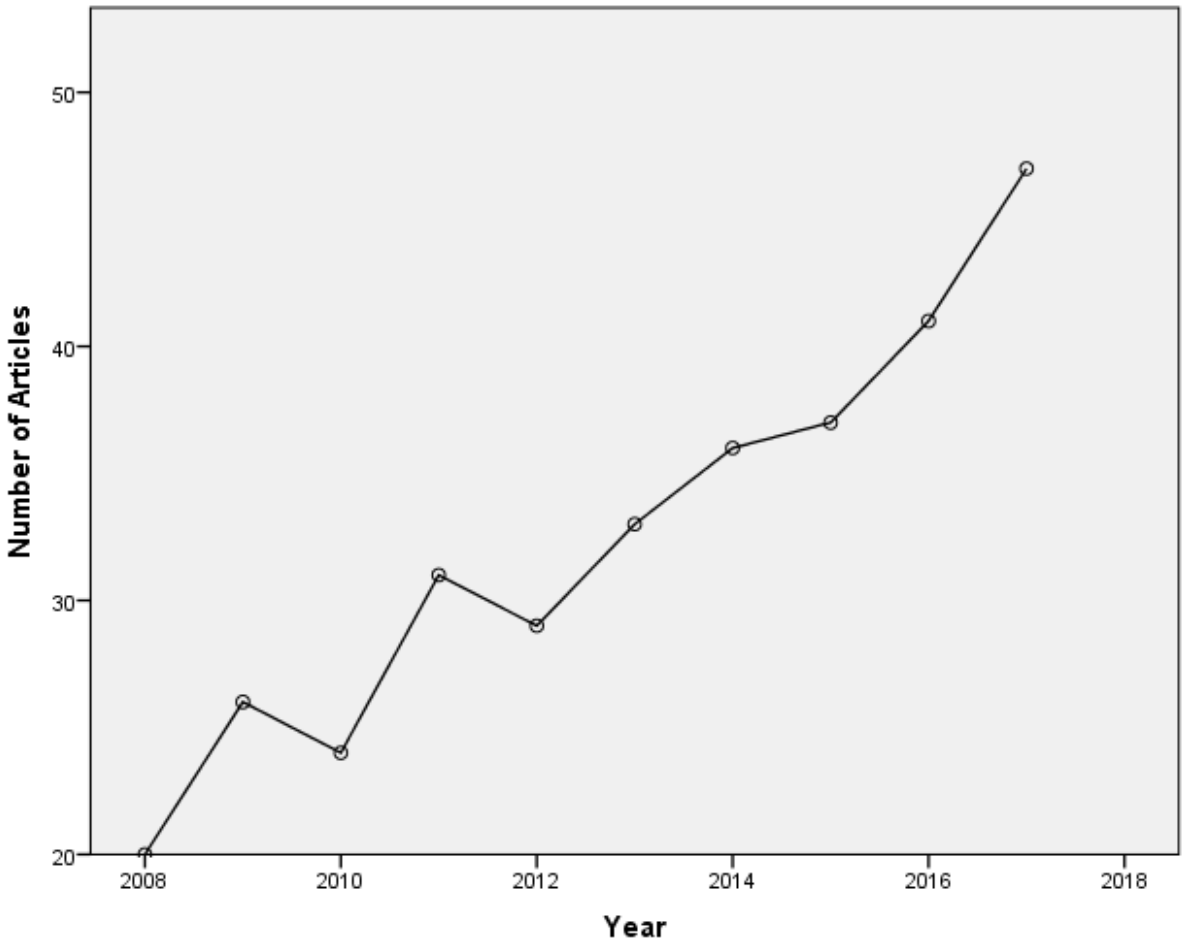

Fig 1

We screened 38 articles (Appendix A) for relevance in terms of specific models to be discussed as per our classification scheme explained below:

Suitable Framework for Development and Classification of Models in Supply Chain Risk Literature:

Within Supply Chain Risk management, there are hardly any frameworks that classify modeling techniques. R. Gaonkar and Viswanadham (2004) provided a broader framework of supply chain uncertainty: Deviation, Disruption and Disaster. Deviations refer to variations in demand, supply or in any other supply chain related process like procurement, costs and production. In a further refined work, R. S. Gaonkar and Viswanadham (2007) divided the risk management process between inbound logistics, operations and outbound logistics. Inbound logistics tackles the concern like sourcing strategies. Outbound logistics is concerned with demand and service level uncertainties and operations are mainly concerned with supply chain network design (SND) issues as supply chain network design is considered to be the most important step for decreasing the overall cost or increasing the overall profits of the chain (Simchi-Levi, Kaminsky, & Simchi-Levi). Another framework by Beamon (1998) categorizes supply chain design and analysis into four types of models (1) Deterministic analytical (2) Stochastic analytical (3) Economic models and (4) Simulation models.

Deterministic Analytical Models:

Based on our classification scheme as discussed above, we evaluated deterministic analytical models based on mathematical programming including “linear programming, non-linear programming, mixed-integer non-linear programming and multi-objective programming”. Mathematical modeling can have either deterministic or stochastic parameters. Various deterministic analytical models have been formulated in discussing sourcing strategies, demand uncertainties and supply chain network designs.

Chen and Yano (2010) provided a model that discussed weather-linked rebate for a manufacturer in order to increase profits. The basic model includes a retailer and a manufacturer that sells seasonal goods under demand uncertainty. The ultimate goal was to improve the coordination in supply chain thus improving profit allocation between two parties. Similarly, Schmitt and Singh (2012) stressed the importance of network utilization and proactive planning I a multi-echelon supply chain under disruption risk. Firm’s resilience to disruption in supply chain largely depends on the measures they have taken in the system by using different models to evaluate impact of risk (C. S. Tang, 2006).

Sourcing strategies have also beein thorouhgly investigated using different mathematical models under deterministic parameters. Yu, Zeng, and Zhao (2009) obtained an objective function to measure the expected profits of two different sourcing modes in the presence of supply chain risk. They also measured the sensitivty of buyer’s expected profits to various inputs with differnet examples. It is believed that multiple sourcing has proven benefits over single sourcing in terms of cost, quality and profits (Silbermayr & Minner, 2014).

Mathematical programming models with deterministic parameters have also been used to evaluate supply chain network designs of organizations under supply chain risk. Huang and Goetschalckx (2014) developed mathematical formulation based on mean-standard deviation for robust supply chain design as the set of all pareto optimal configurations. Wang, Lai, and Shi (2011) developed a multi-objective optimization model that can be used as an effective tool towards green supply chain management.

Stochastic Analytical Models:
Stochastic programming is a framework for modeling optimization problems with the inclusion of uncertainty. Stochastic distribution is widely used to measure demand uncertainties (Hamdi, Ghorbel, Masmoudi, & Dupont, 2018). Taskin and Lodree Jr (2010) assumed that demand is uniformly distributed in modeling variability. A stochastic model was developed by Xanthopoulos, Vlachos, and lakovou (2012) to capture trade-off between inventory policies and disruption risks in a dual sourcing supply chain based on normal distribution of demand. Retail firms also face a demand with uniform pattern Zhu and Fu (2013) based on a newsboy model. Song, Dong, and Xu (2014) developed stochastic model for multiple uncertainties such as production time, variable demands of customers and uncertain raw material supplies. They formed the problem based on multiple suppliers.

Similarly, Sawik (2014a) developed a stochastic mixed integer programming model to integrate supplier selection and customer order scheduling in presence of supply chain disruption risk. Apart from sourcing strategies, stochastic models have also been studied in supply chain network designs. Ramezani, Bashiri, and Tavakkoli-Moghaddam (2013) developed a multi-objecive stochastic model for forward/reverse logistics network design to evaluate systematic supply chain configuration. The focus was on maximizing profits and improving customer responsiveness and quality. A fuzzy inference system was developed by Paul, Sarker, and Essam (2017) to predict changes in future demand over base forecasr using a stochastic model.

As discussed above, demand uncertainties have been widely measured using stochastic models. Baghalian et al. (2013) developed a stochastic model for designing muli-product supply chain based on different production sites. This work extended the earlier work of El-Sayed, Afia, and El-Kharbotly (2010) who developed a multi-echelon forward/reverse logistics network design under risk.

From the discussion above, it is noted that stochastic models have been widely used for different supply chain dimensions under risk like sourcing strategies, network designs and demand/service uncertainties levels. Demand uncertainties have been widely discussed using stochastic models.

Simulation:
Simulation is a process of imitating a system or a real-world situation. Virtually, simulations are being used in every field such as performance optimization, safety engineering etc. Simulation allows us to study a system without building it (Hamdi et al., 2018). Simluation also allows us to find key soultions for uexpected scenarios. In our review, we find some key supply chain decisions based on simulations. Klibi and Martel (2012) used Monte Carlo approach to create plausible future scenarios for supply chain networks. Schmitt and Singh (2012) quantitatively analyzed disruption risk in multi-echelon supply chains using simulations. They showed that in order to control downside risk, a systematic approach is required. Simulations are majorly used in supply chain nerwork designs and sourcing strategies in contrast to stochastic models which are majorly used to meaure demand uncertainties. Costantino and Pellegrino (2010) proposed a real option approach for valuing probabilistic benefits of multiple sourcing. Wu (2012) simulated different interactions of prices, service, sales decision and performance in a multi-echelon supply chain.

Govindan and Fattahi (2017) simulated different situations in a glass supply chain under risk to come up with most effective decision under demand uncertainty.

Table 1 summarizes a 3 X 3 matrix against the two classification schemes discussed:

	Deterministic Analytical	Stochastic Analytical	Simulation
Sourcing Strategies	Silbermayr and Minner (2014) Yu et al. (2009) Li, Wang, and Cheng (2010) Kirytopoulos, Leopoulos, Mavrotas, and Voulgaridou (2010)	Sawik (2014a) Sawik (2014b) Iakovou, Vlachos, and Xanthopoulos (2010) Taskin and Lodree Jr (2010) Xanthopoulos et al. (2012)	Fang, Zhao, Fransoo, and Van Woensel (2013) Costantino and Pellegrino (2010)
Demand/Service uncertainties	Federgruen and Yang (2009) Schmitt (2011) Comes, Hiete, Wijngaards, and Schultmann (2011) Amin and Zhang (2013)	Sawik (2013) Xiao and Yang (2008) Baghalian et al. (2013) Song et al. (2014)	Schmitt and Singh (2012) Wu (2012)
Supply chain network design	Huang and Goetschalckx (2014) Chen and Yano (2010) Wang et al. (2011) Rezapour, Farahani, and Pourakbar (2017) Paul et al. (2017) Hasani and Khosrojerdi (2016)	Oliveira, Gupta, Hamacher, and Grossmann (2013) Goh, Lim, and Meng (2007) Azaron, Brown, Tarim, and Modarres (2008) Hahn and Kuhn (2012) Pishvaee and Torabi (2010) Ramezani et al. (2013) El-Sayed et al. (2010)	Klibi and Martel (2012) Govindan and Fattahi (2017) Pishvaee, Rabbani, and Torabi (2011)

Table 1

CONCLUSION

In this systematic literature review, we have presented a classification scheme based on Beamon (1998) and R. S. Gaonkar and Viswanadham (2007). There are four broad categories of models in supply chain namely (1) dterminisitc (2) stochastic (3) simulations and (4) economic model.s We used three categories out of the four mentioned under the classification process.
R. S. Gaonkar and Viswanadham (2007) divided supply chain risk management under three main processes of value chain i.e., inbound logistics, outbound logistics and operations. We discuss three main areas of supply chain risk (1) sourcing strategies (2) Supply chain network design (SND) and (3) Demand/service uncertainties. Based on the two classification scheme mentioned, we pursued a 3X3 matrix to come up with nine different categories of quantitative models in supply chain risk.

Initially, supply chain risk modeling was used as a key word to figure out various scientific research articles published in various academic databases. A total of 324 articles were screened to find out 38 most relevant articles falling under the classification scheme discussed. We found that stochastic models have been widely used to model demand uncertainties whereas simulations are majorly used for sourcing strategies and supply chain network designs.

Appendix A

Sr. No.	Author	Title	year	Journal	Modeling technique	Main focus	Key pertinent findings
1	(Fang et al.)	Sourcing strategies in supply chain risk management: An approximate dynamic programming approach	2013	COR	Simulation	Sourcing strategies in supply risk management	Approximate Dynamic Programming (ADP) algorithm under supply risk
2	(Federgruen & Yang)	Optimal supply diversification under general supply risk	2009	Informs	Deterministic	Supply risk under uncertain demand	Service constraint model (SCM) and total cost model (TCM) are determined to minimize different inventory based costs
3	(Schmitt & Singh)	A quantitative analysis of disruption risk in a multi-echelon supply chain	2012	IJPE	Simulation	supply disruption and demand uncertainties	Simulation showed that systematic approach is required to control downside risk
4	(Schmitt)	Strategies for customer service level protection under multi-echelon supply chain disruption risk	2011	TR	Deterministic	reducing impact of disruption on customer service	service levels can be improved by proactive inventory placements to cover short disruption
5	(Comes et al.)	Decision maps: A framework for multi-criteria decision	2011	DSS	Multi-criteria decision	Decision making under uncertainties	Use od decision maps is helpful for decision

		support under severe uncertainty			analysis technique		makers facing large, complex problems under uncertainty
6	(Oliveira et al.)	A langrangean decomposition approach for oil supply chain investment planning under uncertainty with risk consideration	2013	CCE	Stochastic	Strategic planning of petroleum product distribution based on logistics infrastructure	Two-stage mixed-integer linear stochastic programming approach is developed for strategic planning of multi-product, multi-period supply chain investment planning problem under demand uncertainty
7	(Goh et al.)	A stochastic Model for risk management in global supply chain networks	2007	PML	Stochastic	Supply chain network risk management	A new solution is provided using Moreau-Yosida regularization. And design an algorithm for treating the multi-stage global supply chain network problems for profit maximization
8	(Klibi & Martel)	Scenario-based supply chain network risk modeling	2012	EJOR	simulation	Supply chain network risk management	Monte Carlo approach is proposed to generate plausible future scenarios
9	(Azaron et al.)	A multi-objective stochastic programming	2008	IJPE	Stochastic	Supply chain design	Multi-objective stochastic model is created for

		approach for supply chain design considering risk					minimization of current investment cost and minimization of financial risk
10	(Huang & Goetschalckx)	Strategic robust supply chain design based on Pareto-optimal tradeoff between efficiency and risk	2014	EJOR	Deterministic	Supply chain design	Mean variance robust design problem (MV-RDP) is modeled. Pareto optimal configuration is found using a finite number of iterations to solve MIQO
11	(Hahn & Kuhn)	Value-based performance and risk management in supply chains: A robust optimization approach	2012	IJPE	Stochastic	Value based performance in supply chains	A direct approach to risk management is pursued using scenario-based information. Different implications of robust optimization approach are derived using a case-oriented example.
12	(Sawik)	Integrated selection of suppliers and scheduling of customers' orders in the presence of supply chain disruption risks	2013	IJPR	Stochastic	Supplier selection and customer orders	Risk averse and risk neutral solutions that optimize, respectively average and worst-case performance of a supply chain are compared for both single and multiple sourcing strategies
13	(Chen &	Improving supply	201	MS	Determinist	Supply chain	A model is developed

	Yano)	chain performance and managing risk under weather related demand uncertainty	0		ic	performance and weather conditions	that will help manufacturer and retailer to limit their risk in adverse weather. For weather rebates, with certain characteristics, the manufacturer can fully hedge his risk of offering a weather rebate by paying a risk premium
14	(Giannakis & Louis)	A multi-agent based framework for supply chain risk management	2011	JPSM			
15	(Govindan & Fattahi)	Investigating risk and robustness measures for supply chain network design under demand uncertainty: A case study of glass supply chain	2017	IJPE	Stochastic / simulation	Supply chain network design	Performance of stochastic model is investigated. Simulation is used to compare different decision making situations.
16	(Silbermayr & Minner)	A multiple sourcing inventory model under disruption risk	2014	IJPE	Deterministic	Sourcing Strategies	Dual sourcing generates better result as compared to single sourcing.
17	(Wu)	Price and Service competition between new and remanufactured products in a two	2012	IJPE	Simulation	Multi-echelon service level	A model is developed with a common retailer and two manufacturers. Profits of supply chain

		echelon supply chain					members are estimated by different interactions of price and service, sales decisions and performance.
18	(Sawik)	Joint supplier selection and scheduling of customer orders under disruption risk: single vs dual sourcing	2014	Omega	Stochastic	Sourcing Strategies	A stochastic mixed integer programming model is developed to integrate supplier selection and customer order scheduling in presence of supply chain disruption risk. Based on the model, risk neutral and risk-averse solutions against average worst-case performance of a supply chain are compared for single and dual sourcing strategy.
19	(Wang et al.)	A multi-objective optimization for green supply chain network design	2011	DSS	Deterministic	Supply Chain Network Design	A model is developed for effective strategic planning in supply chain
20	(Yu et al.)	Single or dual sourcing: decision making in the	2009	Omega	Deterministic	Sourcing strategies	Expected profit functions of two sourcing modes in the

		presence of supply chain disruption risks					presence of supply chain disruption risks are obtained and compared. Sensitivity analysis of buyer's expected profits are also examined
21	(Pishvaee & Torabi)	A possibilisitc programming approach for closed loop supply chain network design uncertainty	2010	Fuzzy Sets and Systems	Possibilisiitic	Supply chain network design under uncertainty	A possibilsitc mixed integer programming model is developed for closed loop supply chain network design problems
22	(Amin & Zhang)	A multi-objective facility location model for closed-loop supply chain network under uncertain demand and return	2013	Applied Mathematical Modeling	Deterministic	Demand uncertainty	A mixed integer linear programming model is proposed that minimizes the total cost in a closed loop supply chain network
23	(Pishvaee et al.)	A robust optimization approach to a closed loop supply chain network design under uncertainty	2011	Applied Mathematical Modeling	Deterministic/Simulation	Supply chain network design	A deterministic mixed integer programming model is developed for designing a supply chain network design. A robust counter-part model is also developed by extending optimization theory. Both models are compared under different test problems
24	(Ramezani	A new multi-objective	201	Applied	Stochastic	Supply chain	A multi-echelon

	et al.)	stochastic model for a forward/reverse logistic network design with responsiveness and quality model	3	Mathematical Modeling		network design	stochastic multi-objective model is developed to evaluate systematic supply chain configuration focusing on maximizing profits, improving customer responsiveness and quality
25	(Li et al.)	Competition and cooperation in a single retailer two supplier supply chain with supply disruptions	2010	IJPE	Deterministic	Sourcing strategies	Sourcing strategies of the retailer are characterized in a centralized and a decentralized system. A coordination mechanism is devised to maximize profits for both suppliers.
26	(Xiao & Yang)	Price and Service competition of supply chains with risk averse retailers under demand uncertainty	2008	IJPE	Deterministic	Demand uncertainty	A price-service competition model for two supply chains is developed to find out optimal decision under demand uncertainty. High risk sensitivity leads to lower optimal service level and prices. Higher service investment efficiency of one retailer leads to a lower optimal service and price of

							the rival.
27	(Rezapour et al.)	Resilient supply chain network design under competition	2017	EJOR	Deterministic	Supply chain network design	A mixed integer non-linear model is developed to find out most profitable network and risk mitigation strategies
28	(Baghalian et al.)	Robust supply chain network design with service level against disruption and demand uncertainties: a real life case	2013	EJOR	Stochastic	Demand uncertainties	A stochastic mathematical formulation is devised for designing a network of multi-product supply chain comprising of several production sites. A transformation based on piecewise linearization method is created to solve the model.
29	(Paul et al.)	A quantitative model for disruption mitigation in a supply chain	2017	EJOR	Deterministic/Stochastic	Supply chain network	A three stage supply chain network is considered and three different approaches are developed. A fuzzy inference system is developed to predict changes in future demand over base forecast. A quantitative model for revising production is

							also developed in reactive mitigation planning.
30	(Sawik)	Optimization of cost and service level in the presence of supply chain disruption risks: Single vs multiple sourcing	2014	Computer and Operations Research	Stochastic	Sourcing Strategies/Service level	A combinational stochastic optimization problem is formulated as a mixed integer program. The objective was either to minimize worst case cost or worst case service level.
31	(Costantino & Pellegrino)	Choosing between single and multiple sourcing based on supplier default risk: A real options approach	2010	JPSM	Simulation	Sourcing strategies	A real options approach is proposed for valuing the probabilistic benefits of multiple sourcing. Results showed that multiple sourcing is better in risky environment. Sensitivity analysis allowed identifying the most important transactional parameters of the two sourcing strategies.
32	(Hasani & Khosrojerdi)	Robust global supply chain network design under disruption and uncertainty	2016	Transportation Research Part E	Deterministic	Supply chain network design	A mixed integer, non-linear model is developed for robust supply chain network

		considering resilience strategies: A parallel memetic algorithm for real life case study					design. Six resilience strategies are proposed and a parallel Taguchi based memetic algorithm is also designed. The model is solved for real life case of manufacturer of medical devices
33	(Iakovou et al.)	A stochastic inventory management model for a dual sourcing supply chain with disruptions	2010	International journal of systems science	Stochastic	Sourcing strategies	A single period stochastic inventory decision making model is proposed that allows capturing the trade-off between inventory policies and disruption risks for an unreliable dual sourcing supply chain network.
34	(Kirytopoulos et al.)	Multiple sourcing strategies and order allocation: an ANP-AUGMECON meta-model	2010	SCM	Deterministic	Sourcing strategies	The paper provides a meta model for supplier evaluation and order quantity allocation based on different mathematical models. The model allows manager to actively evaluate the suppliers while minimizing the cost and mean delivery

							times
35	(El-Sayed et al.)	A stochastic model for forward-reverse logistics network design under risk	2010	Computer and Industrial Engineering	Stochastic	Network design	A multi-period multi-echelon forward–reverse logistics network design under risk model is developed. Problem is developed based on stochastic mixed integer linear programming and objective was to maximize profit.
36	(Taskin & Lodree Jr)	Inventory decisions for emergency supplies based on hurricane count predictors	2010	IJPE	Stochastic	Sourcing strategies	A control policy is developed for stocking decisions based on hurricane forecast model using stochastic programming model. The proposed model specifies cost minimizing inventory strategies for simultaneously meeting stochastic demands.
37	(Song et al.)	Integrated inventory management and supplier base reduction in a supply chain with multiple	2014	EJOR	Stochastic	Demand uncertainties	A stochastic model is developed to cater for multiple production times, uncertain demands subject to

		uncertainties					supply and production capacity constraint. The model further enables us to quantitatively achieve the trade-off between the supplier base reduction and the supplier capability improvement.
38	(Xanthopoulos et al.)	Optimal newsvendor policies for dual-sourcing supply chains: A disruption risk management framework.	2012	Computer and Operational Research	Stochastic	Sourcing strategies	A generic, single period model is developed for capturing the trade-off between inventory policies and disruption risk in a dual sourcing supply chain network. Model is developed for both risk neutral and risk-averse managers under various types of disruptions.

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DECISION SCIENCES INSTITUTE

Question Breakdown Structure (QBS) for Complete Business Storytelling by Agile Teams

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ABSTRACT

Visual analytics dashboards or storyboards are attractive reporting tools getting more popular by analytics users who need to convey business insights to audience effectively. But when presented with a data analysis dashboard or storyboard, how can we be sure that the dashboard or storyboard addressed all the important questions that should have been asked out of the dataset? The goal of this paper is to propose a framework that will help business analytics users to ask the right questions and work as a visual tool to represent an extent a typical analytics has addressed in a given business problem space.

KEYWORDS: Data Analytics, Dashboard, Story Board, Knowledge Space, Problem Space, Agile Management

INTRODUCTION

Visual analytics dashboards or storyboards are attractive reporting tools getting more popular by analytics users who need to convey business insights to audience effectively. But when presented with a data analysis dashboard or storyboard, how can we be sure that the dashboard or storyboard addressed all the important questions that should have been asked out of the dataset? Considering the vastness and intricacies of a business environment, can we say confidently that: 1) a data analyst presenting a dashboard does have all the necessary domain knowledge to come up with all the relevant questions?; and 2) even if he/she knows the business, how do we know the extent the presented insights in storyboards cover with respect to the entire information domain?

Availability of large data and powerful visual analytics tools in conjunction with agile management practice present a great potential for organizations to become highly flexible and effective in decision making. But at the same time, they pose some challenges at the same time. For example, let's assume that an organization has created autonomous agile teams comprised of members from different business units. All these teams have access to the same data sources to come up with business solutions. Since it's not practical on a regular business scenario to arrange data expert or significantly experienced personnel in the overall business domain for each team, it can be assumed that none of the teams will have superior skill of asking right questions that lead to getting relevant business answers from the large set of available data. At the current moment, there are no systematic methods or tools to facilitate business analytics teams to develop necessary questions to lead their analytics investigation.

Now businesses are well aware of the power of big data and the exponential benefit that can be derived by utilizing big data via various data analytics tools. However, even though both the data and analytics tools are readily accessible, businesses still struggle to take the best advantage out of the available data. Moreover, big data analytics investment may result in less than expected ROI (return on investment) if such investments are pushed only by either analytics vendor or data scientists driven by their eagerness of running analyses on businesses' inside data rather than the desire to address business need (David Court, Jesko Perrey, Tim McGuire, Jonathan Gordon, & Dennis Spillecke, 2015). This shows that there is a problem in considering data analytics in seclusion of the business process. This problem can be discussed further in the light of the concept of modern trinity of information as discussed by Dr. Barry Devlin in his book 'Business Unintelligence'. Where he explained how information, process, and people are the three core components of a successful information revolution and how these must be reinvented and restructured to deliver the value expected from big data analytics (Devlin, 2013). Emphasizing only on analyzing data and creating information ignoring the people and process component is destined to be unsustainable.

But in dealing with the 'people' component a challenge lies in the unavailability of people having a combination of domain knowledge and advanced data analysis skills. The best kind of people to deal with the data analytics in a firm are the ones who are not only good at advanced data analysis skills but also great at speaking the language of business and helping business leaders reformulate their challenges in a way that big data can tackle (McAfee & Brynjolfsson, 2012). But people with such level of cross-domain knowledge and expertise is very hard to find (Thomas H. Davenport & D.J. Patil, 2012).

To counter this scenario there have been discussions about incorporating analytics in the business process rather than implementing it as a role of a secluded team of experts (David Court et al, 2015). In this process business users who have the domain expertise are empowered with data analytics tools that are intuitive and do not require a significant level of acquisition of new technical skills such as coding. Intuitive and less-technicality-driven data analytics tools such as Tableau and Rapidminer have delivered the power of visual analytics and modeling to the regular business users who have their domain expertise but lack technical analytics skill sets. This trend of empowering business users with data analytics tools is liberating and has an immense opportunity of adding value to the overall business output. Moreover, such empowerment also opens opportunities to experiment with emerging management techniques such as agile management in a more effective and productive way.

Agile has been widely used process in information technology and software industry but recently it has been considered as a radical alternative to the 'command-and-control-style-management' across different types of industries and at a different level of organizational command level (Darrell K. Rigby, Jeff Sutherland, & Hirotaka Takeuchi, 2016). Having business domain experts from different business units empowered with data analytics skills can improve the performance of agile teams. But for this new type of data users, who are less savvy with the hard skill of data analytics but have the soft skill of business understanding, is there any structure to guide them in their exploration for insights from a bulk of data?

In a regular organizational setup, data analysis process represents the inductive research method. Which follows inductive reasoning process of creating general conclusion from observations of specific phenomena (Uma Sekaran & Roger Bougie, 2016). In the field of inductive research, the concept of Exploratory data analysis (EDA) provides with a guideline on how to approach a dataset and come up with insight. Jeroen de Mast and Benjamin P. H. Kemper proposed a three-step model of EDA where the three steps are as follows (Jeroen de

Mast & Benjamin P. H. Kemper, 2009): 1) Display of the data; 2) Identification of the salient features; and 3) Interpretation of the salient features.

PROBLEM STATEMENT

EDA model provides with a general approach towards data analysis but still, it does not address the issue of the versatility of human pattern recognition (Jeroen de Mast et al, 2009). This means in the context of agile management, different groups would come up with a various set of insights on the same problem by analyzing the same dataset. That pose challenges for the top management team. It is because once they are presented with different analyses from different agile teams there are no ways in practice that link such insights coherently. Moreover, it is not possible for the top management to know how much of the total problem space was considered to derive the insights. This keeps the top management team in dark about how much the presented solutions address the problem space both individually and collectively and how big the area of the unexplored space is.

In summary, business analytics practitioners and users lack a systematic approach to address these issues:

1) What is the totality of a problem space which will work as the source of the related questions?
2) How much of the problem space does a business intelligence dashboard cover and what is yet to be covered?

PROPOSED FRAMEWORK: "QUESTION BREAKDOWN STRUCTURE (QBS)"

As a way of addressing the issues above, we propose a 'Question Breakdown Structure (QBS)'. It is a structure that is similar to the Work Breakdown Structure (WBS), a widely used tool in the project management field. In QBS, the whole business domain is broken down into independent knowledge blocks. This detailed layout of the business domain visually represents the problem space and gives a direction about the range of possible questions that can be asked during an analysis.

QBS can be developed by breaking down the whole business domain into its pieces to represent specific knowledge segments in the business and there could be different approaches that can be developed. When all the bottom level knowledge blocks are summed up, they should represent the entire business domain or knowledge space, which analytics users try to explore for questions. For example, as shown in Figure 1, if a business domain is broken down to pieces using a firm's organizational structure, the resulting knowledge blocks at the lowest level should represent the entirety of the business information from that firm. In the next section, we will use how such QBS is used as a way of demonstrating the proposed QBS framework.

Figure 1 shows the total business domain in the organizational structure format, presenting different packages of potential business knowledge groups at different levels. Breaking down the business domain on different layers should stop where the individual knowledge components are sufficiently detailed enough for future analytics to zoom in. Different knowledge nodes at the bottom layer of the QBS represent very specific individual potential knowledge blocks that can be used that need to be explored and questioned during the analytics process.

This is a significant static structural representation in which the business domain is broken down to potential question-related knowledge blocks that need to be addressed by analytics teams.

This gives us a visual representation of the entire problem space. This works as the source of the possible questioning during the analysis phase. Moreover, once an analytics is done in the form of dashboards and storyboards, the analytics results as answers can be connected to the individual knowledge blocks or nodes in the QBS model as a visual problem space documenting tool. This connection between the knowledge blocks and questions addressed in storyboards are shown as lines in Figure 1. The QBS therefore can display how much of the problem space has been explored by the analytics teams and how much of the problem space has yet to be explored.

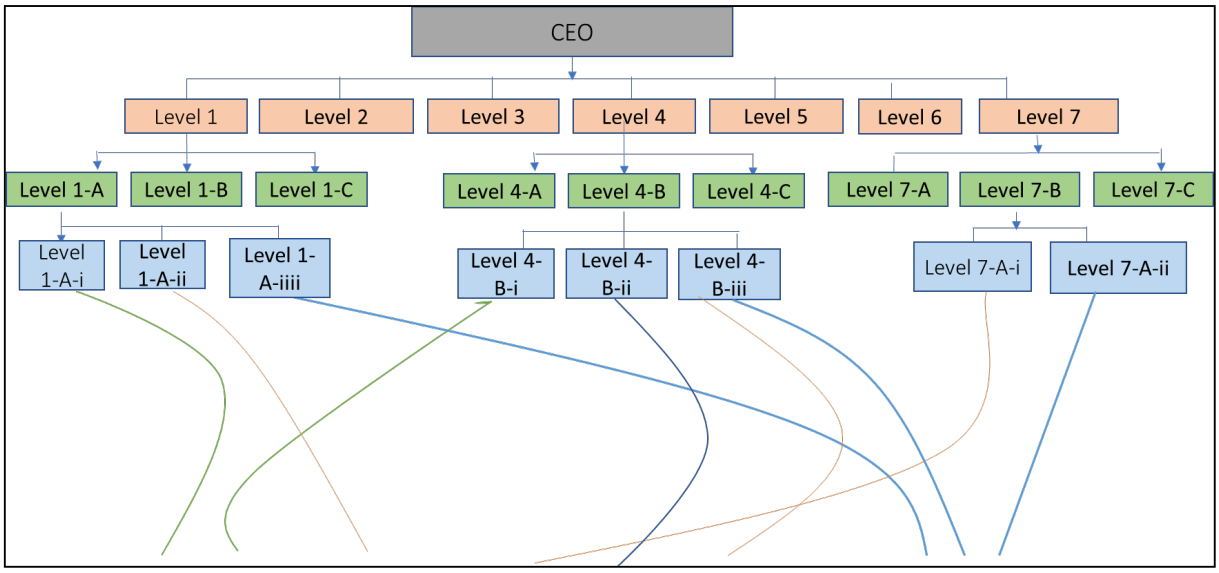

Figure 1. Question Breakdown Structure (QBS) using Organization Structure

CASE

To discuss a use case of our proposed QBS model let's first detail a scenario. Let's assume that a commercial bank has decided to increase its revenue in the coming quarter. To get ideas about ways to generate more revenue, the bank has decided to apply agile management techniques to form 3 agile teams consisting of members from different business units of the bank. All these three teams have access to the same dataset. As found in a regular business setting, we assume that all the members of the teams come from a diversified business domain and thus have a good grasp over the particular function that they work on but not much beyond their areas.

In this scenario, we use the dataset that contains general information about clients (age, job, etc.) as well as more specific information about the current insurance sell campaign (communication, last contact day) and previous campaigns (attributes like previous attempts, outcome). This dataset is from Kaggle.com, an open community of data analysts and data scientists, where it was originally shared by the Data Mining Cup organizing authority from Technical University of Munich (Technical University of Munich, 2017).

As the first step, for this scenario, we developed a QBS for the entire bank as shown in Figure 2 using the functional organizational structure or often called 'U form structure' which is defined as 'an arrangement based on the functional approach to departmentalization' by Griffin (Griffin,

2013). In this QBS, people and units in an organizational process are grouped under functional departments such as finance, supply chain and so on.

Since the dataset provides data that only relates to the consumer banking products and customers, the only related knowledge block in the developed QBS is the consumer and community banking. Therefore only the knowledge areas related to consumer banking activities have been detailed out into different layers and sublayers while keeping the other blocks aggregated.

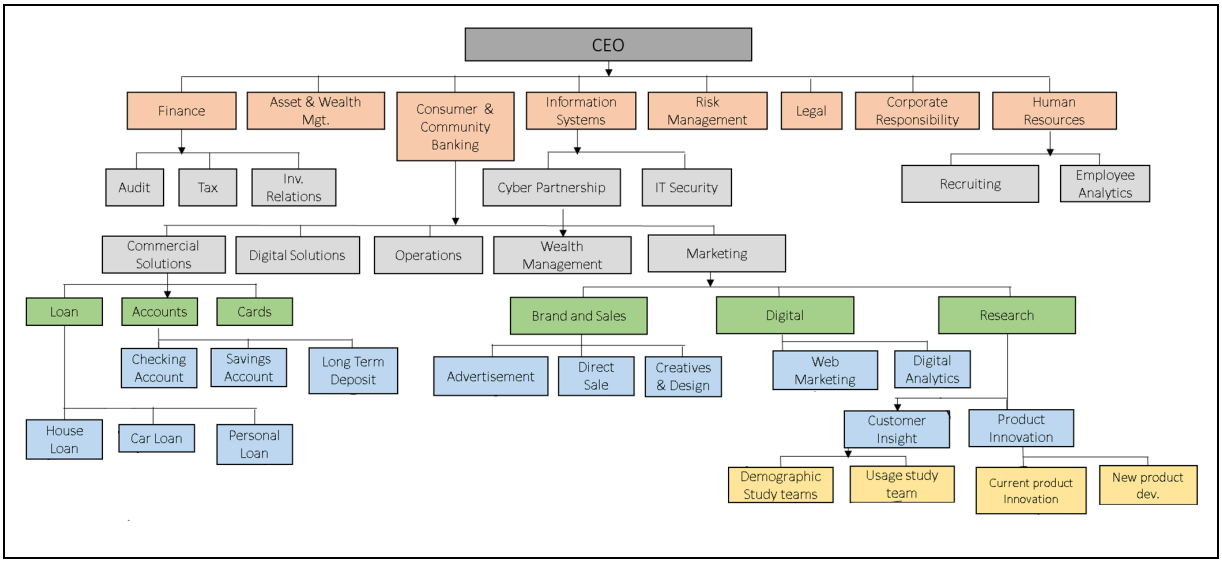

Figure 2. QBS of a Commercial Bank Case

Going back to our scenario of three agile teams looking for ways to increase revenue, we assume that these three teams have differences in their perspectives about increasing revenue. There are different ways that a company can increase its revenue such as by increasing number of customers for existing products, or by reducing cost, or by introducing new products, or by making existing communication more efficient so that maximum number of conversion can be achieved at the lowest cost, or by expanding the operation of the organization in different location and so on. To mimic the reality of having different insights from different teams, we assume that the teams would approach their data analysis from their own perspectives. These perspectives will direct the key questions that they will try to find answers for from their analyses. Table 1 shows these different perspectives and the derived key questions to start off their analytics operations.

Table 1 Team Perspectives and Questions for Analytics Operations

Team no.	**Perspective**	**Question**
01	Increasing number of customers for existing core business	Who should we target for more deposit?

02	Finding out new market for new product	Who should we target for insurance product?
03	Increasing effectiveness of the marketing efforts	How can we make our campaigns more successful?

Based on these key questions, each team approaches the dataset and comes up with storyboards showing their analysis results. Here, by storyboards we mean the data analysis presentation feature available in visualization analytics tools such as Tableau where key findings from analytics operations are presented along with the insights as a series of connected business information found from data.

Story Board 01: Who should we target to gather more deposit?

This team starts with the existing regular banking customers who keep their deposit in the bank. Their prepared data analysis story has four core messages as presented below and available in the visual graphs in Appendix-A:

1. The highest percentage of customers have deposits of less than $1000.

2. Once the customers are clustered based on their account balance, it is seen that customer cluster 02 (balance between $1887 and $6060) and cluster 03 (balance between $6101 and $14144) consist lower share in the total number of customers but the highest share in total dollar value of the deposit.

3. Among the customers from cluster 2 and 3 blue-collar, management, housemaid and technicians have the highest percentage of the total number of customer in these clusters.

Considering all these findings, team 01 proposes customers having a balance between $1000 and $14000 should be prioritized so that they continue their account and professionals from the working areas of management, blue collar, housemaid, and technicians should ger priority when new customers are searched to increase bank deposit.

Story Board 02: Who should we target for insurance products?

This team concentrates on the non-conventional products offered by the bank such as house and car insurance. Their presented data analysis story has four core findings as detailed below and visually presented in Appendix-B:

1. There are slightly more house insurance customers than car insurance customers.

2. Car insurance customers' age varies more widely compared to the age of house insurance customers.

3. Based on 'marital status' doesn't show any significant change in the purchase behavior in neither of the house and car insurance.

4. There are more highly educated customers in car insurance buyers than house insurance buyers.

Considering all these findings, team 02 proposes that comparatively older customers having a university education are the better market to target for car insurance than house insurance.

Story Board 03: What should we do to make our campaign more successful?

Team 03 concentrates on the cold call result and previous campaign data to check which factors make sales call campaigns more successful. Their presented analysis has three core findings as detailed below and visually presented in Appendix-C:

1. The month of May historically has the highest number of attempts but in terms of success ratio June, July and August have had better success.

2. No particularly distinct trend has been observed in terms of success ratio based on day of the week.

3. Customers who accepted previous offer tend to accept a current offer more often than customers who never accepted an offer.

Overall, they propose that Summer time (June, July, and August) provides the best conversions and customers who have accepted previous offers pose a greater chance of accepting the new offer.

Connecting Storyboards to QBS

Although the dataset the teams used for their analyses was same, different teams concentrated on different areas of the dataset that suited their key questions. If we put their areas of interest in the QBS model that we built in Figure 2, we can see that different analyses touched at different knowledge blocks as shown in Figure 3. Table 2 below summarizes how these analyses relate to the different knowledge blocks in the QBS.

Table 2 Relations between analyses and QBS

Analysis Story Board No.	Addressed Knowledge Blocks in QBS
Story board 01	Savings account, Demographic study
Story board 02	Demographic study, Usage study, Current product innovation
Story board 03	Advertisement, Direct sales

In a usual scenario, however, once these three analyses are presented, they are not coordinated with each other and thus don't give any clear picture of how much complete these analyses are with respect to the entire knowledge space of the project they were engaged in. In other words, when the top management team is presented with these analyses, they cannot immediately see which areas of the problem space have been addressed and not addressed by the analyses of the teams.

However, the QBS model connected with the storyboard slides can clearly provide us with information on how much complete the analyses are and a further need of future analyses that have not been done currently.

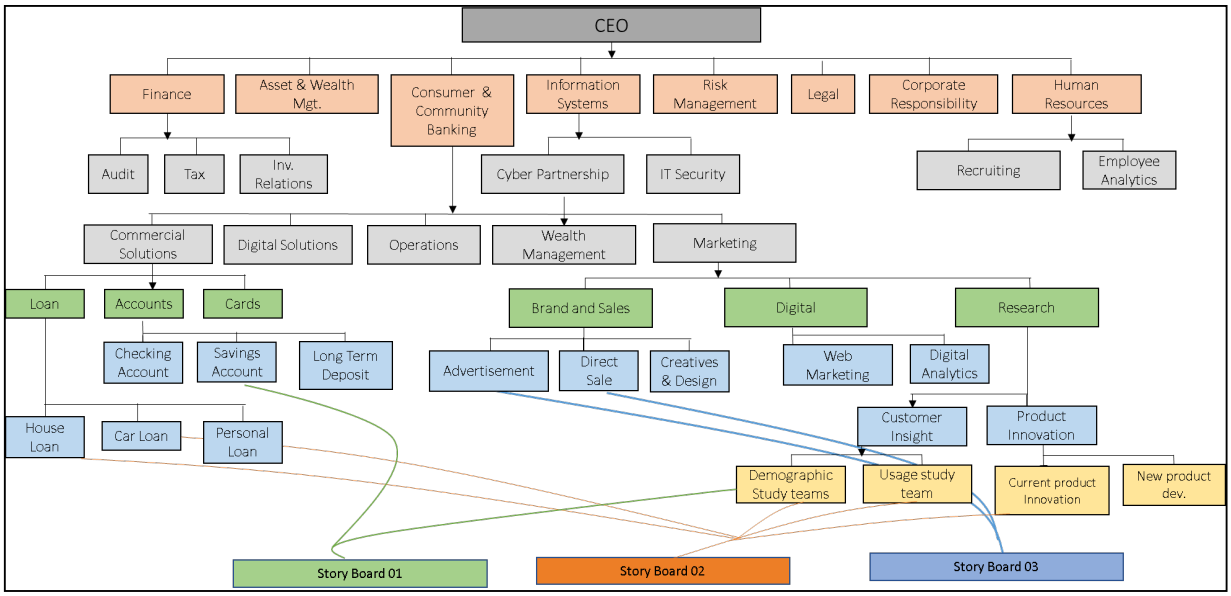

Figure 3. QBS Connected with Teams' Storyboards

DISCUSSION

From Figure 2, we can see that our QBS model produced total 15 knowledge blocks at the last layer while the teams' analyses addressed only total 8 of those blocks. All the three analyses combined cover 53.33% of the problem space considering the unique knowledge blocks that they touched upon. The other 47% of the problem space is not addressed at all by the agile teams. And if we consider the team's contribution separately, the coverage ratio goes even lower as shown in Table 3 below.

Table 3 Percentage of problem space coverage by each analysis

Story Board No.	Addressed areas	Total areas	% of coverage
Story Board 01	2	15	13.33%
Story Board 02	5	15	33.33%
Story Board 03	2	15	13.33%

We get a picture of how the agile teams' analyses, either combined or separately, give a small fractional view of the overall problem space in only one broad vertical of the banking business (consumer banking). If other verticals are considered then the problem space would grow much bigger and eventually the coverage ratios will potentially go down even further. But still, by creating the QBS model of the problem space linked with the analytics storyboards we can get a visual picture of how broad our problem at hand is and how much of it is covered by the analyses presented to us. This give us not only an idea about our scope of understanding on the overall problem but also a direction for further future analysis.

LIMITATION

Application of QBS has its limitations. Some of the limitations are:

- The success of QBS model depends largely on the method used for question breakdown structure. Here organizational chart has been shown as a possible solution. But in different cases different ways of breaking down the business knowledge space may make it more effective.
- A QBS model provides a guideline for the analysts to come up with questions and thus provide a visual representation of the overall coverage of the problem space. It does not provide definitive answers to business questions.
- Application of QBS models will be most effective in cases where a high-level understanding of a problem and knowledge of the limitations or scope of the solutions presented are crucial for the non-technical agile teams and management.

CONCLUSION

This paper addresses one of the challenges that comes along with the incorporation of data analytics in the business process:

1) “How do we know that the analytics teams ask the necessary and relevant questions?; and

2) “How do we know that a presented storyboard from the analytics operation has addressed the problem space properly and by how much?”

The proposed QBS framework can be applied in the business firms who are trying to implement data analytics as a part of their business process. The framework can work as a supportive tool in the successful integration of data driven decision in the regular business process. However, more research is needed in terms of how the QBS is developed other than from an organization structure and various ways of using QBS to improve the analytics operations and documentation.

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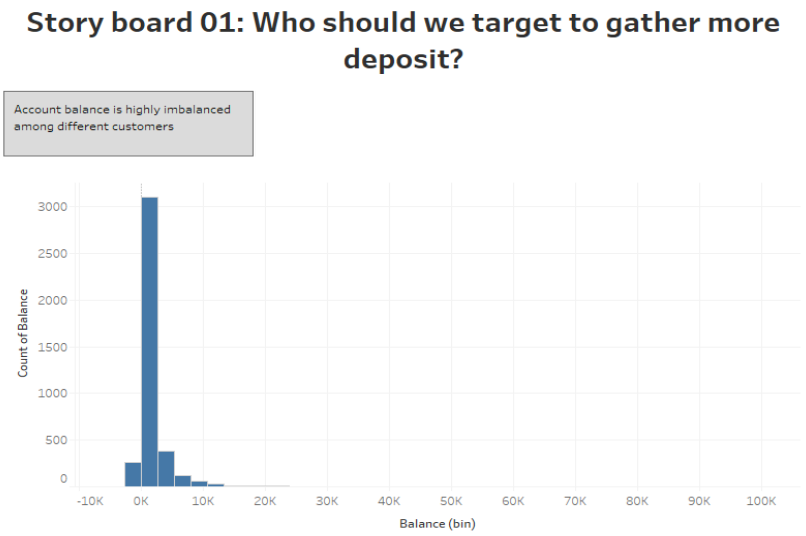
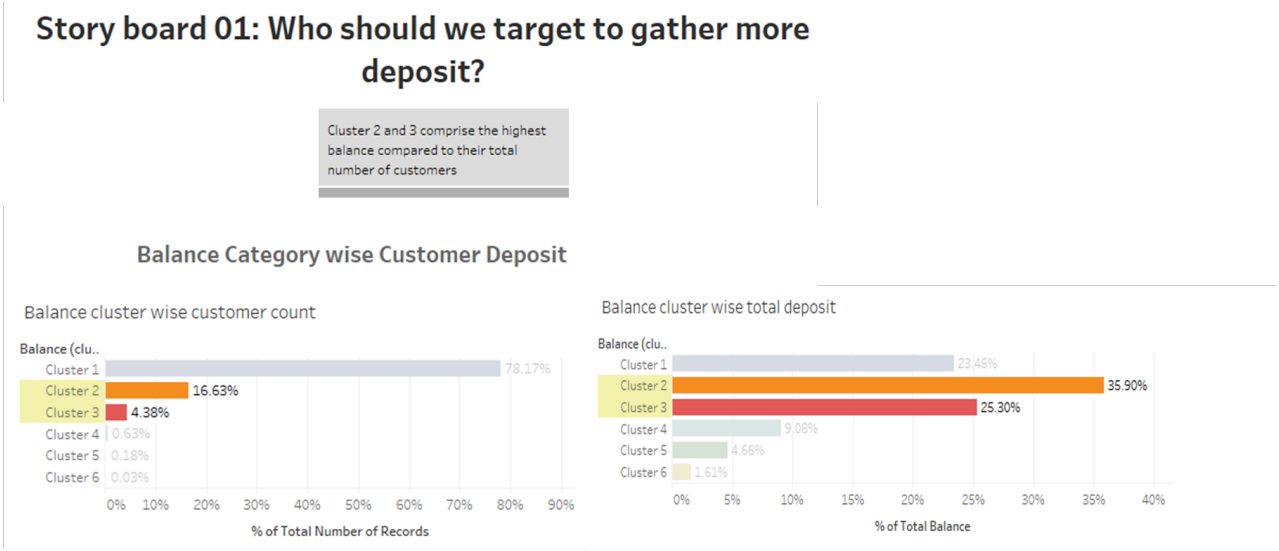
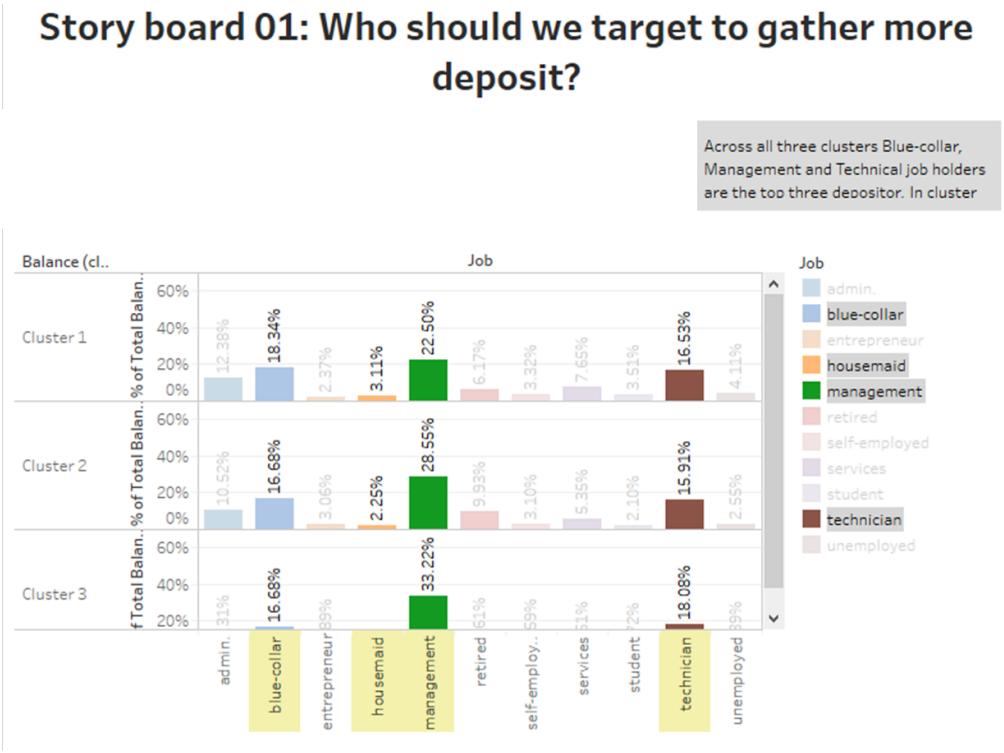
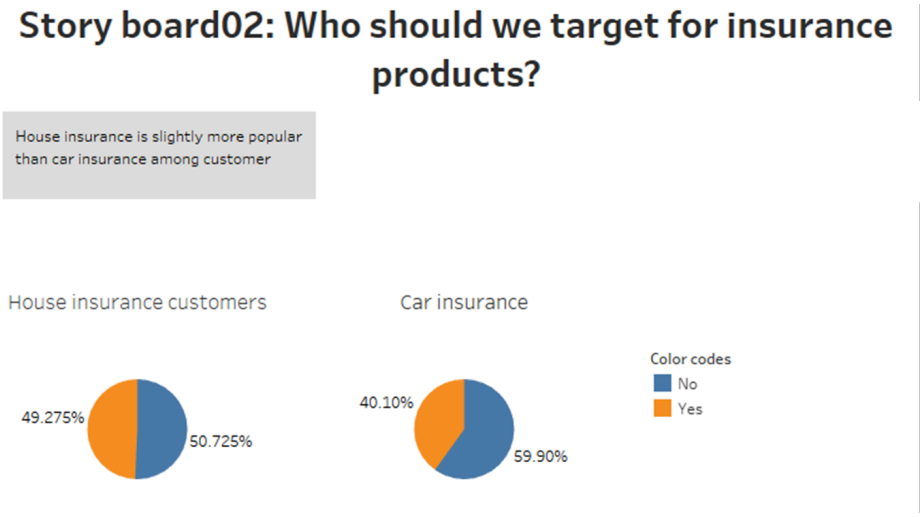
APPENDIX -A: Story board 01

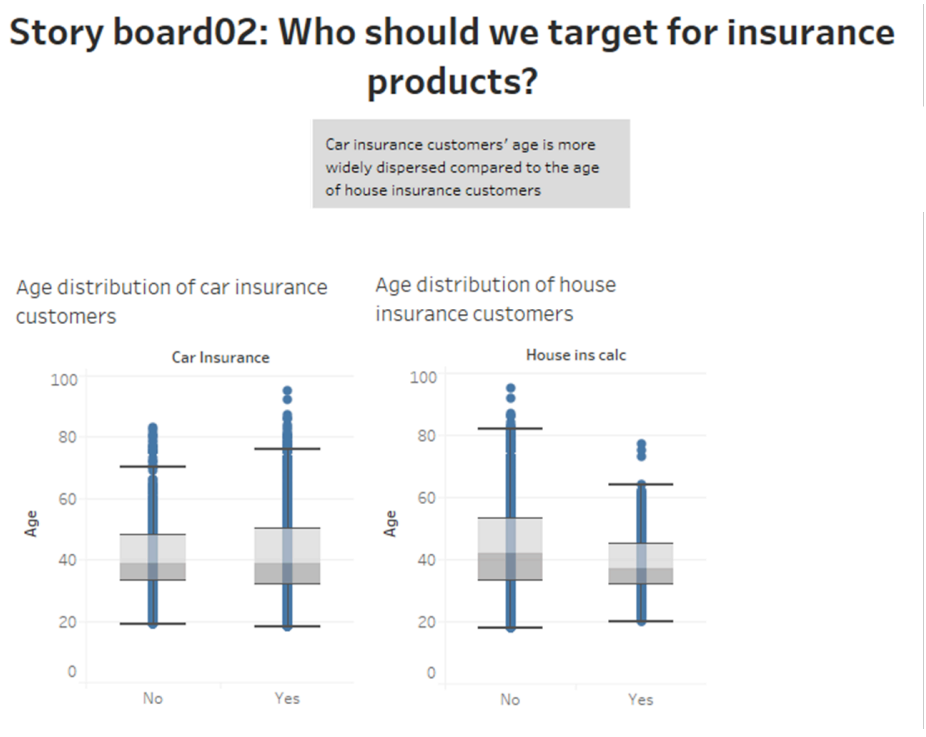


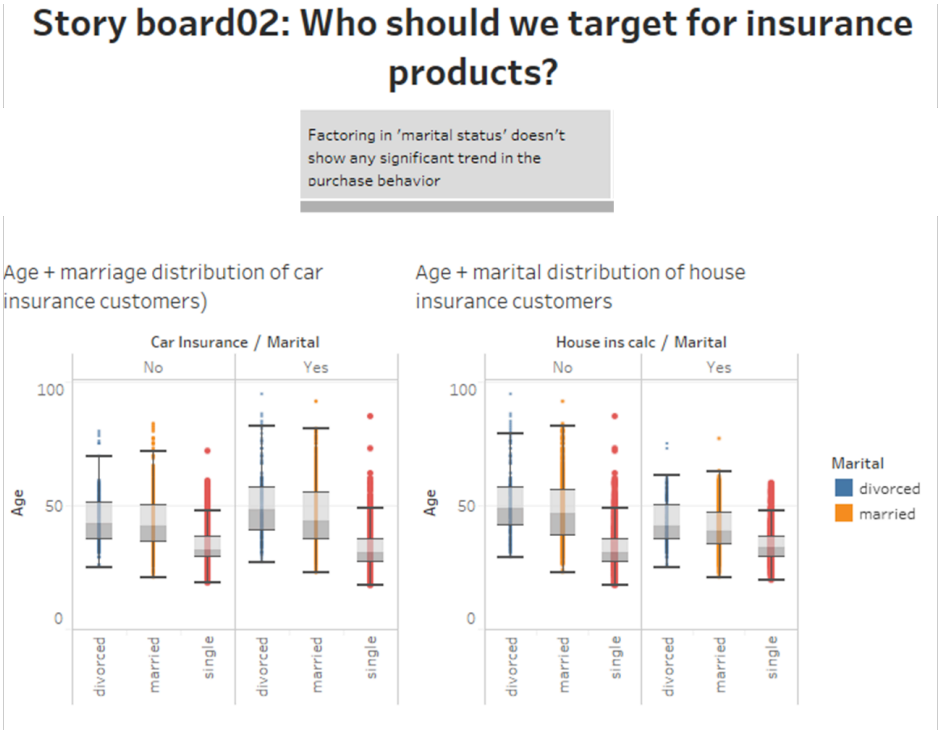


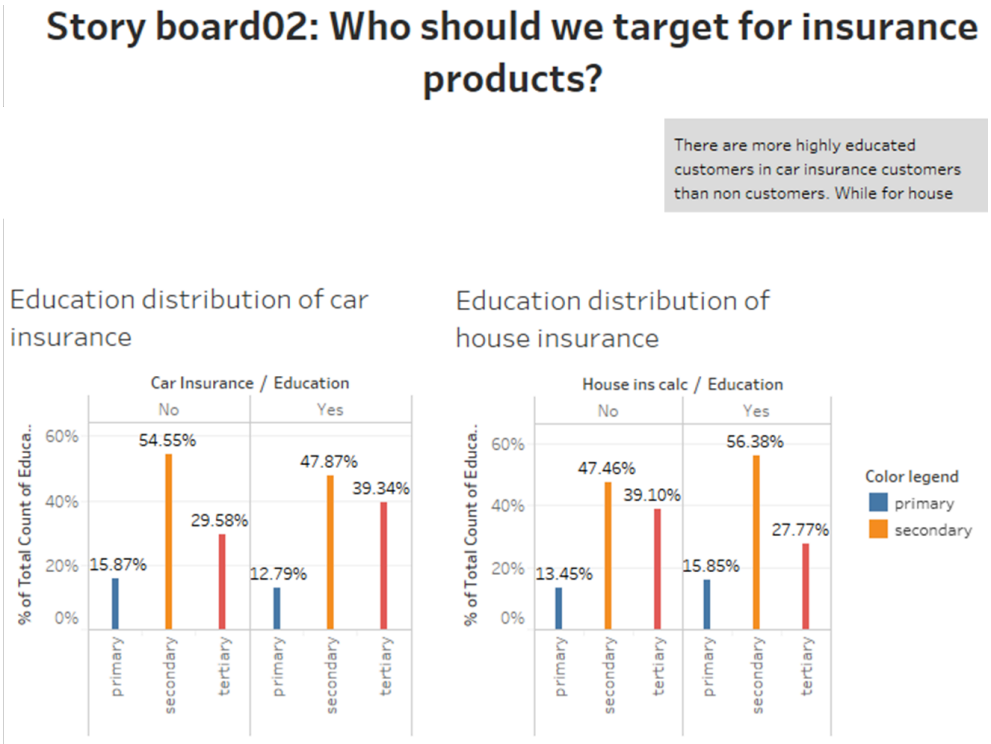

Story board 01: Who should we target to gather more deposit?
Across all three clusters Blue-collar, Management and Technical job holders are the top three depositor. In cluster
Balance (cl..
Job
Cluster 1
Cluster 2
Cluster 3
% of Total Balan..
60%
40%
20%
0%
12.38%
18.34%
2.37%
3.11%
22.50%
6.17%
3.32%
7.65%
3.51%
16.53%
4.11%
10.52%
16.68%
3.06%
2.25%
28.55%
9.93%
3.10%
5.35%
2.10%
15.91%
2.55%
16.68%
33.22%
18.08%
admin.
blue-collar
entrepreneur
housemaid
management
retired
self-employ..
services
student
technician
unemployed
Job
admin.
blue-collar
entrepreneur
housemaid
management
retired
self-employed
services
student
technician
unemployed

APPENDIX –B: Story board 02

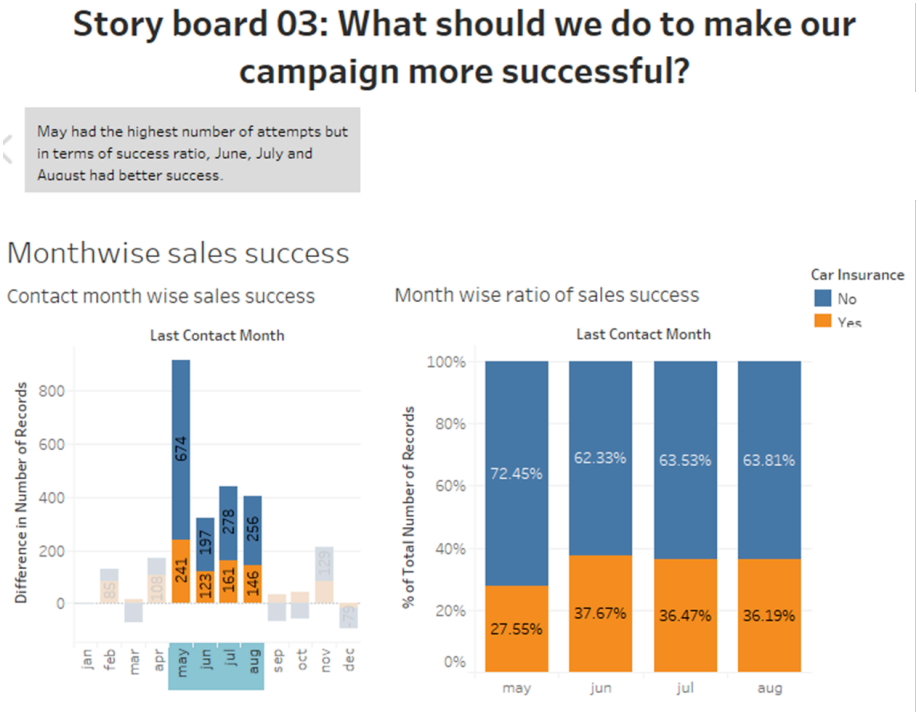


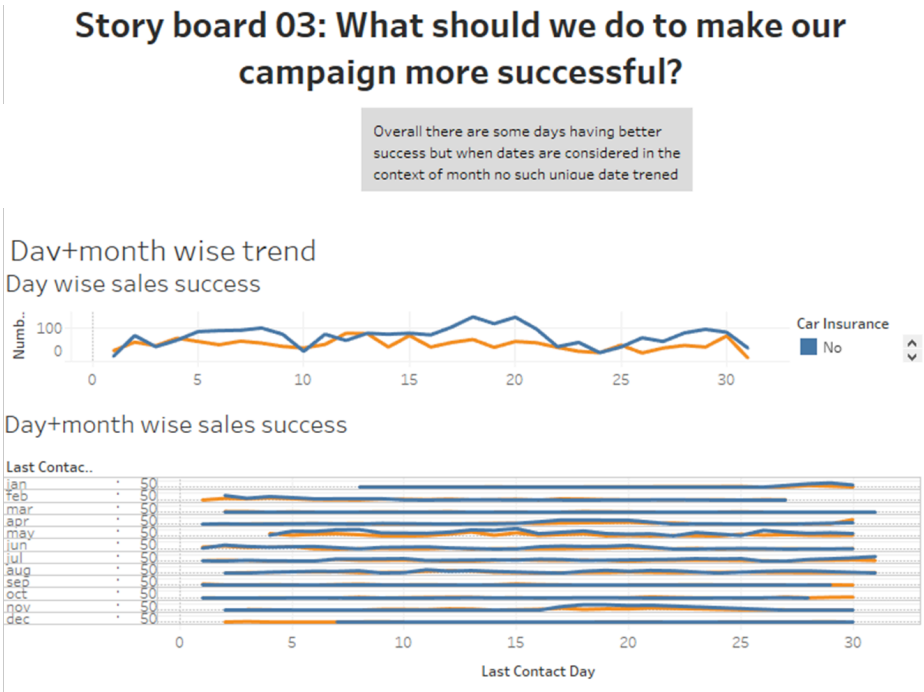



Story board02: Who should we target for insurance products?
Factoring in 'marital status' doesn't show any significant trend in the purchase behavior
Age + marriage distribution of car insurance customers)
Age + marital distribution of house insurance customers
Car Insurance / Marital
House ins calc / Marital
No
Yes
Age
100
50
0
divorced
married
single
Marital
divorced
married


Story board02: Who should we target for insurance products?
There are more highly educated customers in car insurance customers than non customers. While for house
Education distribution of car insurance
Education distribution of house insurance
Car Insurance / Education
House ins calc / Education
No
Yes
% of Total Count of Educa..
60%
40%
20%
0%
15.87%
54.55%
29.58%
12.79%
47.87%
39.34%
13.45%
47.46%
39.10%
15.85%
56.38%
27.77%
primary
secondary
tertiary
Color legend
primary
secondary

APPENDIX –C: Story 03



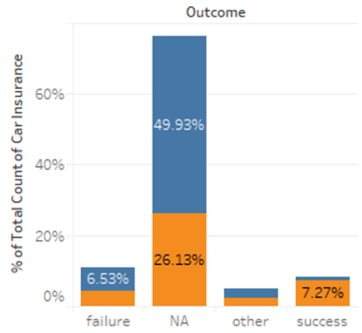


Story board 03: What should we do to make our campaign more successful?

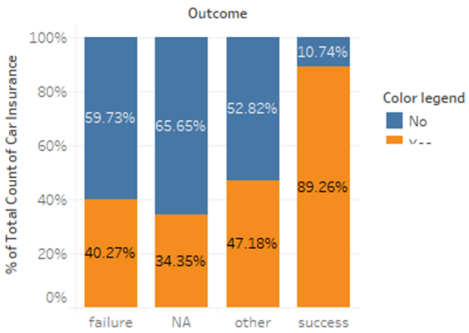
Most of the customers called under current campaign were not contacted before. But customers who accepted previous offer also

Last campaign result vs current sales result

Last campaign outcome and current sales success



Last campaign outcome and current sales success in %



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Reducing Tax Identity Theft by Uncovering and Securing Risk Gateways in the E-Filing Process

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ABSTRACT

This paper investigate whether the increasing adoption of electronic tax filing technologies has inadvertently resulted in corresponding growth in Tax Identity Theft. Data was extracted from Identity Theft complain reports maintained by U.S. government agencies. Our results indicated that, after controlling for general Identity Theft, number of Individual Tax Returns, and Total Refunds, Tax Identity Theft was still positively associated with E-filing and this relationship was mediated by Self-e-filing and Direct Deposit adoption. These findings suggest that the key risk gateways in the Tax Identity Theft process are at self-e-filing and at the direct deposit points.

KEYWORDS: Tax Identity Theft, Risk gateways, e-filing, Technology adoption, Unintended consequences

INTRODUCTION

The Information Age has brought technological innovations that have given consumers new options. Key among these innovations is the Internet, which has changed the way consumers conduct business. Governments are also using the Internet to provide services to citizens. This study will focus on the unintended consequences of the introduction of electronic tax filing by the US govern and subsequent efforts to encourage the citizens to move from manual tax filing to electronic filing (E-filing). Individual taxpayers can now file their own taxes instead of depending on the more expensive tax filing agencies. The adoption of electronic technology in tax filing process has improved the accuracy of tax filing process, reduced the cost for the government and taxpayers, and shortened the lead-time of receiving individual tax refunds (Edwards-Dowe, 2008).

Unfortunately, the U.S. has also seen a dramatic increase in tax related identity theft with the menace becoming the number one scam in the last couple of years (US Internal Revenue Service, 2014). The total amount of refunds issued to fraudulent tax return totaled $5.2 billion in 2010 and is projected to reach $21 billion in the next five years (US Treasury Inspector General for Tax Administration, 2012). If Taxpayer Identity Theft continues to rise at the present trend, the abovementioned gains from e-filing will be in serious jeopardy. This call for an investigation into the relationship between the two occurrence and identification of possible solutions.

This paper examines the increased adoption of new technologies in e-filing and their unintended consequences as a potential explanation for the rise in Tax Identity Theft. Specifically, we asked the questions: Does the increased adoption of technology in individual tax filing contribute to the proliferation of Tax Identity Theft and, if so, how does it contribute to this proliferation?

Answers to these questions will help stakeholders better understand the trend of Tax Identity Theft and devise effective ways to mitigate such threats.

This paper is organized as follows. We first provide a literature review of the advantages and progress made with the adoption of e-filing technologies followed by a review of the growth of Tax Identity Theft. We then develop hypotheses on the relationship between the two and identify possible mitigating factors on the relationship. We present the data gathered and the statistical models developed to test our hypotheses in the methodology section, followed by the results analysis presented in the data analysis and results section. We conclude with the discussion section with interpretation of results found and their implications. Several recommendations are suggested followed by limitations of the study.

LITERATURE REVIEW

Identity theft involves "*stealing of another person's personal identifying information such as social security number, date of birth and mother's maiden name, and then using the information to fraudulently establish credit, run up debt or take over existing financial accounts*"(US Government Accountability Office, 2002). The Identity Theft and Assumption Deterrence Act of 1998 makes it a crime to "*knowingly transfer or use, without lawful authority, a means of identification of another person with the intent to commit, or to aid or abet, any unlawful activity that constitutes a violation of Federal law, or that constitutes a felony under any applicable State or local law" ("The Identity Theft and Assumption Deterrence Act of 1998*", 1998).

Tax Identity Theft is one form of identity theft that involves the illegal use of a potential taxpayer's identity to fraudulently file a tax return and claim a refund (US Internal Revenue Service, 2013b). For several years, Tax Identity Theft has risen over the years and remained the top scam in the "Dirty Dozen Tax Scams" list maintained by the IRS (US Internal Revenue Service, 2010, 2011, 2012, 2013a, 2014, 2016b). The increase is reflected in both the numbers of incidents per year and the monetary loss. The rising trend in these reports suggests that Tax Identity Theft is set to continue topping the list unless significant changes are made. As a first step, we seek to understand the Tax Identity Theft threat in the next few paragraphs.

There are many variations of Tax Identity Theft. Typically Tax Identity Theft starts when a criminal acquires a victim's social security number and electronically files for a tax refund, often early in the tax season to get a head start against the genuine owner of the social security number (Weisman, 2015). The criminal submits false information on the income earned in the year, taxes paid and claim eligibility for various tax credits (e.g., earned income tax credit), all with the aim of maximizing the total tax refund. The criminal then requests IRS either to deposit the refund amount into a direct deposit bank account, or to mail a prepaid card or check. Oftentimes, the IRS issues the refund only to discover the refund was fraudulent when it receives a second tax return filing from the actual owner of the stolen social security number (victim) later in the season. By this time, the criminal will have withdrawn the refund and disappeared (Weisman, 2015).

Despite the public attention on the rise of Tax Identity Theft, peer-reviewed literature on Tax Identity Theft was relatively sparse. Much of the extant literature examined the general identity theft and related frauds, while few focused on Tax Identity Theft. Several reasons may explain this void. First, the study of Tax Identity Theft is relatively new. Its prevalence and severity to society relative to the other forms of identity theft may just be becoming apparent to researchers. Second, different stakeholders do not even seem to agree on a standard name for

Tax Identity Theft. This has created challenges for researchers to collaborate and build on prior works and data sources. This study uses the name "Tax Identity Theft" to emphasize the fact that we are only focusing on the subset of identity theft involving tax returns. Lastly, credible statistics on Tax Identity Theft is lacking. IRS, the authority that keeps all tax data and pays the fraudulent claims, does not seem to know the total number of fraudulent tax returns or the approximate cost of Tax Identity Theft. This lack of information created hurdles for researchers to analyze Tax Identity Theft trends and contributing factors.

Fortunately, the Federal trade commission keeps a database of the identity theft complains annual reports in the US and gives the percentage of the complaints that are tax/wage related (US Federal Trade Commission, 2015). We used the later as a proxy for the number of customers affected by Tax Identity Theft as a way of overcoming lack of actual published statistics on Tax Identity Theft (US Federal Trade Commission, 2015). The next section reviews the increasing adoption of e-filing then investigate whether there is a link of this growth with the rising Tax Identity Theft and the risk gateways being exploited.

THEORETICAL DEVELOPMENT/MODEL

Tax Identity Theft and Growth of E-Filing

Most U.S. taxpayers look forward to filing their taxes and receiving refunds in each tax season. In 2016, Internal Revenue Service (IRS) gave tax refunds totaling $279.857 Billion to 102,424,000 taxpayers; an average tax refund of $2,732 per taxpayer (US Internal Revenue Service, 2016a). This is a significant sum for many households, considering that the 2013 U.S. median household income is $52,250 (US Census Bureau, 2014).

Though many enjoy their tax refund, probably few enjoy the process of filing their taxes. Filling taxes manually is laborious and prone to inaccuracies (Edwards-Dowe, 2008). Besides, the government spent large amount of resources in printing the tax forms and distributing them to the taxpayers.

To ease the burden on the taxpayer, the government has spent the last two decades promoting the adoption of electronic tax filing. The IRS has been encouraging all taxpayers to file their taxes electronically and by the end of 2015 tax season (May 2016), 140,258,000 individual tax returns had been received out of which 123,737,000 which is 88.2% were filed electronically (US Internal Revenue Service, 2016a).

E-filing has several advantages over manual filing systems (Edwards-Dowe, 2008). First, e-filing is convenient to the taxpayer as they can e-file from anywhere at any time resulting in increased customer satisfaction. Second, e-filed submission is delivered instantly to the IRS and a receipt confirmation is made immediately to the taxpayer. This is followed by a quick decision on whether the returns have been accepted by the tax authority or not and associated reasons if not accepted. Third, e-filing enables the reuse of previously entered data such as name, address and other tax entries of the taxpayer, resulting in significant time saving. Finally, the fact that all data is entered via keyboard electronically rather than hand written manually reduces errors, and the electronic system enables data validation and detection of major discrepancies before actual submission (Edwards-Dowe, 2008).

However, the use of new technology can bring unintended consequences. The Internet brings several benefits but also brings into play its dark side which include hacking and identity theft

(Won Kim, Ok-Ran Jeong, Chulyun Kim, & Jungmin So, 2011). Because of its ability to accumulate and disseminate vast amounts of information electronically, the Internet may make theft of personal or financial identity easier (Milne, Rohm, & Bahl, 2004). More specifically, three aspects of e-filing that contributed to its rising popularity, namely simplified electronic data entry, remote filing, and shortened lead time on refund, can also contribute to the prevalence of Tax Identity Theft. This is because a criminal can file many tax returns in a short time (simplified electronic data entry) remotely from anywhere including foreign countries without revealing their identity and with lower risk of apprehension and prosecution.

The large trove of electronic data collected in the tax filing process may become a magnet for data thieves and can be stolen and reused to file fraudulent tax returns. There is already anecdotal evidence to suggest that this is already happening: The Utah tax commission in 2015 noticed a rise in suspicious tax returns (Krebs, 2015). The above examples suggest that the factors that contribute to the increasing adoption of e-filing will also contribute to the growth of Tax Identity Theft and leads to the following hypothesis:

H1: Tax Identity Theft growth is positively associated with e-filing growth

Mediating Effect of Self-E-Filing

Self-e-filing is the submission of income taxes electronically by individual taxpayers instead of going to professional tax preparers, such as H&R Block. In the early days, taxpayers would go to professional tax preparers who were experienced, trained, and with the necessary software tools to do tax returns. However, part of the IRS strategy to increase e-filing involved encouraging tax software companies like Intuit, H&R Block, TaxACT to provide tax e-filing software that is easy to use and affordable (10-30$ range) to individual taxpayers (Yakal, 2015). This resulted in more individual taxpayers using software to file taxes by themselves instead of relying on tax preparation professionals. As competition among these companies intensified, several companies even started providing free online software to qualified individuals (US Internal Revenue Service, 2015b). These factors have driven more individuals to filling their own taxes using these software tools and thus increased individual self-e-filing.

However, the fact that more individuals are self-e-filing also means that it is much easier for an identity thief to self-e-file fictitious taxes using same software products. Previously, filing tax return with help of a professional tax preparer meant that a professional would look at the taxpayer's data in details and verify the numbers from original documents like employee W2 and benefits statements. Thus, it was much harder for an identity thief to present fictitious figures without supporting documents. Also, with self-e-filing, identity thieves can file hundreds of tax returns from the comfort of his/her house without prying eyes. The above rationale lead us to the following hypothesis

H2: The positive relationship between Tax Identity Theft growth and e-filing growth is mediated by self-e-filing growth

Mediating Effect of Direct Deposit

Among the electronic technologies adopted in automating the tax refund process is the use of direct deposit refunds. Tax refund through direct deposit is the electronic transfer of tax refund payments from IRS directly to the taxpayers' bank account. Direct deposit of tax refunds electronically takes less processing time than the traditional process, which involves physically

printing, mailing, depositing, and processing refund checks. Though direct deposit process has a higher upfront setup cost compared to the traditional process, it has a much lower unit processing cost because it eliminates the printing, mailing, and processing costs associated with physical checks. It also eliminates the hassle for taxpayers to deposit and wait for the check to be cleared. Thus, as more individuals turns to e-filing because of these benefits, we expect that more taxpayers will opt to have their refund checks deposited directly to their bank accounts instead of having a check mailed.

While direct deposit process eliminates risks of identity theft associated with the traditional process, it is open to other risks that contribute to the increased Tax Identity Theft. The method eliminates the use of the physical address as a detection point. Mailing a check to the taxpayer's address, means that the taxpayer or a representative must be living on that physical address to pick the check and then deposit it to the bank. However, with direct deposit, a criminal can give a fictitious address without much repercussion, as the money will still be debited to the bank account. The abovementioned rationale suggests that the increased use of direct deposit contribute to Tax Identity Theft growth.

H3: The positive relationship between Tax Identity Theft growth and e-filing growth is mediated by direct deposit growth.

Though the rise of Tax Identity Theft coincided with the increasing adoption of tax filing technology, it is possible that the rise in Tax Identity Theft is unrelated to technology adoption in tax filing process but due to other factors that have become more significant over the recent years. For example, the Tax Identity Theft growth trend may simply be attributed to the growth of individual tax return filed, annual refunds approved. Alternatively, Tax Identity Theft growth may be a natural consequence of increasing popularity of identity theft. As such, we include the annual total number of individual tax returns filed (Individual Tax Returns), annual total number of refunds issued, and count of identity theft complaints (Identity Theft) as control variables in our regression models.

RESEARCH METHODOLOGY

Data Description

In order to test the hypotheses developed, we retrieved archival data from various government agencies to be used in the regression models presented in the Statistical Models section. The dependent variable, Tax Identity Theft, is the count of Tax Related Identity Theft complaints received by FTC in a given year. We use this as a proxy for the count of actual tax return identity theft cases in the U.S. since the latter is not known. The US Federal trade commission has been releasing annual reports of all the consumer complaints that it has received since 2006 (Sentinel Annual Data-Book) comparing the annual counts by year (US Federal Trade Commission, 2015). These complaints include General Identity Theft (Identify Theft) and the percentage of General Identify Theft complaints that is tax/wage related fraud for each year. Thus, we derived the Tax Identity Theft count each year (the dependent variable) based on the number of identity theft complaints for that year multiplied by the given percentage that is tax fraud related in that year. This study used identity theft complaints over the last eleven years (2004-2014) as reported. General Identity Theft count from each year (Identify Theft) was used as a control variable.

We retrieved values of independent variable (E-filing) and the mediating variables (Self-e-filing and Direct Deposit) from the IRS' filing season statistics archive covering years 2009 to 2015 (US Internal Revenue Service, 2015a). E-filing is the count of individual taxpayers who filed their personal taxes electronically in a given year. Self-e-filing is the count of individual taxpayers who personally filed their taxes electronically. Direct Deposit is the count of individual taxpayers who had their tax refund deposited directly into their bank account. We also retrieved value of Individual Tax Return, the count of taxpayers who filed their personal taxes in a given year, and Total Refund, the count of total refund issued in a given year, from the same source, to be used as control variables.

Statistical Models

Three sets of regression models are necessary to test the mediation effects of self-e-filing and direct deposit on the relationship between e-filing and Tax Identity Theft.

Model 1: *Tax Identity Theft* (y) = β_0 + β_1*Identity Theft* + β_2*Individual Tax Return* + β_3*Total Refund* + β_4*E-filing*

Model 2A: *Self-e-filing* (y) = β_0 + β_1*Identity Theft* + β_2*Individual Tax Return* + β_3*Total Refund* + β_4*E-filing*

Model 2B: *Direct Deposit* (y) = β_0 + β_1*Identity Theft* + β_2*Individual Tax Return* + β_3*Total Refund* + β_4*E-filing*

Model 3: *Tax Identity Theft* (y) = β_0 + β_1*Identity Theft* + β_2*Individual Tax Return* + β_3*Total Refund* + β_4*E-filing* + β_5*Self-e-filing* + β_6*Direct Deposit*

The mediating effects of self-e-filing and direct deposit are established (Baron & Kenny, 1986) if:
(1) The independent variable affects the dependent variable in the first regression model (Model1)
(2) The independent variable affects the mediating variable in the second set of regression models (Models 2A and 2B).
(3) The effect of mediating variable on dependent variable must remain significant in the third model and the effect of the independent variable on dependent variable must weaken relative to the first regression model.

DATA ANALYSIS AND RESULTS

Multiple Regression Analyses

The results of multiple regressions analyses are presented in Table 1. Four regression models were tested, and they were organized into three groups. Models 1 examined the effects of E-filing (independent variable) on Tax Identity Theft (dependent variable), respectively. Models 2A and 2B examined the relationships of E-filing with Self-e-filing (Model 2A) and Direct Deposit (Model 2B), respectively, where Self-e-filing and Direct Deposit were the mediating variables. Finally, Models 3 examined the effects of E-filing, Self-e-filing, and Direct Deposit on Tax Identity Theft.

These results indicated that (1) there was a significant relationship between the independent variable and the dependent variable (Model 1), (2) there was a significant relationship between the independent variable and each of the mediating variable (Models 2A and 2B), and (3) the mediators were significant predictors of the outcome variable in an equation including both the mediator and the independent variable (Model 3) and the effect of the independent variable on dependent variable was weakened relative to when the mediator is excluded (comparing results

from Model 3 with that from Model 1). Thus, taken together, these results suggested that self-e-filing and direct deposit mediated the relationship between e-filing and Tax Identity Theft.

Table 1: Multiple Regression Analysis Results

	DV: Tax Identity Theft	DV: Self-e-filing	DV: Direct Deposit	DV: Tax Identity Theft
	Model 1 (β[a])	Model 2A (β[a])	Model 2B (β[a])	Model 3 (β[a])
Control Variables:				
Identity Theft	0.27	0.04	-0.00	0.18
Individual Tax Return	-0.06	-0.08	-0.03	0.06
Total Refund	-0.28	-0.00	0.24**	0.17
Independent Variables:				
E-filing	0.98***	1.02***	0.84***	0.22
Self-e-filing				2.27†
Direct Deposit				1.85†
Model Summary:				
R-Squared	0.94	0.99	0.99	0.98
Adjusted R-Squared	0.90	0.99	0.99	0.96
F Value	22.28**	241.98***	250.32****	39.81**
(N = 11)				

[a]Standardized regression coefficients
†p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001

DISCUSSION AND CONCLUSION

The findings from this study provide practical implications for Tax Identity Theft mitigation and contribute to the state of the art in technology acceptance research. Our results indicated that, after controlling for Individual Theft, Individual Tax Return, and Total Refund, Tax Identity Theft was still positively associated with E-filing adoption and this relationship was mediated by Self-e-filing and Direct Deposit adoption, as hypothesized earlier. These findings confirmed that the growth in Tax Identity Theft did not just happen because of increased tax return filing or increased general Identity theft but was, at least in part, caused by the increased adoption of e-filing technology. Furthermore, the results suggest that the increased e-filing adoption contributed to the growth of Tax Identity Theft through increased adoption of self-e-filing and direct deposit.

The findings shed light on the mechanism of how the adoption of technology in tax refund process influence Tax Identity Theft. Economic principles dictate that resources are scarce and great effort should be taken to make sure that the available resources are used in the most efficient and effective way possible (Samuelson & Nordhaus, 2009). Thus, better understanding of Tax Identity Theft mechanism will allow stakeholders to focus on these vulnerability points with all available resources instead of spreading them across the organization.

The best way to address information security problems is through a risk-based approach (Shameli-Sendi, Aghababaei-Barzegar, & Cheriet, 2016). This require conducting a risk analysis and identifying risks gateways and then designing a security defense (Boyle & Panko, 2015). The findings from this study suggest that the key risk gateways in the Tax Identity Theft process are at self-e-filing and at the direct deposit points. The knowledge of these risk gateways allows security engineers to implement smart security instead of brute force security in that

countermeasure are only placed at key strategic points instead of placing them in every possible terminal end point.

Our findings also support treating direct deposit as a key detection point in the process. The use of direct deposit allows criminals to bypass security detection mechanism such as bank tellers matching a customer's ID with his or her facial physical features. While we are not suggesting IRS should discourage the use of direct deposit, measures should be set up to detect fraudulent direct deposit requests.

While this study yielded interesting results, it is not without limitations. As reported earlier, our identity theft data is based on counts of reported General identity theft complaints rather than counts of actual identity theft events. This is common in identity theft research as real data on identity theft is often difficult to obtain and investigators must rely on reported incidents. Furthermore, the reported complaints likely represent lower bounds for the actual cases. Still, there is a chance that this limitation may affect the finer relationship among the variables in our models. We do not expect the main effects to be different but it is hard to be 100% certain unless actual identity theft data is available. We leave this for future research hoping the IRS can avail this data.

REFERENCES

References available upon request

DECISION SCIENCES INSTITUTE
Research Methodology for Healthcare Productivity Studies

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ABSTRACT

We present a multi-phase methodology for productivity studies in a large hospital setting. The illustration shown in this paper is based upon an initial study to understand the implementation of a Computerized Physician Order Entry (CPOE) system at an academic medical center. CPOE is a major facet of electronic health records (EHR), and it is hypothesized that CPOE implementation may increase both productivity and patient safety. This paper presents the methodology used in this study in order to provide guidance for future research on viable, scientific methods for testing hypotheses for process and information system improvements in a complex healthcare environment. Some initial results that help illustrate the benefit of the methodology are also provided.

KEYWORDS: healthcare, methodology, process mapping, work sampling, electronic health records

INTRODUCTION

We present multi-phase methodology for productivity studies in a large hospital setting. The illustration shown in this paper is based upon an initial study to understand the implementation of a Computerized Physician Order Entry (CPOE) system at an academic medical center. The medical center was interested in understanding the potential increased productivity over the life cycle of a patient's stay in the hospital, especially since there was some resistance by medical care providers to utilize the CPOE system. Reports of previous resistance to utilizing CPOE by physicians at other medical centers heightened the concerns of the medical center's administrators.

For these reasons, the medical center requested a structured methodology that was evidence based and statistically sound that would provide clear substantiation to both the medical care providers and administration. This paper will mainly present the methodology used in this study and will also present some results that help illustrate the benefit of the methodology. The main methodologies used are geographical mapping, process mapping, and work sampling.

LITERATURE REVIEW

Efficiency Analysis

Process mapping has been widely used in many industrial settings, including in healthcare. The use of process mapping in healthcare typically is initiated through lean manufacturing and Six-Sigma programs. For example, see Savory & Olson, 2001, for a list of guidelines provided for process mapping use in hospitals.

Work sampling studies have been used extensively in manufacturing for decades but are now starting to enter the healthcare sector. Ben-Gal, et al., 2010, present the use of work sampling for determining physician staffing at hospitals, and Upenieks, 1998, provides a discussion on how this method can be used to assess nursing efficiency.

CPOE

Numerous articles have been written over the past 20 years that discuss the need for CPOE, as well as the challenges that exist in implementing CPOE in hospital settings. One of the main stated benefits of CPOE is increased patient safety, since CPOE is a part of an electronic health records (EHR) system, that not only includes reported data on the patient, but also uses sophisticated decision support systems to ensure that prescribed medications are called for by a physician in acceptable protocols and do not negatively interact with other medications or specific patient allergies. Berger & Kichak, 2004, discuss these issues in detail. Devore & Figlioli, 2010, and Khanna & Yen, 2014, further elaborate on lessons learned and various hospital experiences with implementing CPOE.

It is important to note that actual experiences in CPOE implementations indicate difficulties of many types, including resistance by physicians to use the technology as well as productivity reductions and information errors.

Due to the known and expected hurdles in the CPOE implementation associated with this article, the CPOE champions and hospital administrators decided to determine how both short-term and long-term productivity levels could be methodically assessed and requested the author to design a multi-phase approach for this purpose.

PROCESS MAPPING PHASE

The objective of process mapping phase was to observe various physicians, nurses, and pharmacists to determine the work processes these healthcare providers perform throughout their work shifts. Based on these observations, the research team, which including the author and three graduate students, created process maps (also called flow charts) to illustrate the detailed work flows. These process maps were later used as the basis for the Task Lists for the the work sampling studies.

The goal of this project was to obtain a baseline reference on the work processes of various healthcare providers before CPOE was implemented throughout the medical center. We found, however, that approximately 80% of the General Internal Medicine (GIM) patients were CPOE patients, that is, that the orders for these patients were entered using CPOE whenever appropriate. Some orders, such as those for MRIs, could not be entered using CPOE and must either have a written order submitted or a phone order. None of the patients for Cardiac Care Unit (CCU) and General/Trauma Surgery (G/TS) were CPOE patients. The pharmacy received orders by CPOE and also by phone and fax, which are the two common methods for sending prescriptions from non-CPOE implemented units.

Traditionally, each patient has a record that contains information on his or her symptoms, diagnosis, vitals, and progress. This information is collectively called the patient's chart and is kept in a 2-inch binder. However, for CPOE patients, much of this information, such as vitals, is recorded in the computer, which is a database that contains all of the patient's computerized

information at the medical center. Other information, such as progress notes continued to be stored in a patient's binder that held paper-based forms. Patients' information, whether it be held in a paper form in a binder or in electronic form still called "the chart".

Geographical Maps

Ideally, all patients assigned to a particular service would be located in designated areas reserved for that service. At the time of this study, however, the medical center was operating at full capacity. Therefore, many patients were placed into rooms as the beds became available and a physician team's patients would be located on multiple floors. Figure 1 shows a "geographical map, which is a process map that shows typical movements of a physician throughout the facility.

It became evident when reviewing various geographical maps that physicians would often be walking to other locations, sometimes to different buildings in order to complete their tasks. Movement tasks clearly would need to be an essential part of the productivity studies.

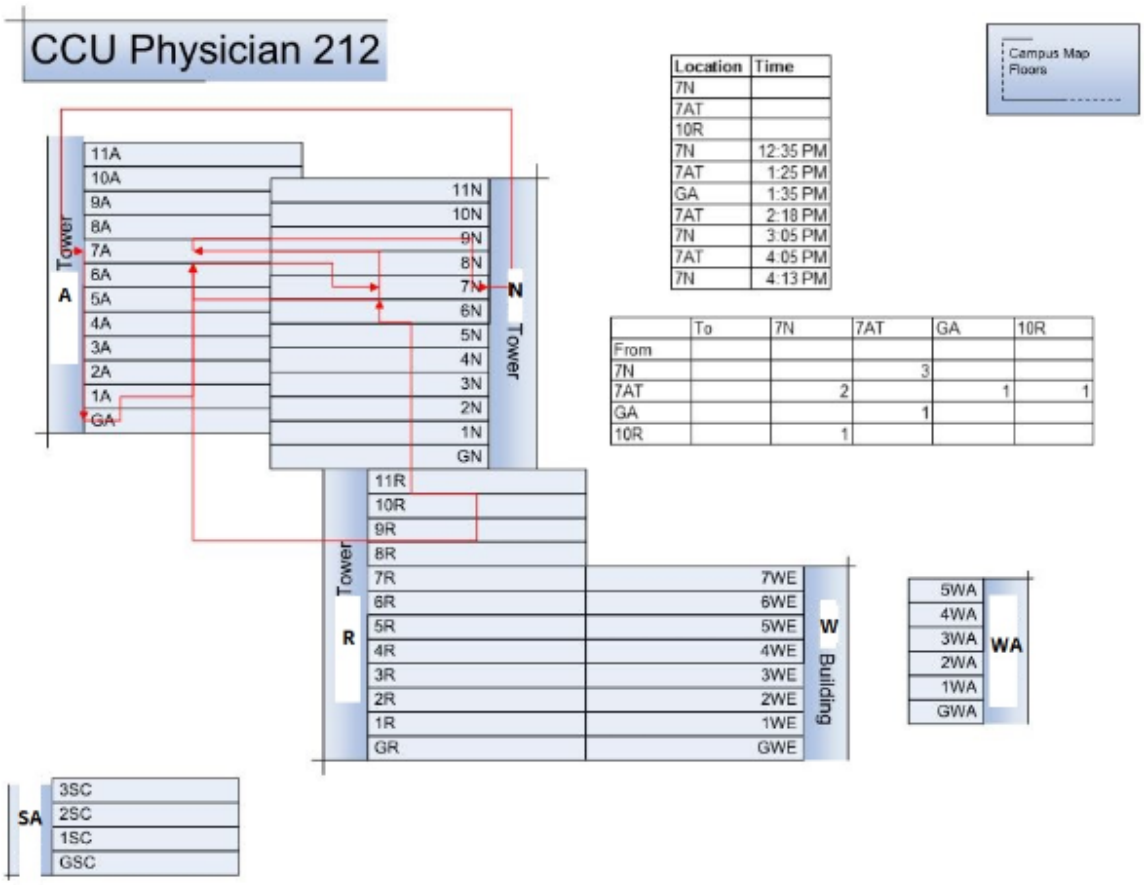

Figure 1: Geographical Map of a CCU Physician

Nursing Process Map

Since this article's main objective is to present a multi-phase methodology for use in EHR productivity studies, only the nursing main process map and descriptions are provided. Figure 2 provides the graphical view of the nursing process map.

Nurses are assigned to a specific floor, which generally corresponds to a specific service, like GIM. Nurses are assigned to a block of patient rooms. The number of patient rooms varies, depending on the service. There is at least one medication (med) cart for each block of rooms, except in the CCU where there is one med cart for each patient. The med cart contains medicines for all patients in the block except for those medicines kept in an AcuDose machine or in a refrigerator. Medicines kept on the med cart are separated by patient. AcuDose machines are located in every unit and contain IV fluids, expensive medicines and controlled substances. Pharmacy technicians periodically deliver medicines to the med carts, AcuDose machines, and refrigerators throughout the day.

The nurses have a set of six primary activities that occur in a relatively random fashion throughout the day. Almost all of the nursing activities fall into one of these six primary categories. These six categories are: administer medications; check for new orders; communicate; admit, discharge, and transfer patients; documentation of given care; and patient care.

Administer Medications

Administering medications involves a significant portion of a nurse's day. Most medications are administered at Standard Medication Administration Times (SMAT), such as 8:00 am, 12:00 pm, or 4:00 pm. However, not all medications are given at these times, as a patient may receive a dose every four hours, six hours, twelve hours, twenty-four hours, or as needed. Additionally, some medications cannot be given at the same time without the risk of an adverse reaction. Therefore, although the nurse will have many medications to give at SMAT, he or she will also give single doses of medications throughout the day.

The nurse begins the medication administration process by looking up a patient's medication list in either the information system or on the Medication Administration Guide (MAG). The medications are entered into the information system regardless of whether a patient is in CPOE. Thus, any nurse can obtain the patient medication list through this outlet. However, the MAG is not used on floors that have CPOE. As the nurse reviews the medication list, he or she determines whether a medication is in the patient's bin on the nursing cart in the hallway or in AcuDose. If the medication is in AcuDose, the nurse must walk to the AcuDose machine and go through the verification process to obtain the medication. This subprocess generally takes 1-5 minutes, as opposed to 10-30 seconds to get a medication from the patient's bin on the medication cart. In order for a nurse to administer a chemotherapy or insulin medication, he or she must have another nurse verify the dose. This additional step requires another 1-5 minutes of nurse time.

Before the nurse administers medications to a patient, he or she completes an assessment. The assessment includes checking the patient's vitals and, if necessary, the blood-sugar level or other relevant levels. After the assessment, the nurse administers the medications and charts those medications in the information system. If the nurse is also using a MAG, then it is

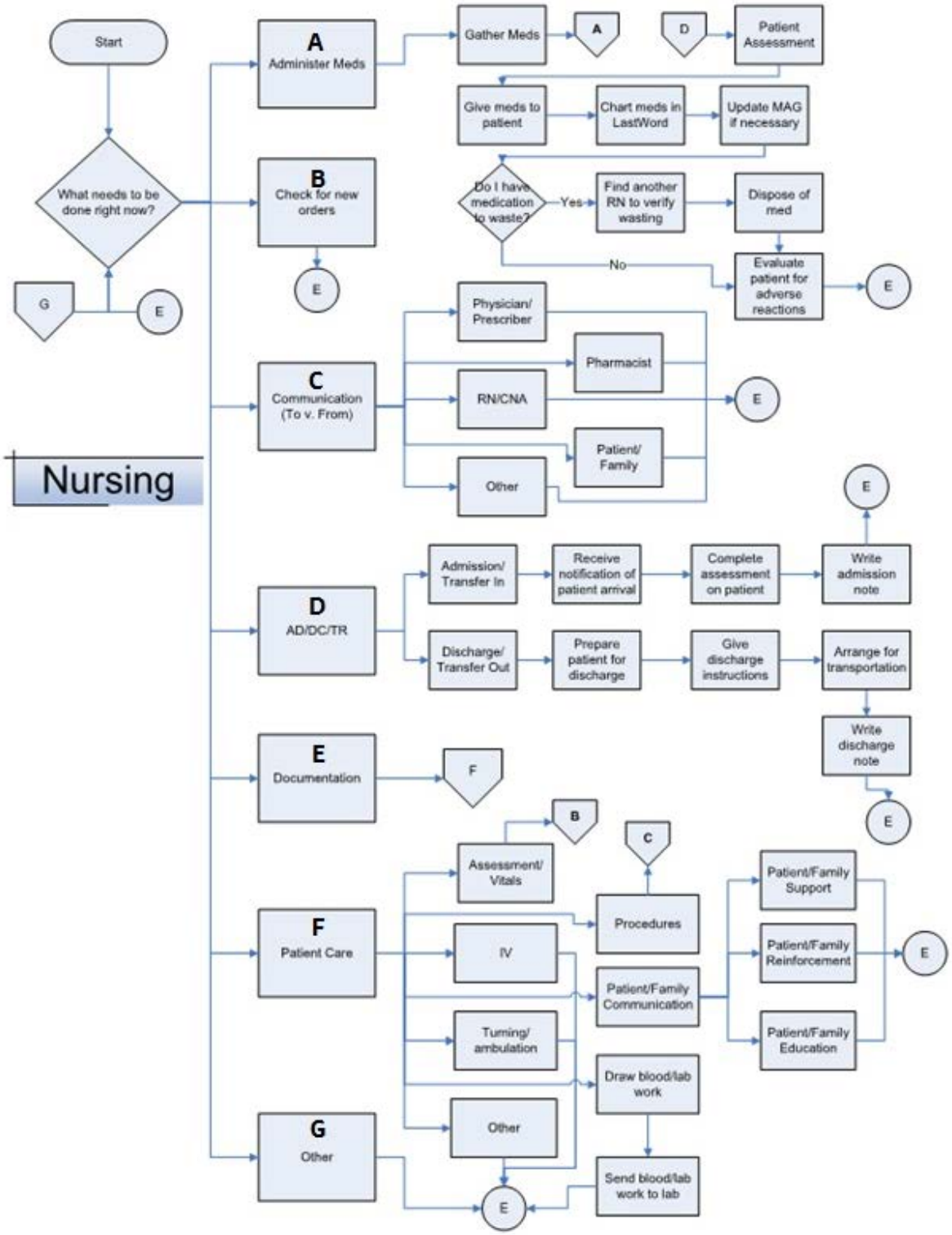

Figure 2: Nursing Process Map

updated at the same time. When there is excess medicine that cannot be saved for the next dose, the nurse must "waste" the medication, and another nurse must witness and verify that this is done. The final step in administering medications is for the nurse to evaluate the patient for any adverse reactions. The entire medication administration process usually takes about 5-20 minutes per patient, depending on the number of medications the patient must receive.

Check for New Orders

Throughout the day, nurses must check for new patient orders. On a CPOE floor, the nurse may search the record in the information system. On a non-CPOE floor, nurses must look to the patient's paper binder of records. Depending on the unit, this is either kept at the nurses' station or outside of the patient's room. The new order is usually "flagged" by placing it in the binder so that it protrudes from the top. Additionally, the unit secretary may give a carbon copy of the order to the nurse. Note that a new order does not necessarily require immediate attention; the order may be for medication to be administered several hours later.

Communication

A good portion of the nurses' day is spent communicating with others. Nurses commonly speak with: physicians and other prescribers; pharmacists; other nurses and CNAs; patients and their families; and other healthcare providers. The communication may be initiated by the nurse or the other party and may take place at any time. Topics may include, but are not limited to, patient updates; informal notification on new orders; questions about the patient's status; or non-business-related discussions. Note that communication here is distinguished from communication with the patient, or the patient's family regarding the patient's care (e.g. support, reinforcement and education) that is considered part of the Patient Care process.

Admit, Discharge, and Transfer Patients

While any given floor may have 0-8 admissions, discharges, or transfers into or out of the unit, during a day, we observed that one nurse will usually not have more than three or four of these events over two days. The process for both a new admission and a transfer into the unit is the same, as is the processes for a discharge and a transfer out of the unit. When there is a new admission or a transfer, the unit secretary will receive notification. The unit secretary will alert the charge nurse, who then makes the decision of in which room to place the patient. The charge nurse then informs the nurse assigned to that room.

Upon the patient's arrival, the nurse performs an assessment on the patient. The thoroughness of this assessment varies depending on whether the patient is a new admission or a transfer. A new admission requires a more complete assessment since there is no documentation tracking the patient over time. After completing the assessment and ensuring that the patient is settled, the nurse writes an admission or transfer note and places it in the chart. This subprocess requires approximately 20-45 minutes of the nurse's time.

For a discharge or a transfer out, the nurse prepares the patient for departure. This involves getting the patient dressed if he or she is leaving the hospital as well as securing all IV lines for transfer or removing them for discharge, among other tasks. If the patient is being discharged, the nurse goes over the discharge instructions. These instructions inform the patient of how to take any required medications at home, any physical therapy instructions, dietary instructions,

wound care instructions, and activity guidelines. It takes the nurse 5-15 minutes to go through the discharge instructions with the patient. Regardless of whether the patient is being discharged or transferred, either the nurse or unit secretary must arrange for transportation.

Finally, the nurse writes a discharge or transfer note after the patient leaves. The entire discharge or transfer out process takes about 15-45 minutes.

Documentation of Care Provided

Documentation is a ubiquitous task throughout the nurse's shift. Four primary areas of documentation were noted. First, all phone or verbal orders must be documented. Second, any patient care should be documented, such as changing dressings, adjusting IVs, and the patient's condition. Third, charting is considered documentation; charting includes recording that medication has been given, refused, or was not available, as well as a patient's vital signs. Finally, other miscellaneous documentation is required, such as accident reports and discharge papers.

Patient Care

The patient care process includes a broad array of tasks and can take a significant portion of the nurse's shift. There are six major categories of patient care: physical assessment/vitals, procedures, IV care, patient/family communication, turning/ambulation, and blood/lab work. To perform a complete assessment, the nurse performs a physical exam on the patient in addition to checking vitals. When the nurse begins a shift, he or she performs a complete physical exam on each patient. After this initial assessment, the nurse will perform many additional assessments throughout the day, which we observed to be less thorough. For example, the nurse checks vital signs on all patients throughout the day, but this process takes only 1-2 minutes, including the charting.

While the nurse is completing a physical assessment, he or she may make pre-charting notes of important information. These notes are informal and serve as a resource when the nurse does the formal charting. Formal charting either in the paper chart or in LastWord is the last step of the assessment process. Overall, the entire assessment process takes approximately 1-30 minutes, depending on the thoroughness of the assessment.

A nurse may be involved in procedures in several ways. Most frequently, the nurse preps the patient for a procedure that will occur at another location within the hospital. This includes arranging for transportation, securing all IVs and lines for transport, and sometimes accompanying the patient to or during the procedure. Nurses are required to accompany patients on procedures when the patient is deemed by a physician to be incapable of moving to the procedure room on his or her own. Additionally, the nurse may assist with routine and scheduled procedures or emergency procedures within the patient's room. In these cases, he or she may gather supplies, call a lab technician or other healthcare provider, confer with or assist a physician, or assist another nurse. While the procedure process generally takes 5-30 minutes, it can take much longer if the nurse accompanies a patient throughout a procedure or for emergency procedures.

If a patient has an IV, the nurse provides various kinds of care for it throughout the day. He or she checks it to make sure that it is open and clean. Also, the nurse may need to change the

line during the day. IV care is a relatively small part of a nurse's day, as it requires only 5-10 minutes of time. Similarly, turning and ambulation are quick processes. If a patient is confined to the bed, the nurse will turn him or her throughout the day. If the patient can get out of bed, the nurse will help the patient move within the room, such as from the bed to a chair. A physical therapist may come to help the patient with any further ambulation. Turning and ambulation requires approximately 1-5 minutes.

The nurse provides patient care through patient and family communication in three ways: support, reinforcement, and education. Patient and family support involves psychological support. Reinforcement are reminders as to what the patient needs to be doing to improve his or her health, as originally determined by a physician or other healthcare provider. Finally, education entails activities such as informing the patient and family about a medication that the patient is taking or explaining a procedure that the patient will have. Overall, patient and family communication lasts about 1-20 minutes on each occasion.

The final major category of patient care is blood and lab work. We observed that the majority of patients need lab work completed at least once every day, while many patients require multiple labs per day. This is especially true of patients who take medications whose dosage depends on the patient's blood levels immediately prior to medication administration. Although a lab technician will generally draw the labs, the nurse must ensure that this is completed when scheduled. We also observed that the nurse sometimes draws the labs. For example, if a physician orders a STAT lab, the nurse will draw the blood and send it to the lab through the tube system. Drawing and sending labs takes 5-20 minutes. Finally, the nurse checks all of the completed labs as the results return. If any results are abnormal, the nurse must decide whether to alert the physician. Generally, it only takes the nurse 1-5 minutes to check lab results.

WORK SAMPLING PHASE

The second part of the improvement analysis focused on a work sampling study designed to determine 1) if the observed tasks and task lists were sufficient and 2) the proportion of time spent by the health care providers on each of the tasks. The work sampling study allowed the subjects to record the activities that were being performed at random times during their work shift.

We used the information provided by the detailed process mapping phase to determine a "task list" that would be used in a work sampling study. The task list for nurses is provided below.

Nurse Task List Description

The Nurse Task List consists of seven major categories: Administer Meds, Review Orders, Communication, Admission/Discharge/Transfer Patient (Pt), Pt Care, Documentation, and Other.

Administer Meds

The five subcategories for Administer Meds correspond to the five primary tasks completed by nurses during the process of administering medications to patients: Gather & Prepare Meds, Physical Assessment, Give Meds, Chart Meds, and Waste Meds. Gather & Prepare Meds is

the process of collecting medications from AcuDose machines, the medicine refrigerator, and the nursing cart and preparing the medications for administration, such as removing pills from wrappers. A Physical Assessment of the patient is given by the nurse prior to drug administration. Give Meds is the act of administering the medications, such as hanging IV bags and watching the patient swallow oral medications. Chart Meds documents the administration of the medications. Waste Meds occurs when the nurse must document the accidental wasting, e.g. the drug needed to be disposed of due to accidental breakage of the container, of an expensive medication or controlled substance.

Review Orders

The Review Orders category is divided according to the medium of the order: Paper Order and CPOE Order.

Communications

The Communication subcategories correspond to the methods by which a nurse may communicate: Place Call/Page, Received Call, and Face-to-Face. Each of these subcategories is divided according to whom the nurse is communicating: another Nurse/CNA, Doctor/Prescriber, Pharmacist, Pt/Family, and Other. Furthermore, Doctor/Prescriber is divided by the topic of conversation: Verbal Order or Other. The Pt/Family item is for general communications with a patient or patient's family, such as directions to the cafeteria. Communications specific to patient care is found in the Pt Care category (described later) under Pt/Family Communication. The Other item refers to other people to whom the nurse may speak, including a respiratory therapist or a nutritionist.

Admit/DC/Transfer Pt

The Admit/DC/Transfer Pt is for patient movement into and out of the unit or floor. The two subcategories are Admission/Transfer In and Discharge/Transfer Out. Tertiary items for these subcategories represent the typical tasks required for the patient movement. For Admission/Transfer In, the tertiary items are: Notified of Incoming Pt, Settle Pt, Orient Pt, Write Admission Note, and Other. Notified of Incoming Pt indicates that the nurse is notified by the unit secretary that either a newly admitted patient or will be arriving on the unit or floor or a patient will be transferring in from another unit. Settle Pt refers to moving the patient into the room and perform other tasks required for having the patient stay on the floor, such as connecting IV tubes, oxygen flow monitors, and heart monitors. Orient Pt refers to describing information necessary for the patient's stay, such as hospital rules and how to use the television remote.

For Discharge/Transfer Out, the tertiary items are Prepare Pt, Review Meds/Orders with Pt, Arrange for Transportation, Collect Pt's Documents, Write Discharge Notes, File Pt's Documents, and Other. Prepare Pt refers to preparing the patient for departure, including disconnecting IVs, closing off the oxygen flow, and disconnecting a heart monitor. Review Meds/Orders with Pt means discussing the physicians discharge orders and what medicines to take when at home and how often. Arrange for Transportation refers to the nurse telling the unit secretary to call for someone to assist the discharged patient to the hospital door. Collect Pt's Documents refers to collecting and preparing the patient's documents, such as teaching notes and plan of care, for departure. Write Discharge Notes refers to writing final progress notes in

the patient's chart or plan of care. File Pt's Documents refers to putting all of the patient's documents into the patient's chart.

Patient Care

The Patient (Pt) Care subcategories pertain to the tasks associated with general patient care. They are Physical Assessment/Vitals, Pt/Family Communication, Procedures, Turning/Ambulation, Inspect IVs, Draw Blood/Lab Work, and Other. Pt/Family Communication refers to imparting information specific to the patient's care to the patient or family. Examples of this type of information include reminding the patient of how to perform breathing exercises or how to care for surgical incisions at home. There are three types of care specific information which corresponds to the tertiary categories: Support, Reinforcement, and Education. Tertiary categories for Procedures are: Wound Care, Prepare Pt for Procedure, Perform Emergency Procedure, and Perform Routine/Scheduled Procedure. Prepare Pt for Procedure refers to task associated with preparing the patient for a procedure that may performed either in the patient's room or off the floor. These tasks include gathering equipment or supplies, such as a mobile heart monitor or gauze pads and syringes. Perform Routine/Scheduled Procedure refers to procedures that the nurse performs, such as removing a sheath from a patient after a stent is implanted.

Documentation

Subcategories of Documentation are: Charting, Pt Care, Telephone/Verbal Orders, and Other. Charting refers to documenting the patient's vitals and other standard patient items, such as the cleanliness of the patient's IV location and the patient's assessment of his or her level of pain. Pt Care refers to writing notes related to patient care, such as daily plan of care updates and progress notes. Documentation of a Telephone/Verbal Order includes completing a Nursing/Pharmacy Communication Form.

Other

Subcategories under Other consist of: Stock Cart, Personal Time, and Other. Stock Cart entails gathering supplies from the Par Stock room and stocking the nursing cart.

<u>WorkStudy+ Software</u>

Handheld devices were loaded with a software program called WorkStudy+ created by QueTech. Preliminary tests were performed with a subset of subjects in order to determine the best settings and presentation features for this sampling study. One program feature was the random timer with an alarm that could be set over a range of time with a uniform distribution. Graphical analysis of the subset data, confirmed that the random alarms occurred as expected.

Another setting tested by the team with a subset of subjects was the random timer alarm. The alarm could be set for several different audible rings or one vibrate setting. The research team concluded that the vibrate setting did not adequately notify the user of the pending observation as it could not be felt to be vibrating within the user's pocket consistently. The team also discovered that the alarm was designed with a window of opportunity to record observations. That is, when it was time to make an observation, the device would power on. After ten seconds, the alarm would ring and continue ringing for a set period or until the user began

recording the observation. If the subject did not record the observation within the set period or if the subject began to record the observation but did not complete the recording by the time the window closed, the program recorded a missed observation.

Lastly, the research team experimented with the layout of task list activities on the device. There are several layout options. The device task list activities could be arranged in a table that could be arranged with any combination of two, four, or eight rows and one, two, or three columns. The row heights could also be set to a dynamic setting that would adjust the row heights as necessary but to no smaller than the initial number of rows. The limitation was that the table settings would be same for all screens, no matter the number of activities to be listed. For example, if the first screen held a three by three table to accommodate nine options, but a second screen only required a table of four options, the box size of those options for the second screen would be equal to the box size for the three by three table. The research team determined that, based on the initial version of the physician task list, a table of four rows and two columns was ideal. This effectively limited the number of categories to be listed on any one screen to eight options.

We performed a usability test of the devices with two volunteers. They were each given a device to carry as they worked in the hospital. The random timer was set for a range of twenty to thirty minutes with an average of twenty-five minutes. Another setting was a window of opportunity of sixty seconds. The hospitalists carried the devices for approximately four hours. The hospitalists were asked to focus on the usability of the device, such as the alarm beeping and the window of opportunity, as well as the veracity of the items on the task list. Feedback indicated that the window of opportunity needed to be extended to longer than sixty seconds as the volunteer subjects were being timed out of the window of opportunity before being able to complete the observation recording. Other feedback indicated that the time range was adequate, the beeping was not very intrusive, and the task list items were accurate. In response to the window of opportunity, we extended it to ninety seconds.

Prior to the approval of the Physician Task List, a preliminary version of the list was loaded onto the devices using WorkStudy+ template in Microsoft Excel. When the final version of the Physician Task List was approved, that list was uploaded onto all devices. This cycle was repeated during the approval process for each of the task lists.

All participants were personally instructed by a member of the research team on the use of WorkStudy+ immediately prior to the commencement of their participation in the work sampling study. They were also given a hardcopy of the relevant task list and the contact number for one of the members of the research team.

COLLECTION OF WORK SAMPLING RESULTS

Once all data was collected from the subjects, we analyzed the means and performed Tukey range tests. In Figure 3, we list a partial set of nurse work sampling information. This information was considered extremely enlightening by the medical center's administration, and would inform the design the CPOE system, as well as other design decisions for the medical center's operations.

Element Description	Sum Entries	Percent Count
<All elements>	640	100.00%
Administer Meds	83	12.97%
Chart Meds	5	0.78%
Gather & Prepare Meds	36	5.63%
Give Meds	41	6.41%
Physical Assessment	1	0.16%
Admit/DC/ Transfer Pt	25	3.91%
Admission/ Transfer In	13	2.03%
Notified of Incoming Pt	1	0.16%
Orient Pt	1	0.16%
Other	2	0.31%
Settle Pt	6	0.94%
Write Admission Note	3	0.47%
Discharge/ Transfer Out	12	1.88%
Arrange for Transportation	1	0.16%
Collect Pt's Documents	3	0.47%
File Pt's Documents	1	0.16%
Other	2	0.31%
Prepare Pt	3	0.47%
Write Discharge Notes	2	0.31%
Communication	81	12.66%
Face-to-Face	68	10.63%
Doctor/Prescriber	11	1.72%
Other	8	1.25%
Verbal Order	3	0.47%
Nurse/CNA	37	5.78%
Other	7	1.09%
Pt/Family	13	2.03%
Place Call/Page	5	0.78%
Doctor/Prescriber	4	0.63%
Other	1	0.16%
Verbal Order	3	0.47%
Pt/Family	1	0.16%
Received Call	8	1.25%
Nurse/CNA	6	0.94%
Other	1	0.16%
Pt/Family	1	0.16%
Documentation	117	18.28%
Charting	96	15.00%
Other	2	0.31%
Pt Care	15	2.34%
Telephone/Verbal Order	4	0.63%
Other	64	10.00%
Other	16	2.50%
Personal Time	43	6.72%
Stock Cart	5	0.78%
Pt Care	130	20.31%
Draw Blood/Lab Work	19	2.97%
Inspect IVs	21	3.28%
Other	14	2.19%
Physical Assessment/Vitals	25	3.91%
Procedures	31	4.84%
Perform Emergency Procedure	2	0.31%
Perform Routine/ Scheduled Procedure	17	2.66%
Prepare Pt for Procedure	2	0.31%
Wound Care	10	1.56%
Pt/Family Communication	8	1.25%
Education	3	0.47%
Support	5	0.78%
Turning/ Ambulation	12	1.88%
Review Orders	23	3.59%
CPOE Order	8	1.25%
Paper Order	15	2.34%

Figure 3: Representative Work Sampling Data

TUKEY STATISTICAL TESTS

Figure 4 provides a small subset of the work sampling results to illustrate the final step of the productivity analysis phases. Here, we see that nurses in GIM spend significantly more time administering medications than do nurses in CCU and G/TS. Recognition of this difference can provide insights into prioritizing electronic health record applications like CPOE, since the use of CPOE in GIM will likely have the potential to increase nurses' productivity there as compared to the other two services, especially CCU.

Administer Meds

Administer Meds

Tukey HSD[a,b,c]

Group	N	Subset 1	Subset 2
CCU	7	9.667%	
G_TS	9	17.681%	17.681%
GIM	5		22.754%
Sig.		.222	.530

Means for groups in homogeneous subsets are displayed
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 71.005.

a. Uses Harmonic Mean Sample Size = 6.608.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

- **Gather & Prepare Meds**

Gather & Prepare Meds

Tukey HSD[a,b,c]

Group	N	Subset 1	Subset 2
CCU	7	6.502%	
G_TS	7	7.611%	7.611%
GIM	3		15.550%
Sig.		.938	.068

Means for groups in homogeneous subsets are displayed
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 25.402.

a. Uses Harmonic Mean Sample Size = 4.846.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

FIGURE 4: Representative Tukey Range Tests

CONCLUSION

A comprehensive approach to studying productivity issues due to CPOE implementation was illustrated. A multi-phase approach was utilized, starting with observations of healthcare providers, then moving onto geographical and process mapping. Based upon the detailed process information learned, a work sampling study was designed and executed with commercially available software, WorkStudy+.

The data gathered from WorkStudy+ was then statistically analyzed to better understand where differences in work efforts occurred. It can be seen that the number of volunteers in each provider category were limited due to the difficulty of performing such a study in a working health care environment. Ideally, it would be beneficial to increase the number of study participants, and, therefore, the number of observations in order to increase the reliability of the results. Nevertheless, it can be observed that even with limited number of participants, relatively good statistical results were obtained.

Such a systematic approach to obtaining data in a complex, real-life service setting provided the constituents reliable information for determining design decisions related to the use of electronic health records. With increasing complexity of medical treatments, insurance and regulatory reporting requirements, and internal information needs, it will become even more important to analyze the current and proposed designs of electronic health record systems. A systematic approach using the operations management and industrial engineering methods applied in manufacturing settings will likely substantially improve both efficiencies and effectiveness in the health care arena.

FUTURE RESEARCH

This study was conducted at a single facility with a particular set of operating and information designs in place. Future research needs to expand the number of health care facilities tested in order to provide more generalizable results. In addition, testing more comprehensive improvements to electronic records systems in a longitudinal setting can provide organizations with a better understanding of the startup time required to see benefits across a variety of design options.

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DECISION SCIENCES INSTITUTE
Resource Dependence Driving Deficiency Premiums in B2B Supply Chains in the Bop

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ABSTRACT

Purpose
The paper comments on resource dependence dynamics of inter-organizational relationships in base of the pyramid (BoP) markets and elaborates related deficiency premiums.
Design/methodology/approach
The data was collected as field observations. Resource dependency theory is employed to analyze findings of the study.
Findings
The results of the study show that the financially poor micro-entrepreneurs remain on the losing edge in B2B supply chains in BoP markets.
Research limitations/implications
The qualitative findings of the empirical research need further validation using quantitative research designs.
Originality/value
With earlier empirical works in BoP literature mainly focusing business-to-customer linkages, the extent paper will further enrich the understanding of B2B business environment at the BoP.

KEYWORDS: Supply Chain Management, Business-to-Business, Base of the Pyramid, Field Observations, Resource Deficiency Premiums.

INTRODUCTION

Development through commerce agenda for those making the bottom tier of the world income pyramid put forward by Prahalad and colleagues (Prahalad, 2006; Prahalad and Lieberthal, 2003) have succeeded in gathering notable attention from concerned scientific community (Kolk *et al.*, 2014; Khalid and Seuring, 2017). The foremost BoP literature either tried to problematize BoP case or tended to stir multinational corporations' (MNCs) attention to start commerce in potentially lucrative informal markets of BoP (Prahalad, 2006; McMullen, 2011). While the BoP research stream has gradually developed from a consumer oriented (Ahlstrom, 2010; Weidner *et al.*, 2010) through a producer oriented (Agnihotri, 2013) to a partner oriented (Simanis *et al.*, 2008) inclusive business domain, business relationships and issue of poverty premiums was mainly dealt with from a business-to-consumer (B2C) perspective in extant literature (Karnani, 2007). Indeed, humble consumers are exploited on hands of the local businesses who while offering mainly utility items do charge certain price premiums. However, the consumer centered justifications for this malpractice in B2C supply chains are far diverse than ones presented by BoP researchers so far. The BoP literature in simplistic terms considers illiteracy, weak purchasing power and inconsistent and unreliable sources of income as prime causes forcing consumers to pay poverty premiums (Agnihotri, 2013). The respective literature has however not yet investigated the B2B dimension of the malpractice and therefore has yet to explore if relationships further up a supply chain remain a cause of the phenomenon. Instead of having a holistic end-to-end supply chain perspective, BoP literature by far has focused on a bifurcated,

localized and a more consumer centered B2C perspective in order to analyze case of premiums in subsistence markets.
Individual businesses today are considered as nodes forming a wider supply chain network, with core assumption implying 'each node of the chain effects others'. The indigenous entrepreneurs working in subsistence markets remain not an alien to the fact. Not only that the supply chain actors working up a supply chain can be prone to same malpractices happening down the chain but can also be a cause of downstream challenges.
In such a context the study aims to explore how inter-organizational relationships in BoP frame advent of poverty premiums. The study while analyzing business relationships using resource dependency theory (RDT) as theoretical lens, incorporates B2B dimension in a largely B2C centered poverty premium discussion. While doing so the paper presents the case of the indigenous entrepreneurs. The paper argues that not only the consumers but also the humble local businesses in peculiar informal market setting of BoP are paying premiums to their relatively advantageous suppliers. Furthermore, the paper while also maintaining in-line with the core understanding of supply chain management literature elaborates on how the B2B practices have an impact on B2C domain of respective supply chain. The extent paper therefore maintains that challenge of premiums cannot be tackled by solely aiming at B2C focused interventions converging on final consumer empowerment strategies.
Furthermore, while relating empirical findings with RDT, the paper also analyses highly dependent indigenous micro-entrepreneurs' relationship with their immediate suppliers. We are of the view that RDT while talking about causes of a dependent relationship between organizations, its' respective pros and cons and strategies that can help businesses reduce interdependency, can provide valuable insights to peculiar situation of indigenous business in resource scarce business environments. At the theoretical level, the paper thereby tries to incorporate RDT in a highly concrete BoP debate (Halme *et al.*, 2012). The paper in the context of RDT will also open a new theoretical window to better analyze an asymmetric B2B supply chain in BoP.
The rest of the paper is structured as follows. The next section presents a brief overview of the concerned published literature. Following section introduces the reader with the methodology employed. Findings of the study are presented in the next section. Last but not least a discussion is presented after findings and a brief conclusion makes the concluding section of the paper.

LITERATURE REVIEW

Base of the Pyramid (BoP)

Since the earliest publications of Prahalad and Lieberthal (1998), Prahalad and Hart (1999) and also Prahalad, (2006), people making up the bottom tier of world income pyramid and largely dependent on informal market economy for their subsistence (Arnold and Williams, 2012) are referred to as BoP in management related literature (Kolk *et al.*, 2014). The terms subsistence markets (Elaydi and Harrison, 2010), subsistence consumers (Weidner *et al.*, 2010), subsistence businesses and subsistence entrepreneurs (Toledo-López et al., 2012) have been used by researchers to refer to the fragile nature of economic activity at the BoP. Furthermore, the very use of the term "subsistence" while referring to BoP in general, points to the critical nature of financial capital in the particular settings. While lack of financial capital resources remain a defining characteristic of BoP (Kistruck et al., 2011), literature presents and comments on different types of capital resources that remain vital for doing business in BoP (McMullen, 2011).
Over the years the BoP debate has gradually developed from a consumer and marketing centered call of market intervention for MNCs to a partner and capability nurturing notion for

sustainable development of BoP through promoting business related activities (London *et al.*, 2010; Calton *et al.*, 2013). The BoP literature in general considers slow economic activity in BoP markets, a result of varied number of reasons from illiteracy to absence of logistical and institutional infrastructure. Therefore, a sundry of proposals to kick start economic activity at the BoP focusing both business model and product innovations have been presented by BoP researchers over the years (Hall *et al.*, 2012; Kistruck *et al.*, 2013; Hall *et al.*, 2014; Fawcett and Waller, 2015).

An examination of the earliest published BoP literature reveals that devising mechanisms to lower down the poverty premiums, remains one among the core foundations of whole premise of the research stream (Prahalad, 2006; Karnani, 2007). BoP scholars argue that MNCs are well able to reduce poverty premiums while earning decent profits by offering their products and services to BoP after reconfiguring their products and pricing strategies (Agnihotri, 2013). This should lead to the creation of win-win scenario for both MNCs and poverty stricken inhabitants of resource scarce business environments (Viswanathan *et al.*, 2009; Van den Waeyenberg and Hens, 2012). Since the seminal BoP literature was largely consumer focused and scholars have primarily dealt with B2C issues, the poverty premiums are mainly understood and dealt with from a consumer oriented perspective (Acosta *et al.*, 2011; Kolk *et al.*, 2014). While, indigenous BoP businesses remain part and parcel of the same resource scarce communities, little effort has yet been undertaken to study the advent of the premium phenomenon in B2B market interactions. The apparent research gap has not only baffled our wholesome understanding of the issue, but has also contributed towards positing consumer focused and rather “incomplete” solutions to the challenge (Agnihotri, 2013). Furthermore, the actor based viewpoint of BoP literature (focusing either consumers or producers) has contributed towards dealing with poverty premiums in a relatively narrower actor focused rather than in a more holistic supply chain perspective.

Though the absence of logistical infrastructure has been highlighted, and strategies to address related challenges have been presented earlier (Vachani and Smith, 2008), over the time concerned researchers have started viewing the BoP in a broader supply chain perspective (Sodhi and Tang, 2016; Khalid and Seuring, 2017). Calls for redesigning supply chains to address the unique challenges of BoP and involving the disadvantaged supply chain actors in value creating activities along the supply chains have emerged (Hall and Matos, 2010; Fawcett and Waller, 2015). Sodhi and Tang (2014, 2016) argue that the BoP market is different from the formal markets on account of two main challenges to deal with. First, challenge being lowering down high transaction costs arising from dealing with a large number of small transactions. Second, insuring the fair distribution of rents generated by supply chains among the advantaged and disadvantaged supply chain actors. Since both of these issues are supply chain related we think that examining BoP related issues in an overarching supply chain perspective instead of localized actor based view can be a potential way forward. By supply chain perspective we mean the basic understanding of the concept, viewing individual businesses as segments (nodes) of a wider and more complex network with activities happening in one part of the chain effecting or traveling to other parts.

Having said that, we argue that the issue of poverty premiums also needs to be studied in a wider supply chain perspective. Examining the structure and inter-organizational relationships upward a BoP supply chains can enrich our understanding of resource scarce business environments while providing new insights to deal with associated challenges. Given the scarcity of resources in BoP, the RDT can offer a theoretical background for analyzing the question taken up in the extent paper.

THEORETICAL DEVELOPMENT/MODEL

Resource Dependency Theory (RDT)

Since the influential work of Pfeffer and Salancik (1978), RDT has been widely employed to suggest and explain strategies employed by organizations to reduce "environmental interdependence and uncertainty" (Hillman *et al.*, 2009). "Rooted in an open system framework" (Barringer and Harrison, 2000), RDT talks about *why* and *how* organizations work to reduce other's power, meanwhile establishing their own supremacy. Power*,* understood in terms of control over fundamental resources thereby builds a core construct, RDT uses to explain interdependence in inter-organizational relationships along a supply chain (Bode *et al.*, 2011; Drees and Heugens, 2013). It must be kept afore that RDT is distinct from resource based view presented by e.g. Barney (1991). While the resource based view focuses on internal firm resources, RDT talks about the external environment of an organization influencing it. RDT considers organizations not to be autonomous entities rather constrained by their external business environment therefore in order "to understand the behavior of an organization (one) must understand the context of that behavior – that is, the ecology of the organization" (Pfeffer and Salancik, 1978, p. 1). The social context of the organization thereby is considered imperative for understanding organizational behavior. Core assumptions of RDT can be summarized as follows:

1. To a large extent organizations are not internally self-sufficient with respect to strategic resources (Heide, 1994; Paulraj and Chen, 2007).
2. To get access to respective strategic resources organizations are dependent upon other firms (external environment).
3. Organizations intentionally establish "formal and semiformal links with other firms" in order to "reduce uncertainty and manage dependence" (Ulrich and Barney, 1984; Paulraj and Chen, 2007)
4. While managing dependencies for the sake of their personal (corporate) benefit "organizations must acquire control over critical resources in an effort to decrease dependence on other organizations" (Barringer and Harrison, 2000).
5. Furthermore, organizations must "acquire control over resources that increase the dependence of other organizations on them" (Barringer and Harrison, 2000).

RDT thereby considers firms to be inherently resource scarce. Moreover, in a wider perspective the theory also assumes firms to be operating in an uncertain and resource scarce business environment (as the external organizations focal firm is interacting with remain also not self-sufficient). Business entities thereby lacking in one or the other resources needed to run their normal business operations have to interact to fulfill each other's needs. The inter-organizational interaction gives rise to a whole range of relationship continuum from transactional associations to strategic alliances. Though, the interaction among the organizations on one hand serves to provide respective firms with the needed resources and thereby mitigate associated uncertainty, however, on the other hand it creates dependencies. RDT posits that inter-organizational interactions do remain prone to opportunistic intentions of interacting firms, who purposefully structure these relationships to manage dependencies in their own favor. Inter-organizational relationships therefore remain one among the different options employed by firms to manage interdependencies in an uncertain business environment (Barringer and Harrison, 2000). It should be kept afore that RDT considers relationships among organizations only a mean to acquire critical resources, possession of whom is considered a source of power.
This paper will use RDT to analyze inter-organizational relationships in a highly social, volatile and resource scarce business environment i.e. BoP markets.

RDT and Inter-organizational Relationships

Inter-organizational relationships help firms achieve their business objectives by integrating otherwise segregated physical and intellectual resources. As mentioned earlier, in an open market environment firms engage with each other to get accesses to critical resources they lack otherwise (Pfeffer, 1972). This need to obtain resources creates dependencies among firms. Based on the concept of interdependence (Paulraj and Chen, 2007), the basic arguments of RDT and its perspective on inter-organizational relationships are summarized by Pfeffer (1978, pp. 26-27) as:

1. The fundamental units for understanding intercorporate relations and society are organizations.
2. These organizations are not autonomous, but rather are constrained by a network of interdependencies with other organizations.
3. Interdependence, when coupled with uncertainty about what the actions will be of those with which the organizations interdepend, leads to a situation in which survival and continued success are uncertain
4. Organizations take actions to manage external interdependencies although such actions are inevitably never completely successful and produce new patterns of dependence and interdependence.
5. These patterns of dependence produce inter-organizational as well as intra-organizational power, where such power has some effect on organizational behavior.

Focusing “on control, power, and vulnerability” (Bode *et al.*, 2011), RDT asserts that firms by establishing inter-firm relationships tend to reduce uncertainty in their external resource requirements. Firms are therefore inclined to manage the resource provision uncertainty in their external business environment by increasing depth and breadth of their supply chain relationships. A reciprocal relationship therefore can be imagined between environmental uncertainty and inter-organizational relationships (strategic relationships) (Paulraj and Chen, 2007). In line with the said argument and while considering the strength of relationships from an intensity of information exchange perspective Bode *et al.*, (2011) maintain that “the more environmental uncertainty a firm face, the more information it needs to gather and process to achieve a given level of performance”. Relying on the logic it can therefore be anticipated that frequent exchange of information and extensive relationships among supply chain actors will be highly evident in a volatile and uncertain business environment.

Furthermore, RDT talks about the power factor in inter-organizational relationships especially when these relationships are asymmetric and dependent. RDT theorists maintain that, firms while decreasing their dependence upon external environment, simultaneously increase dependence of external business entities upon themselves (Pfeffer and Salancik, 1978). RDT thereby considers inter-organizational relationships a tool used by business organizations to increase their market power relative to other businesses, by getting hold on complementary assets. Access to critical resources is pursued as a strategy to counteract business ambitions of other supply chain actors particularly competitors (Barringer and Harrison, 2000).

RDT thereby attempts to provide theoretical foundations explaining the complex setting of inter-organizational relationships in an uncertain external environment, where strategic relationship building and opportunistic intentions go hand-in-hand. The guiding principle in relationship building remains the maximization of focal firm’s business interests.

RDT and BoP

RDT has been rarely used to analyze the case of the BoP. For example, though Schuster and Holtbrügge (2014) have used RDT to elaborate market entry strategies for foreign firms in BoP,

the theoretical framework has yet to be used to study the relationships among the indigenous firms operating in a resource scarce business environment.

RDT provides valuable insights about the interaction of firms with their external environment while also trying to explain how the firms can better deal with the respective challenges effecting their business outcomes. Considering firms to be operating within the constraints imposed by provision of restrained/controlled means of production, resource dependence perspective intends to elucidate the strategies that can help firms guard their business interests in a limited resource environment. In context of resource scarce and volatile business environments of BoP, inter-organizational relationships not only function to get access to otherwise lacking resources but also to compensate for institutional voids. The concerned literature considers institutional voids as among the prime factors responsible for the poor market performance in particular and underdevelopment of BoP in general (Parmigiani and Rivera-Santos, 2015). BoP researchers therefore, consider inter-organizational relationships with traditional and non-traditional stakeholders (social capital) as a means to compensate for institutional voids and therefore essential for successfully operating in BoP (Web *et al.*, 2010). Bridging institutional voids and gathering capital resources for developing operational capabilities of BoP entrepreneurs, therefore can be regarded as the core functions firms try to pursue through establishing external relationships. Firm's relationships in BoP in context of fulfilling dual objectives of resource provision and institutional voids can thus potentially be a special case for analysis using the theoretical lens of RDT.

BoP literature while highlighting the need for firms operating in peculiar informal business environments to strengthen their internal resource base, acknowledges the role of external stakeholders in providing the respective business entities with capabilities they otherwise lack (Calton *et al.*, 2013; Hahn and Gold, 2014). Table 1, categorizes the different types of capital resources literature suggests firms need to have to survive in the volatile business environment of BoP.

Table 1: Capital resources in BoP markets

RESOURCES	EXPLANATION		REFERENCES
Social capital	Relational capital	Trust, identification and obligatory traits among organizations	(Wagner, 2011; Ansari *et al.*, 2012)
	Cognitive capital	Shared ambition, vision, and values	
	Structural capital	Strength and number of ties between actors	
Financial capital	Financial resources a firm can leverage upon to build its competitive advantage		(McMullen, 2011; Kistruck *et al.*, 2011)
Human capital	Human resources enabling firm to achieve its strategic objectives		(Bardy *et al.*, 2012)

BoP literature also highlights the variation among different firms in terms of capital resources to operate in BoP. While some of the firms operating in BoP are reported to be rich in social capital, they usually lack in terms of financial and human capital (Ansari et al., 2012). Absence of ample financial institutions and uneducated/untrained labor force remain prime reasons for lack of both of the respective capitals with indigenous firms. On the other hand, certain BoP firms (MNCs) appear to be rich in financial and human capital, lack in social (Ghauri et al., 2014). Thereby, making it difficult for them to comfortably operate in a highly social business environment. The capital resources therefore appear to be a limiting factor both for indigenous and foreign firms in BoP.

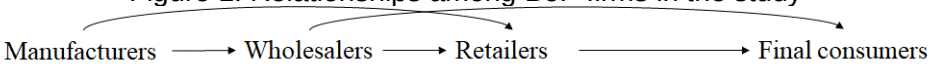
The issue of resources thus appears to be a point of convergence between BoP and RDT. While possession of resources (Table 1) potentially defines the existence of a firm in BoP markets, the RDT elaborates how one can access these resources. One should keep afore that the RDT theorists propose inter-organizational relationships as one among the different strategies that firms can employ to get access to deficient resources and thus decrease the supply related uncertainty in their external business environment (Barringer and Harrison, 2000). Corresponding to the propositions of RDT inter-organizational relationships in BoP may serve to compensate for the lacking capital resources i.e. financial and human capital for indigenous firms (filling institutional voids created by absent financial and education/training institutions) and social capital for MNCs (London and Hart, 2004). The apparent theoretical synergies among the relatively mature RDT and still evolving BoP research stream point to the fact that the argumentation of the former can be used to serve the purpose of later.
The extent paper tends to further explore this convergence of RDT and BoP on capital resources. RDT will be taken as the theoretical underpinning to analyze how inter-organizational relationships to get access to critical resources lead to generation of premiums in BoP markets. Since RDT considers firm power to be dependent upon the possession of critical resources. Firm relationships in human and financial resource sensitive BoP markets can be expected to be power based or opportunistic in nature. Firms can be imagined to be competing for the possession of the respective resources, as they remain relatively more inadequate than social resources (social capital) in BoP markets.

METHODOLOGY

Data Collection

The paper presents qualitative findings of an empirical study conducted in Pakistan during 2015-2016. While the data for the principal study was gathered using a structured questionnaire, the qualitative findings of the survey presented in this paper were collected as field observations to further enrich the principal quantitative findings. Qualitative data thus gathered helped better understand the interviewee and BoP business environment in a B2B context. The target population was indigenous micro-entrepreneurs operating with in a B2B business domain. Respondents were predominantly involved in manufacturing (suppliers) and retail (buyers) businesses. The retailers in this case were kiosks getting their supplies from manufacturers and wholesalers and selling it to final BoP consumers. Their merchandise consisted of various utility items from food and garments to stationary and basic electric equipment. Since the wholesalers doing business in the study area were found to be relatively “big” and couldn’t be regarded as micro-entrepreneurs, none of them was part of the sample and thereby included in the study.
The sample was drawn using snow-ball and convenience sampling techniques. The core criteria used to define micro-entrepreneurs (respondents) was number of employees (being 1-5) and subjective observation of the premises of the respondent’s workplace. The said data collection

Figure 1: Relationships among BoP firms in the study



techniques were specifically warranted in our context, since no reliable database was available to draw sample from. The respondents were usually either the owners of the businesses or general managers responsible for running the whole business independently. A pilot study was conducted with 10 respondents beforehand to identify potential avenues of improvement of data collection instrument. After completion of pilot study 50 face-to-face interviews were conducted

while not specifying any particular industrial sector. The strategy provided liberty to gather opinions from a very diverse business community representing various industrial sectors. A typical interview took approximately 45 minutes and were primarily conducted at the respondent's work premises and in regional language (i.e. Punjabi the mother tongue of the first author). While the interviews were audio-recorded, the filed observations are recorded in black and white. Furthermore, follow-up questions were asked during the course of interview to better understand the context and further enrich qualitative findings.

Data Analysis

The process of analyzing the data for this study started with transcribing the interviews and field observations. The transcription involved not only 'decoding' audio-recorded data in black and white and further streamlining filed observations, but also translating the respective data from regional language into English. While the field observations remained the prime source of qualitative data, on certain occasions data from structured interviews was consulted for better comprehension of the context.
RDT asserts that nature of the firm relationships are very much dependent upon and framed by its external environment. Since the research question taken up for the study remains enquiring how inter-organizational relationships in BoP frame advent of poverty premiums, it was deemed relevant to not only assess the general B2B business environment of BoP for indigenous micro-entrepreneurs, but also, the nature of dyadic buyer-supplier relationships focusing B2B supply chain. Having the qualitative data transcribed, the next step was unitizing the now relatively ordered filed observatory data into categories. The two respective categories were developed and titled as *B2B business environment at the BoP* and *nature of dyadic B2B relationships*. The process of grouping the data in categories was once revised in order to increase the reliability of coding process.

Qualitative data corresponding to the category 'B2B business environment at the BoP' was mainly inductively analyzed. Analytic induction procedure corresponds to intensive examination of strategically collected data to understand a specific phenomenon and establish its causes (Saunders *et al.*, 2006, p. 498). However, RDT was primarily employed to analyze the data pertaining to the category 'nature of dyadic B2B relationships'. It remains worthwhile mentioning that the results of analytic induction helped better understand the context and thereby make sense of B2B relationships assessed in context of RDT. The study therefore helped further establish relevance of yet another long-sought theoretical infrastructure to evaluate and tackle with BoP proposition and challenges, particularly those related to development and functioning of inter-organizational relationships (Ansari *et al.*, 2012; Schuster and Holtbrügge, 2014). The insights related to the B2B business environment yielded by inductive analysis of the qualitative data and nature or inter-organizational relationships in BoP studied in background of argumentation of RDT are presented in the next section.

Validity and Reliability

Credibility of the responses has been established by engaging the researcher (first author) native to the particular societies for data collection and prolonged engagement with the respondents. The two factors enabled develop familiarity with their cultural, social settings, and interests, and further, allowed to define the scope of interview. Additionally, through persistent observations follow-up questions were asked, which provided depth to the interview and proffered authors with relevant information for the findings of the study. Similarly, through the implementation of thick description technique, transferability of the study findings has been increased (Holloway, 1997).

Through the inductive analysis of B2B business environment and employing RDT argumentation for assessing inter-organizational relationships in BoP, theoretical triangulation of the study findings has been warranted. Theoretical triangulation allows the researchers to use multiple theoretical perspectives to interpret the data (Patton, 2001). The technique is often employed to establish conformability of the data in qualitative research. Therefore, the theoretical background applied in the study corroborates the consistency of findings.

FINDINGS

As has been highlighted earlier in the previous section that the qualitative data has been evaluated in backdrop of the two research objectives, the findings of the study will therefore be presented accordingly.

BoP Business Environment in B2B Context

To assess the general B2B business environment in BoP the respondents have been asked about the challenges and comforts of doing business in their peculiar informal market environment. The particular issues brought to light by the respondents are detailed below.

Physical Infrastructure

In the context of the acute power crises Pakistan was facing at the time of data collection, power shortage issue was most frequently mentioned challenge micro-entrepreneurs were dealing with. However, in line with what has been documented earlier under notion of missing infrastructure in BoP related literature (Berger and Nakata, 2013; Arnold and Valentin, 2013), we maintain that given the relaxation of magnitude of problem, power shortage issues are not unique to area under investigation. Having said that, the power shortage came up as one of the main obstacles hindering the respondents achieve their optimum performance potential.
Missing or absent logistical infrastructure has been presented as one of the striking characteristics of BoP markets in related literature (Vachani and Smith, 2008), however, while mainly speaking in context of B2C business environment. Surprisingly logistical issues were not regarded as a bottleneck by the respondents of this study. The micro-entrepreneurs seemed to have developed certain indigenous strategies to deal with missing logistical infrastructure e.g. using three-wheelers (auto-rickshaws) to transport relatively small batch sizes.

Institutional Voids

Having said about the business supporting physical infrastructure, respondents also mentioned how institutional voids are restricting their business growth (Parmigiani and Rivera-Santos, 2015). Absence of ample financial institutions to fulfill the working capital needs of indigenous businesses has been highlighted during survey (Akula, 2009). Furthermore, some respondents also pointed towards the corrupt and exploitative practices of officials of the few micro-finance institutions doing business in the region.
It has been further revealed that, though, to a large extent micro-entrepreneurs want to pay tax and thereby become formalized, astronomical tax rates and prevalent corruption of tax officials often keeps them from becoming part of the formal economy. The respondents seemed unanimously acknowledge the fact that illiteracy and absence of efficient judicial and other regulatory institutions remains the prime cause of exploitation of micro-entrepreneurs by opportunistic public and private officials (Van den Waeyenberg and Hens, 2012).

Micro-entrepreneurs as Lenders

It has been pointed out earlier by Weidner *et al.* (2010, p. 561) that "owners of small businesses in these markets (BoP markets) often play the role of lender", however while talking in perspective of B2C transactions. The qualitative findings of the study have concluded that the narrative stands true also for B2B market transactions (dyadic buyer-supplier transactions between retailers and manufacturers respectively in our case). Not only micro-entrepreneurs themselves lend their produce to their customers but also get their supplies on a deferred payment mode. The respondents have highlighted that a major part of B2B business transactions materialize on a deferred payment mode, with no guaranteed payback time negotiated or followed. Sometimes these deferred payments account for more than two-third of total business transactions.
While the deferred payments provide a financial life line to micro-entrepreneurs and enable them run their businesses during hard times, fraudulent practices remain common. Institutional voids further encourage black sheep exploiting their lenders. The intensity of such malpractices is so wide spread that most of the respondents have put the lost or deferred payments as second most cited challenge indigenous micro-entrepreneurs have to deal with. One can imagine the plight of affectees if one also takes into perspective the institutional voids in BoP. Furthermore, it has also been reported that relatively stronger suppliers use to lend supplies to their disadvantageous customers as part of an exploitative business strategy. While knowing that with meager financial capital at their disposal, the humble business customers are unable to get raw material, suppliers provide them with vital supplies on above market rates thereby charging them a capital deficiency premium. The modest business earnings, deferred payments and fraudulent practices in market keeps buyers from clearing the exorbitant bills with their suppliers. Relatively advantageous suppliers thereby gradually succeed in building a 'loyal' customer base to whom they can sell their output while charging a certain deficiency premium. The exploitative practice not only restricts business growth in BoP but also dictates nature of inter-organizational relationships which will be discussed in more detail later on.

Skilled Labor

While it is presumed that an abundant rather over supply of labor has paved the way for use of labor intensive technologies in BoP (Ray and Ray, 2010), the availability of skilled labor remains scarce. The third most mentioned challenge micro-entrepreneurs were facing after power shortage and lost payments was thereby related to human capital. The advantages of a trained labor force for businesses have been highlighted earlier in the BoP literature (Arnould and Mohr, 2005). However, the respondents of the study maintained unavailability of sufficiently skilled labor force as a major efficiency draining factor for their businesses.
Having said that we maintain that provided the general shortage of a trained labor force, inadequate human capital is effecting both financially strong and poor actors in BoP market.

China Factor

Indigenous micro-entrepreneurs in BoP due to their scarce resources usually remain unable to achieve economies of scale and scope (Karnani, 2007; Elaydi and Harrison, 2010) and thereby compete with big international players. "Due to China's rapid growth and integration with global markets, Southeast Asia's poorer economies are losing comparative advantage in labor-intensive manufacturing" (Coxhead, 2007). Inflow of relatively cheap alternative products in local markets has further made life difficult for respondents of this study. The micro-entrepreneurs have pointed towards lack of willingness of regional and national governments to keep a check

on imported items to safeguard local industry. Though few respondents manufacturing certain traditional and localized products remained neutral, majority reported losing business to Chinese products despite of the gigantic size of the BoP market. The owner of a small workshop employing 6 workers and manufacturing handmade shoes mentioned;
"it is becoming difficult to sustain the business with every passing day, before there were the big market players with heavy pockets who established big factories and snatched away our workers and now the influx of machine made cheaper Chinese shoes have made it difficult for us to compete ……. buyer in our market is always searching for cheaper products".

Obsolete Technology

In line with what has been reported earlier for telecom and automotive sector of India by Ray and Ray (2010; 2011), indigenous manufacturers have found to be using outdated technology. The vast majority of manufacturers realize the dire need to update their machinery however capital constraints and illiteracy restricts them to do so. Respondents of the study acknowledged that illiteracy impedes them from getting know how of latest technological advancements in manufacturing industry. A respondent manufacturing handles for electric irons in his house mentioned;
"you can see how we are making them (handles) by using this manually operated press. It requires good amount of muscle power and we know we are not efficient. The automatic press costs about Rs. 1,00,00,00 (US$ 9900 approx.) it's more efficient and gives quality output but we cannot afford it"
The phenomenon being general in nature for the BoP markets needs policy initiatives to be taken at national level in order to educate indigenous manufacturers and provide them with needed finances for technological upgrading.

Nature of Dyadic B2B Relationships in BoP

Having commented on the B2B business environment of BoP, this section will mainly deal with findings of the study related to dyadic buyer-supplier relations of indigenous micro-entrepreneurs in BoP. Furthermore, it is worthwhile mentioning that the respondents have been asked about three aspects pertaining to nature and strength of inter-organizational relationships i.e. frequency of contact, medium of contact and quality of relationships.

Frequency of Contact

Corresponding to what have been reported earlier in the BoP related literature, the respondents of the study were found to remain in frequent contact with each other (Hill, 2010; Hahn and Gold, 2014). It has been reported that the frequency of contact largely, however, not solely remains dependent upon the intensity of business transactions. Frequency of dyadic contacts though increases during high season, it does not entirely fade away during times of low business activity. The social bonds also make it possible for micro-entrepreneurs to keep seeing each other at different social gatherings. The micro-entrepreneurs contact each other sometimes just to convey the message 'I am still around'. One of the reasons justifying frequent contact with other businesses in BoP has been elaborated by one respondent as:
"In a dynamic business environment like BoP, with businesses appearing and disappearing quite recurrently, 'the call' is essential to keep other party aware of one's presence"
Furthermore, micro-entrepreneurs being devoid of formal organizational structures evident in large business organizations, the contacts are developed and managed mainly by owners of respective businesses.

Medium of Contact

Responding to question related to channel of contact, the micro-entrepreneurs were found to be mostly using mobile phones to communicate with other supply chain actors. Extensive geographical coverage of telecommunication technology and its affordability has made it possible for micro-entrepreneurs to expand their businesses (Van Sandt and Sud, 2012). Furthermore, it was also reported that visiting work premises of each other, meeting on various communal and social gatherings and discussing general life related issues apart from business was a common practice.
The informal nature and frequency of inter-organizational interactions highlight the much advocated social aspect of business relationships in BoP literature.

Quality of Relationships

When asked about the nature of relationships with their suppliers/customers (depending on if the respondent was manufacturer or retailer), the replies poised a complex picture of inter-organizational relationships in BoP. In spite of being in frequent informal contacts with each other generally the micro-entrepreneurs doubt the healthy nature of these relationships for their businesses. Relatively smaller businesses were found to be suspicious about the opportunistic intentions of relatively stronger business affiliates. They commonly believe bigger players doing business only for sake of their vested benefits and disregarding the general business interests of other supply chain actors. Though a very few of suppliers also appeared to be standing on the losing side, normally buyers were found to be weaker than their respective suppliers. Lack of sufficient working capital, weak purchasing power, selling in small quantities on deferred payments (while charging poverty premiums) and illiteracy remain the prime causes of relatively weaker financial position of buyers in dyadic relationships. Suppliers (manufacturers) while having relatively sound working capital to leverage upon, selling in large quantities (while charging poverty premiums) normally were found to be financially better-off then their business customers (retailers). In spite of the unhealthy nature of relationships the financially poor retailers intend to keep these associations to ensure a continuous supply of raw material in context of the dynamic and uncertain nature of external business environment (consider for example issue of lost or deferred payments touched earlier). On the other hand, financially strong suppliers appeared to ‘invest’ (by lending supplies) on buyers, in order to capitalize on business associations so developed by building a loyal customer base. The respective dyadic relationships among micro-entrepreneurs thereby appeared to be of opportunistic in nature. The next section will elaborate further on the dyadic inter-organizational relationships in BoP in context of argumentation of RDT.

RDT and Inter-organizational Relationships in BoP

An uncertain external business environment remains one of the defining characteristics of BoP (Hall *et al.*, 2014) . RDT asserts that firms in such a volatile business environment are inclined to interact with other supply chain actors in order to gather maximum information pertaining to their external environment (Paulraj and Chen, 2007). An increase in depth and breadth of inter-organizational relationships will therefore be evident in such a scenario as is depicted by the findings of this study. Furthermore, RDT proposes that firms by establishing such relationships will try to decrease their dependence on external environment while increasing dependence of external business affiliates upon themselves. While managing external dependencies firms produce new patterns of interdependencies subject to their social context Pfeffer and Salancik (1978, pp. 26-27). Corresponding to arguments of RDT one can anticipate that the unique

business environment of BoP relative to formal markets warrants exclusive modes of inter-organizational relationships.

It seems worthwhile highlighting here again that the respondents of this study regarded financial capital as the source of power. The claim appears justified when seen in context of arguments presented in BoP literature, considering social capital vital for BoP firms, regardless of their size and position in the supply chain (Ansari *et al.*, 2012; Reficco and Márquez, 2012). The fact can therefore be conveniently appreciated that the indigenous firms doing business in BoP must have accumulated social capital enabling them pursuing their business activities. Furthermore, the respondents of this study regardless of their role (buyers or suppliers) frequently highlighted how the underdeveloped human capital is effecting their business performance. The observation seems in accordance with BoP literature regarding issues like illiteracy and untrained labor force among the prime causes of underdevelopment of these regions (Kistruck et al., 2013; Shivarajan and Srinivasan, 2013). Social and human capital thereby appear as "constants" in this study since one (social capital) remains prime requirement of doing business for various indigenous BoP firms and second (human capital) is effecting all the business entities in BoP. With two types of resources remaining constant for respondents of this study, presence of financial capital stands out as the only type of resource determining power of the respective BoP actors.

An powerful actor in a dyadic relationship is thereby considered as one having more financial capital to leverage upon relative to other. While both the financially strong and poor actors in a dyadic relationship try to reduce uncertainty and manage interdependencies, their approach to achieve the objective differs. We have found that in context of BoP, financially strong actor naturally tends to pivot more on the financial power it enjoys to mould relationships in its own favor. On the other hand, financially poor actor tries to protect its business interests by focusing more on relationship building activities in order to showcase its trustworthy stature. Furthermore, respondents reported to be trying to increase dependence of other actors upon themselves while pursuing unique business strategies crafted in their respective internal and external resource provision environment (Lusch and Brown, 1996). In line with arguments of RDT, resources, may they be financial or another can thus be seen as being exploited by firms to manage interdependencies leading to maximize their respective market power relative to other supply chain actors (Caniëls and Gelderman, 2007; Boons *et al.*, 2012) . Analyzing exhibit of power by relatively financially strong actors or their trustworthy stature by financially poor actors in their mutual effort to decrease uncertainty and manage interdependencies can help better understand B2B business environment and inter-organizational relationships in BoP.

Financially Strong Suppliers in BoP

RDT asserts that the power is a consequence of access to or ability to leverage upon the resources a firm needs to run its business operations (Hillman *et al.*, 2009). Working (financial) capital remains one of the prime resources an entrepreneur needs to run its business operations. Not only the monetary capital is a resource in its own capacity but it also enables a firm to get access to other resources it needs to run its business. The formal markets have developed the necessary institutional infrastructure to provide businesses with the needed finances not only to manage their running business expenditures but also to fulfill their business growth needs. Defined by the lack of their monetary capital, importance of financial resources increases manifold in BoP (Kistruck *et al.*, 2011). Resource scarce BoP firms not only require financial resources to furnish their working capital needs but also to get access to other supplies which they need to run their business operations.

Likewise, the respondents of the study understood the market power in resource (financial) scarce business environment of BoP to be a consequence of strong financial resources of respective firms. The results of the study depicting suppliers to be enjoying a relatively powerful

and thereby an advantaged position in inter-organizational relationship in BoP mirror their sound financial position. Furthermore, in context of uncertain business environment of BoP, building and maintaining a loyal consumer base could help suppliers defuse external risks. The business strategy of BoP suppliers, in context of buyer-supplier relationships and postulates of RDT will thereby be focused at achieving three objectives. First, ensure a strong financial performance to uphold their market power. Second, build and maintain a loyal customer base, to reduce market related environmental uncertainty and boost financial performance and third, increase dependence of buyers upon themselves.

It has been observed that BoP suppliers succeed in achieving these objectives mainly by using their financial power. Financially poor buyers facing capital constraints normally approach advantaged suppliers via certain 'common friends' or other social contacts. Suppliers having known the destitute financial position of their 'new' customers, offer them to purchase goods on a deferred payment mode (lending). In return of their 'courtesy' suppliers charge above market price for their merchandise, a fragility/resource deficiency premium indeed. It should be kept afore that, business being relationship driven in BoP, the common friends or other social contacts play the role of guarantor for materializing such transactions. The suppliers in this case like vicious money lenders, try to keep an equilibrium whereby financially poor buyers while remaining unable to clear their bills in one go, continue to purchase goods on above market prices. Furthermore, it was also observed that each supplier depending upon its financial position decides for himself how much capital he can afford to 'block' in market, for building such a customer base suiting to his opportunistic intentions.

The business strategy thereby in accordance with postulates of RDT enables financially strong suppliers; (1) to decrease down external uncertainty by building a loyal consumer base (2) build their power by making financially poor buyers dependent upon them (3) maintain their power (financial resources) by charging above market rents and building a customer base and (4) decrease their own dependence upon external business actors (buyers).

Financially Poor Buyers in BoP

Financially poor buyers try to reduce environmental uncertainty and manage interdependencies as poised by RDT, while pursuing a business strategy crafted in their own specific context and different from that of relatively financially strong suppliers. From an RDT perspective the supply related uncertainties could occur as a consequence of "(1) lack of superior relational aspects or (2) power imbalance in favor of the supplier firm" (Pfeffer and Salancik, 1978; Paulraj and Chen, 2007). As has been mentioned earlier the financially poor buyers due to their weak financial resources have thin financial capital cushion to leverage upon. Buyers therefore appeared to focus more on relationship building (social capital). Building a trust worthy stature of themselves for their suppliers and extending their supplier base were found to be core pillars of their external business strategy in wake of volatile business environment of BoP. It is worthwhile noting that their efforts related to building social capital remain primarily supplier focused.

To manage uncertainties and decrease their dependence upon other actors (suppliers in this case), buyers tend to extend and diversify their supplier base. Though streamlining firm's supply base by reducing number of suppliers remains the popular notion of modern supply chain management literature targeting formal market scenarios (Lemke *et al.*, 2000), vice versa is believed to be a constructive and thereby practiced business strategy by indigenous businesses in BoP. Respondents of the study mentioned that the financially poor buyers are inclined to increase their supplier base for two main reasons. First, to increase their 'working capital' (in form of raw material). One should keep afore that normally these supplies are received on a deferred payment and thereby are kind of lent/borrowed from suppliers. In this way financially poor buyers by using their business relationships and social contacts become able to get access to financial capital needed to expand their business. Social capital therefore can be seen

as a mean to get access to financial capital. Second, to ensure a continuous supply and avert any supply related risks (e.g. in case any of the supplier stops supplying goods due to any potential disputes developed on payment related issues). Thereby reducing supply related uncertainty in precarious business environment of BoP. The two mentioned reasons partially explain cause of consent of financially poor buyers to pay above market rents for getting their supplies. Having said that we think that, the extent to which the supplier extension and lending strategy remains beneficial for businesses in BoP needs careful scrutiny. As pointed out earlier in the relationship driven business context of BoP, extending the supplier base remains dependent on the social contacts. Financially poor buyers therefore reported to care more and spend substantial part of their off-work time in relationship building.

It was learned that financially poor buyers also use supplier relationships to offset competition and thereby increase their power. Having secured their supply base, the buyers try to increase breadth of relationships in their effort to strike some exclusive business deals. Social capital gradually maturing into exclusive business partnerships helps buyers defuse competition and thereby gain upper hand in their local markets.

The financially week buyers by virtue of their relationship building efforts and in accordance with propositions of RDT become able to (1) decrease supply related and financial uncertainty by extending their supply base (2) decrease dependence on suppliers by building a diversified supplier base (3) increase their power by diffusing competition via entering into exclusive partnerships with their suppliers. Relationship building thereby plays crucial role in realizing business interests of buyers in uncertain markets of BoP as proposed by RDT.

Table 2: Resources and business strategies in BoP

RESOURCE	FIRM IN POSSESSION	FIRM LACKING RESOURCE
Financial capital	Use financial capital to get access to other resources and thereby manage dependencies in their own favor	Diversify and extend relationships with direct and indirect business actors
Social capital	Use relationships to get access to other resources and thereby manage dependencies in their own favor	Get access to financial resources to manage dependencies or face market exclusion

DISCUSSION

Functioning institutions remain primitive for markets to function and play their part in development of societies. While institutional infrastructure is “taken for granted as a passive background” in formal markets, their absence results in market exclusion (Mair *et al.*, 2012; Reficco and Marquez, 2012). Devoid of formal institutions (i.e. formal laws and regulations and the corresponding enforcing apparatus, communication and transport infrastructure related elements providing society’s basic needs and encouraging economic activity and capital markets), informal institutions (i.e. values, relationships, beliefs, norms) derive markets in BoP (Kistruck *et al.*, 2011). Respective scholars have commented extensively on how informal institutions can substitute for formal institutions in running markets in BoP (London and Hart, 2004). The extent paper tends to enrich the concerned literature by presenting empirical evidence showing how the informal institutions in form of relational capital decreases exclusion in B2B markets. Furthermore, using the arguments presented by RDT it also tends to highlight the power factor at play in BoP business relationships and its side effects on financially week actor in context of buyer-supplier relationships.

Using argumentation of RDT Schuster and Holtbrügge (2014) have commented on strategies that can help foreign firms enter into and operate in BoP markets. However, in this paper we

have used logic of RDT to look more into relationships among local BoP business actors. In line with the popular opinion of BoP scholars, we maintain that the informal institutions in form of relationships remain a business qualifying criteria in BoP. The relationship based business environment of BoP can be justified theoretically by taken into account the resource dependency argument. In a resource scarce business environment like BoP, extensive relationship building with a wide array of direct and indirect business actors is not only meant to get access to internally deficient resources but also to bridge institutional voids. Trust based relationships with intermediaries compensate for formal institutions in developed markets to link together and create “spaces for interaction” (Schuster and Holtbrügge, 2014) among buyers and suppliers in BoP. Furthermore, the relational capital is also used to get access to critical business resources as has been presented in the case of the financially poor buyers in the paper.

Having said that the findings of the paper suggest the power of respective actors playing crucial role in defining the nature of BoP relationships. RDT theorists propose power to be a product of access to resources a firm need to run its business operations. Inability of firm to internally furnish all of its resource needs compels it to interact with its external business environment which creates dependencies. More dependent an organization is on its environment to get its resources, less power it enjoys and vice versa (Pfeffer and Salancik, 1978). The extent paper identifies two resources i.e. financial resources and relational resources simultaneously at play in defining power and nature of buyer-supplier interaction in BoP. Characterized by its poverty the respective scholars acknowledge the financial resource scarcity of BoP actors. However, the respective literature by mainly encouraging MNCs to start business operations in BoP, has seldom considered monetary capital a resource in its own capacity compelling firms to interact with external environment for its possession in BoP markets (Kolk *et al.*, 2014).

Direct and indirect relationships are vital to operate in relationship driven business environment of BoP (Arnould and Mohr, 2005). With social capital being a business qualifying criteria, importance of monetary resources in a financially deprived business environment increases manifold. One should keep afore the institutional voids to provide businesses with the needed capital in BoP. Power in such a context and as has been reported by the respondents of the study, is largely defined by the financial capital a firm has on its disposal. The study therefore in context of BoP buyer-supplier interactions considers, powerful firms as the ones with relatively more financial resources in BoP. Table 2 in line with the findings of the study presents different strategic options employed by BoP firms with in context of varying financial and relational resource possessions.

One among the core arguments presented by the seminal advocates of BoP in favor of the foreign business interventions in marginalized societies was to reduce down poverty premiums (Prahalad, 2006). Since the original BoP literature remains consumer oriented, the poverty premium issue was mainly dealt within a likewise context. BoP literature since its inception remained overshadowed by works either highlighting the issue of premiums or presenting business strategies to reduce it, however, mainly dealing with it in a B2C market context (Agnihotri, 2013). Correspondingly the approach posed by the respective scholars to address the challenge of premiums was consumer focused and mainly incorporated such strategies as consumer education, running ethical marketing campaigns and encouraging business competition in BoP (Arnold and Valentin, 2013). The very disposition of seminal BoP literature led to concentrate more on B2C issues while overlooking B2B challenges in BoP. Likewise, little effort has been undertaken to explore B2B market transactions and trace back the roots of premiums further up a supply chain.

The extent study intends to fill the apparent research gap by looking more into B2B market transactions in BoP. During the course of investigation, it was learned that premiums remain a common practice in B2B markets. Extending the poverty premium debate, we maintain that the malpractice not only remains a practiced reality in B2B transactions but it also travels further

down respective supply chain. The poverty premium charged by businesses in B2C markets is thereby partially if not solely a result of the trickledown effect of what is happening up a supply chain within B2B business domain. Analyzing the premium issue using the theoretical lens of RDT, we consider the premium in B2B markets as a resource deficiency premium charged from the business actors enjoying relatively disadvantageous position (less power).
In light of the results of the study we think that employing a localized actor based (consumer) perspective and focusing only B2C markets might not be enough to address the challenge of poverty premiums. Analyzing BoP markets within a holistic supply chain wide perspective can help better address the challenge. The study has elaborated on the role of power and dependence in developing relationships in uncertain business environment of BoP. RDT considering power and dependence as the underlying forces shaping the inter-organizational relationships in volatile business environment, can prove to be a helpful tool for future researchers working to address the premium issue.

CONCLUSION

The paper presents qualitative findings of an empirical study focusing dyadic buyer-supplier relationships among indigenous micro-entrepreneurs in BoP. The findings of the study have then been evaluated using inductive analysis and in light of arguments presented by RDT. The study revealed that in accordance with published BoP literature the business in BoP is relationship driven. Indigenous micro-entrepreneurs appeared to prefer doing business with 'known ones'. However, in absence of market regulating institutions to overlook these business relationships and resulting business transactions, business interactions appeared to be opportunistic in nature. Furthermore, market power is generally perceived as an outcome of financial capital. Firms with relatively stronger financial muscle are perceived as enjoying advantageous position in the dyadic interactions.
Powerful supply chain actors, mostly, however, not solely being suppliers in our case, appeared to use their financial resources to mould inter-organizational relationship in their own favor. While doing so, financially strong actors try to increase dependence of other organizations upon themselves and decrease their own dependence upon them. Furthermore, while managing these interdependencies, care is taken to sustain and build power securing resources on sustainable basis. However, the strategy employed by respective business entities to achieve the three objectives i.e. maintain and increase their power, decrease their dependence on external businesses and increase dependence of other actors upon themselves, differs depending upon their respective role in market/supply chain.
The study further revealed that in wake of power and dependence driven dyadic relationships relatively financially poor actors are paying a deficiency premium. The deficiency premium thereby denotes the insufficient/deficient financial capital of respective firm. The extent paper augments B2C centered poverty premium argument back to B2B interactions in BoP. BoP scholars thus also need to consider and trace the source of poverty premiums further upward a supply chain. It can be the case that a retailer charging a poverty premium to its already destitute customers, himself is paying the deficiency premium to its suppliers. Poverty premiums in B2C market therefore can also be seen as a trickledown effect of B2B transactions and not something novel introduced solely by retailers serving final consumers in BoP.
The paper also tries to extend the scope of largely B2C centered BoP literature while moving into domain of B2B interactions. Responding to call of Ansari *et al.* (2012) for employing diverse theoretical infrastructure to analyze the case of BoP, we have used RDT to examine inter-organizational relationships in our case. Though the arguments of RDT are mainly employed to analyze the dyadic interaction between manufacturers (suppliers) and retailers (buyers) in this paper, we are confident that the theory can be used to look into more diverse business interactions in BoP.

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Responsibility Assessment of Information Security Breach from the Perspective of Hackers

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ABSTRACT

Analysis of the responses of 166 hackers reveals that moral affect mediates the effect of perceived intensity of emotional distress on responsibility assessment only in an ill intention systems security breach, and consideration of consequences strengthens the relationship between moral affect and responsibility assessment only in a good intention breach.

KEYWORDS: Hacker, Moral affect, Moral intensity, Consideration of consequences, Responsibility assessment, Intent, Information security breach

INTRODUCTION

Modernity creates liquid online relationships where one's life and identity are choices that depend on how one seeks pleasure, creates identities, engages with others, and solves problems (Coulthard & Keller, 2012). This liquid modernity allows a voluminous amount of information exchange via social media (e.g., Facebook, Twitter, and Instagram), e-commerce, and online banking which raises concerns about information security (Benson, Saridakis, & Tennakoon, 2015) and privacy (Garg & Camp, 2015) because users may have little understanding of how information systems operate (Ben-Asher & Gonzalez, 2015). Thus, users may be clueless about what could happen to their personal information, pay little attention to information security, and put their trust in the competency of security service providers (Alsmadi & Prybutok, 2018). Users' ignorance of the important implications of an information security breach provides an opportunity for hackers to breach into information systems, leading to increased number of reported information security breaches (PricewaterhouseCoopers, 2017). Users may be victims of information security breaches and suffer emotional distress (Elhai & Hall, 2016). Even if users have not been victims of an information security breach, they might be able to make inferences about the victims' situation and experience similar emotions as the victims (de Melo et al., 2014; Parkinson, 2011). While emotional distress may motivate users to use information system with precaution (Burns et al., 2017; Mamonov & Benbunan-Fich, 2018), users may feel overwhelmed with precautionary efforts, decrease their intention to engage in precautionary behavior (van Schaik et al., 2017), and pay little attention to information security issues. Thus, user efforts alone may not be sufficient for combating the issue of information security incidents. We add contribution to the literature by examining the information security issue from the perspective of hackers to enhance understanding of security breach. This insight may assist regulatory authorities and information security professionals develop effective strategies for handling the security issue.

Hackers break into information systems in an unauthorized manner with one or more of the following intentions: increase security, improve technology, protect privacy, monetary purposes, or release anger and frustration (Chiesa, Ducci, & Ciappi, 2009). Hacking is a violation of criminal law regardless of a hacker's intentions because it involves unauthorized access to a system (National Institute of Justice, 2000). Morality research (e.g., Bandura, 2001; Fida et al., 2016; Haidt, 2003) asserts that individuals engage in an action only when they perceive the action to be morally right. However, the moral perspective of perceived right versus wrong may be different from that of the legal perspective. For example, some individuals use pirated software because they believe this does not cause any harm to the companies and they may even feel that such action is morally right (Bhal & Leekha, 2008) even though it is illegal to do so (Menell, 2018). Thus, individuals may focus on moral values instead of the legality of an act when they decide to engage in an act. This study aims to shed light on whether moral values explain hackers' engagement in information security breaches.

Hackers may possess moral beliefs that are incongruent with their out-groups (Chiesa, Ducci, & Ciappi, 2009; Pieters & Consoli, 2009). According to The Hacker Manifesto: The Conscience of a Hacker (The Mentor, 1986), hackers constantly look for challenges and are passionate about breaking limits. They search for inadequacies and vulnerabilities in information systems so that they can direct the attention of system developers to potential threats and vulnerabilities. They believe that such an act suggests good moral values and sense of responsibility if they fully and privately disclose on a timely basis to developers and organizations so that the problem is taken care of before anyone could actually engage in malicious exploitation of the vulnerability (Chiesa, Ducci, & Ciappi, 2009). However, if the problem remains unsolved for a specific period of time, hackers might disclose the system vulnerabilities to the public. Kapustkiy and Kasimierz hacked an Indian embassy website located in seven different countries (Switzerland, Italy, Romania, Mali, South Africa, Libya, and Malawi) in November 2016 (Bonderud, 2016), and left a note alerting the embassy about the vulnerabilities; however, this notice was ignored. Subsequently, the breached data were announced publicly. The event drew the attention of the Indian embassy and the developers were instructed to fix the problem immediately with the assistance of Kapustkiy and Kasimierz. After the breach, the Indian embassy thanked Kapustkiy and Kasimierz for breaking into the website to draw their attention to the vulnerabilities. This breach is a good example of the hackers' moral values and sense of responsibility. Kapustkiy indicated later that he believed his act was morally right because the vulnerabilities were fixed with little data leakage (Patterson, 2017).

The information system environment facilitates increased abstract representation of actions which trigger utilitarian moral judgment (Barque-Duran et al., 2017) where the perceived benefits and costs determine the morality of an act (Bartels, 2008; Mill, 1861/1998). While harming someone is a moral dilemma, this act may be acceptable if it increases the well-being of a large number of people (Conway & Gawronski, 2013). This suggests that Kapustkiy's act (discussed earlier) may be morally acceptable if the perceived benefit (e.g., improving information systems security) is greater than the perceived cost (e.g., the victims' emotional distress). A perpetrator's intent determines the extent of one's perceived benefits versus costs; specifically, compared to an act with ill intention, an act with good intention is likely to be perceived as more beneficial and elicit positive feelings (Martin & Cushman, 2016). This study examines the intent of a hacker to promote understanding of whether hacking is morally acceptable.

Hackers may break into systems to release anger and frustration with the intention to cause damage to others (Chiesa, Ducci, & Ciappi, 2009). For example, a hacker known as "Peace"

stole and attempted to sell at least 200 million Yahoo's user data on the black market which devastated users and caused them to change their Yahoo's account information (BBC News, 2016). Selling personal data on the black market has a negative impact on the victims and such an act reflects the perpetrator's ill intention. Hackers may also engage in information security breaches without the intention to harm anyone but to improve security, enhance technology, or protect privacy (Chiesa, Ducci, & Ciappi, 2009). However, hacking with a good intention can still elicit unpleasant feelings. While Kapustkiy and Kasimierz breached the Indian embassy's websites to force the embassy to take information security seriously without any intention to cause damage, the breach caused anxiety to the embassy because it involved sensitive data that could be used for cyber espionage campaigns (Kumar, 2016). Hackers may not be aware that security breaches can cause emotional distress to a victim; especially when they believe that they have a good intention. Hence, increasing the awareness of hackers about the victims' emotional distress may lead them to become cognizant of the implications of information security breaches from the victims' perspective.

The purpose of this study is to investigate whether hackers react differently to information security breaches when a perpetrator possesses either an ill or good intention. To our knowledge, limited research is available for promoting understanding of whether intent induces different levels of moral affect (i.e., perceptions of the extent of a perpetrator's feelings of regret, sorrow, guilt, and shame) explains the effect of perceived intensity of emotional distress on responsibility assessment. Further, research is sparse on enhancing understanding of whether the nature of a perpetrator's intent affects the moderating role of consideration of consequences in the relationship between moral affect and responsibility assessment. This study attempts to shed light on these important issues. Increased understanding of the relationships among the intent of an act, moral affect, consideration of consequences, and responsibility assessment of an information security breach from the hackers' perspective may shed light on their continued engagement in the act despite the disapproval of society. The findings can help inform future research on development of effective strategies for dealing with the vulnerability issue.

We posit that moral affect explains the effect of perceived intensity of emotional distress on responsibility assessment (i.e., mediating hypothesis) and consideration of consequences strengthens the impact of moral affect on responsibility assessment (moderating hypothesis) regardless of the intent of an act. We recruited hackers from two major hacker conferences. They completed a questionnaire containing items which assessed their perceptions of the intensity of the victims' emotional distress, moral affect, consideration of consequences, and responsibility assessment of a breach. Analyses of the usable responses of 166 hackers support the mediating hypothesis in the case where a perpetrator harbors an ill intention; this effect is not observed when the perpetrator has a good intention. The results also support the moderating role of consideration of consequences in the relationship between moral affect and responsibility assessment when a perpetrator has a good intention. This suggests that hackers disapprove of an act with an ill intention without considering the consequences of the act. When a perpetrator engages in an act with a good intention, hackers tend to perceive the act to be morally acceptable after they consider the consequences of the act.

The remainder of this paper is organized as follows. The next section reviews the relevant literature and develops the hypotheses. Then, the research method and results are presented. Finally, the findings of this study, its limitations and suggestions for future research are discussed.

LITERATURE REVIEW

Moral Intensity

Moral intensity theory states that each act has a certain degree of moral intensity and the degree of intensity needs to reach a certain threshold before one can recognize an act as a moral issue and see a need for a moral response (Jones, 1991). The degree of moral intensity may vary based on six characteristics: magnitude of consequences, probability of consequences, temporal immediacy, proximity, and concentration of effect (Jones, 1991). Prior research (Jordan et al., 2012; McMahon & Harvey, 2007; Robertson et al., 2010) suggests that it may not be necessary for all of these components to be present for the formation of perceived moral intensity of an act. We focus on magnitude of consequences, probability of consequences, and temporal immediacy because these components are appropriate for the information security incidents examined in this study.

Magnitude of consequences refers to all the harm caused to the victims of a moral act in question (Jones, 1991). An act that causes the death of a human is of greater magnitude of consequences than an act that causes a person to suffer a minor injury (Jones, 1991).

Probability of consequences is defined as a joint function of the probability that an act actually occurs and causes the predicted harm (Jones, 1991). For example, selling a gun to a known armed robber has greater probability of harm than selling a gun to a law-abiding citizen (Jones, 1991).

Temporal immediacy is the length of time between the present and the onset of consequences of a moral act (Jones, 1991). For example, releasing a drug that causes an acute side effect has greater temporal immediacy than releasing a drug that causes a side effect after 20 years (Jones, 1991).

Moral intensity is perceived to be high when one believes that a victim suffers severe harmful consequences (magnitude of consequences), actually experiences the harmful consequences (probability of consequences), and suffers from the immediate consequences (temporal immediacy) (Jones, 1991). When an act is perceived to have high moral intensity, one may consider the act as involving a moral issue and engage in moral behavior (Frey, 2000; Jones, 1991). However, moral behavior may not occur when perceived moral intensity is below one's threshold (Barnett & Valentine, 2004; Jones, 1991). Suppose an employee installed a company's licensed software onto his or her home computer against his or her colleagues' suggestion to purchase a separate license for personal use. This act may elicit high moral intensity because the harmful consequences (negative emotions such as disgust and anger) are immediate and has actually occurred, leading to the perception of the act as morally unacceptable (McMahon & Harvey, 2006). Now, suppose one's colleagues have mixed opinions on use of the company's licensed software for personal purposes. This situation may not elicit high moral intensity because the colleagues' mixed opinions dilute perceived harmful consequences; therefore, the act may be perceived as less morally unacceptable (McMahon & Harvey, 2006). Elicitation of moral behavior may necessitate increased awareness of the harmful consequences which accentuates the victims' well-being and propel a need for restoring justice for the victims (Greene et al., 2008).

Moral Affect

Moral affect (i.e., regret, sorrow, guilt, shame, and anger) elicits intuitive and automatic emotions in response to an act that violates a person's moral beliefs, even though the act may harm others rather than that individual (Haidt, 2007; Janoff-Bulman & Carnes, 2013; Tangney, 1991). Moral affect entails implicit reactions to an act because of one's concern about the interests or welfare of the victims or society at large (Gray & Schein, 2012; Haidt, 2003).

Individuals' desire for belongingness to their social group (Baumeister & Leary, 1995) may cause them to monitor and constrain their own behavior when they encounter a moral violation by exhibiting a prosocial behavioral in response to a situation (i.e., a desire to restore justice or reciprocate an act of kindness) (Ford et al., 2018; Haidt, 2003). Emotions such as shame, guilt, sorrow, and regret may be elicited to assist individuals to cope with a specific situation that fits in with their social groups (Haidt, 2003; Leyens et al., 2000). Individuals may attempt to help, comfort, or alleviate the suffering of the victims (Stellar et al., 2015) to convey the perception that they are concerned about the well-being of others and to mitigate concerns about the uncertainty of their helping behavior (Grant & Gino, 2010).

Moral affect is critical when an act involves a conflict between one's good intention and the resultant harmful consequences of the act (Greene, 2008). For example, in a trolley problem, one has to decide between (a) pulling a switch to divert a runaway boxcar headed toward five agents to one agent on a side track, and (b) abstaining from pulling a switch to leave the runaway boxcar headed toward one agent while five agents were on a side track. The findings suggest that abstaining from pulling a switch is perceived to be morally wrong to a greater extent than pulling a switch (Hauser et al., 2009; Navarrete et al., 2012). Individuals' need for engagement in a prosocial behavior may be so strong that they cannot ignore or do nothing to help regardless of the number of victims involved (Greene et al., 2001; Hauser et al., 2007; Navarrete et al., 2012).

Although prior research indicates that moral affect may be invariant across groups (Hauser, 2006), it may differ across groups for an act involving in-group norms (Rutland et al., 2010) because of society's influence on their moral beliefs (Haidt & Graham, 2007) which lead them to side with a perpetrator of the act rather than the victims. When individuals perceive their group to be superior to other groups, their moral affect may favor their own group instead of their outgroup (Leyens et al., 2000).

Intent versus Consequences of an Act

The consequences of an act, commonly used to judge a perpetrator's wrongdoing in the legal systems, is a critical factor for assessing responsibility (Miller et al., 2014). While thoughts about an illegal act without actual commitment of the act may go unpunished, killing someone without an ill intention may be punishable (Miller et al., 2014). Further, punishment for an attempt to kill someone may not be as severe as actually killing a person. Individuals may consider a perpetrator's intent and the consequences of an act when they address the moral issues of the act (Cushman, 2008; Killen & Smetana, 2015). They may attempt to understand a perpetrator's mental states (desires, motives, beliefs, or intent and how these relate to what actually occurred) before forming a conclusion on the consequences of the act (Cushman & Young, 2011).

Both the intent and consequences of an act influence assessment of the moral implications of the act (Miller et al., 2014). Two theories can be used to explain the relationship between the

intent and consequences of an act. Blame blocking posits that harmful consequences cause one to focus more on the consequences of an act instead of a perpetrator's intent (Cushman, 2008). For example, shooting but missing a victim may be viewed to be less wrongful than shooting a victim who happened to be struck and harmed by a lightning instead of the shooting. Although the victim's injury is not a direct consequence of the perpetrator's act, individuals may link the consequences to the perpetrator and conclude that this would not have occurred if the perpetrator had not shot the victim. According to two-process theory, individuals generally engage in a single-process by considering only the consequences when assessing the morality of an act (i.e., the harmful consequences of the immoral act regardless of intent); however, unintended harmful consequences create a cognitive conflict which may cause individuals to blame a perpetrator for the harm but not blame the perpetrator for causing the harm because it is unintended (Cushman, 2008). When individuals experience this conflict, they may utilize a two-process model where the consequences of an act are assessed and a perpetrator's mental state is analyzed to evaluate the wrongfulness of the act (Cushman, 2008). Unintended harmful consequences that result from a good intention remind individuals of alternatives that a perpetrator could have chosen without causing any harm; hence, an act may be judged as wrongful, suggesting that a perpetrator's good intention may not mitigate the resultant harm (Cushman, 2008). While one may focus on a perpetrator's mental state or the consequences of an act (Cushman & Greene, 2012), an act with harmful consequences may cause one to focus more on the consequences rather than the mental state of the perpetrator (Young & Saxe, 2011).

HYPOTHESES DEVELOPMENT

The Mediating Role of Moral Affect

Suppose someone hacks into a system and obtains the confidential information of customers. This perpetrator might engage in this activity to steal information or test the security of the system. Regardless of the perpetrator's intention, the victims are likely to suffer emotional distress because their personal information is stolen. We posit that our hacker participants may believe that the victims actually and immediately suffer severe harmful consequences (i.e., stolen personal information). That is, the victims would not have been harmed if the act had not occurred. Therefore, perceived intensity is expected to be high, leading to judgment of the act as a moral issue (Jones, 1991). Once an issue is perceived as a moral issue, our hacker participants may utilize moral reasoning, engage in moral behavior, (Brandon et al., 2007; Jones, 1991), and hold a perpetrator responsible for the act.

The victims' emotional distress experienced as a result of an act either with an ill or good intention suggests an unpleasant situation that lead our hacker participants into the belief that the perpetrator should have feelings of regret, sorrow, shame, and guilt for causing emotional distress to the victims (de Graaff et al., 2016). This reaction provides a basis for intuitions about the degree of morality of an act (Haidt, 2008). Since emotional distress is an undesired emotion, it is likely to influence hackers to judge the perpetrator's act as morally unacceptable. Specifically, our hacker participants may be motivated to behave in a prosocial and equitable manner because they are concerned about the welfare of the victims (Haidt, 2003; Killen & Smetana, 2015; Wright et al., 2017). Hence, they may hold a perpetrator responsible for an information security breach regardless of whether the act has ill or good intention. The above discussion suggests that moral affect mediates the impact of perceived intensity of emotional distress on responsibility assessment, regardless of a perpetrator's intent, leading to the first hypothesis as follows:

H1: Moral affect explains the effect of perceived intensity of emotional distress on responsibility assessment, regardless of the nature of the perpetrator's intention.

The Moderating Role of Consideration of Consequences

An information security breach perpetuated either with an ill or good intention elicits a moral affect which accentuates a need for concerns about the victims' well-being (Haidt, 2003; Killen & Smetana, 2015). Hackers might engage in a good deed to restore the victims' welfare to maintain their moral values (Wright et al., 2017). Hackers may hold a perpetrator responsible for causing emotional distress to the victims regardless of the intent (ill or good) of the information security breach. When prompted to consider the consequences of a breach either with an ill or good intent, hackers may focus on the harm caused to others which elicits a negative emotional response (Bucciarelli et al., 2008) that increases responsibility assessment. Hackers may believe that the victims would not have been harmed if the breach had not occurred even if a perpetrator does not have any intention to cause harm to others. Hence, consideration of consequences is predicted to direct attention to the harmful consequences caused to the victims regardless of the perpetrator's intent, increasing the strength of the negative emotional response. To restore equity for the victims, hackers may assign increased responsibility to a perpetrator. We propose that Consideration of consequences may enhance the impact of moral affect on responsibility assessment. Finally,

H2: Consideration of consequences strengthens the impact of moral affect on responsibility assessment, regardless of the nature of the perpetrator's intention.

METHOD

Research Instrument

We develop two hypothetical scenarios describing different information security incidents in a business context based on court documents available on the U.S. Department of Justice website, and reports published by the Bureau of Justice Statistics, Computer Security Institute, and media. One scenario discussed an incident with an ill intention while the other scenario described an incident with a good intention. The materials reveal that taking revenge on corporations, stealing confidential information for financial purposes, and destroying corporate systems are common examples of incidents with an ill intention in corporate system intrusions. Revenge is used to represent ill intention in this study because it occurs frequently in intrusion reports. Corporate systems may also be intruded with the intent of helping to improve systems security. Helping behavior (i.e., testing security measures for detecting and mitigating weaknesses) is utilized to represent a perpetrator's good intention in this research. The information provided in the scenarios is adapted from actual computer incidents in the court documents.

Pretest

The research instrument was pretested with 28 senior accounting students and improved based on the feedback received from these participants.

Task

Participants read two hypothetical scenarios, answered questions pertaining to the scenarios, and provided demographic information. All participants received a T-shirt in for their voluntary participation in this study. The order of the scenarios was not randomized. Our participants may be less vulnerable to order effect because they relied on their personal moral beliefs rather than external factors such as information from other cases when they evaluated cases involving moral issues (Wright, 2010). In addition, the pretest results indicated that the order of the scenarios did not have an effect on the participants' responses.

Participants

We recruited hackers at two major hacker conferences. The Mahalanobis distance test reveals that 15 out of 181 responses had probability values below 0.001, suggesting lack of representativeness of the sample examined in this study. Therefore, the responses of 15 participants were excluded from analysis, resulting in 166 usable responses. The hackers' age ranged between 18 and 63 years and the mean was 34. About 94% were males and 76% worked in the field of information systems (e.g., system engineers, systems security professionals, programmers, and consultants). Except for six participants, all hackers engaged in hacking activities ranging from one to 45 years and the mean was 10.49 years. The participants' demographic information (age, work experience, and hacking experience) did not have an impact on our results.

Measurement of Variables

Intensity of Emotional Distress

Our three-item perceived intensity of emotional distress scale is adapted from moral intensity theory (Jones, 1991; Singhapakdi et al., 1996). Participants responded (on a 7-point scale with 1 = strongly disagree and 7 = strongly agree) to questions assessing their perceptions of the magnitude (the victims would suffer serious emotional distress), probability (the victims would definitely suffer emotional distress), and temporal immediacy (the victims would immediately suffer emotional distress) of the consequences in the ill or good intention scenario.

Moral Affect

The literature on moral affect (e.g., de Hooge et al., 2011; Ghorbani et al., 2013; Tangney et al., 1996) suggests that emotions such as guilt, shame, sorry, and regret are activated when individuals evaluate an act that causes harmful consequences to the victims. We use a four-item moral affect scale to assess (on a 7-point scale with 1 = strongly disagree and 7 = strongly agree) the participants' perceptions of whether the perpetrator in the hypothetical scenarios should feel guilty, shameful, sorry, and regret for engaging in the act.

Responsibility for an Act

Our dependent variable (on a 7-point scale; 1 = strongly disagree and 7 = strongly agree) measures the hackers' assessment of the perpetrator's responsibility for the breach.

Consideration of Consequences

We measure consideration of consequences (on a 7-point scale; 1 = strongly disagree and 7 = strongly agree) via the hackers' assessment of the perpetrator's responsibility for the consequences.

RESULTS

Measurement Model

The measurement models for the ill and good intention scenarios are used to assess the psychometric properties of two latent variables – perceived intensity of emotional distress and moral affect.

Confirmatory Factory Analyses

The measurement model fit indices (χ^2 = 0.000; CFI = 1.000; RMSEA = 0.000; SRMR = 0.000) are acceptable for perceived intensity of emotional distress for the ill and good intention scenarios. The measurement model is just-identified because this construct has three items. The factor loadings of the perceived intensity of emotional distress construct are acceptable for the ill (0.678-0.834) and good (0.707-0.838) intention scenarios.

The measurement model fit indices (χ^2 = 1.419; CFI = 1.000; RMSEA = 0.000; SRMR = 0.012) and factor loadings (0.742-0.899) for the moral affect construct are acceptable for the ill intention scenario. The measurement model fit indices (χ^2 = 0.276; CFI = 1.000; RMSEA = 0.000; SRMR = 0.004) and factor loadings (0.787-0.939) for the moral affect construct are also acceptable for the good intent scenario.

Table 1: Loadings, Cross-Loadings, and AVEs for Multi-Item Constructs

Panel A: Ill Intention			
	Factor Loadings Distress	*Factor Loadings* Affect	AVE
Magnitude of consequences (The victims would suffer serious emotional distress as a result of hacker's action)	**0.727**	0.247	0.553
Probability of consequences (The victims would definitely suffer emotional distress as a result of hacker's action)	**0.834**	0.362	
Temporal immediacy (The victims would immediately suffer emotional distress as a result of hacker's action)	**0.678**	0.192	
Regret (The hacker should regret the act)	0.147	**0.742**	0.709
Sorry (The hacker should feel sorry for the act)	0.296	**0.852**	
Guilty (The hacker should feel guilty about the act)	0.328	**0.864**	

Table 1: Loadings, Cross-Loadings, and AVEs for Multi-Item Constructs			
Panel A: Ill Intention			
	Factor Loadings Distress	*Factor Loadings* Affect	AVE
Ashamed (The hacker should feel ashamed of the act)	0.302	**0.899**	
Panel B: Good Intention			
	Factor Loadings Distress	*Factor Loadings* Affect	AVE
Magnitude of consequences (The victims would suffer serious emotional distress as a result of hacker's action)	**0.707**	0.013	0.592
Probability of consequences (The victims would definitely suffer emotional distress as a result of hacker's action)	**0.794**	0.008	
Temporal immediacy (The victims would immediately suffer emotional distress as a result of hacker's action)	**0.838**	-0.050	
Regret (The hacker should regret the act)	-0.030	**0.931**	0.775
Sorry (The hacker should feel sorry for the act)	0.040	**0.787**	
Guilty (The hacker should feel guilty about the act)	0.073	**0.820**	
Ashamed (The hacker should feel ashamed of the act)	-0.004	**0.939**	
Distress = Intensity of Emotional Distress, Affect = Moral Affect			

Reliability Tests

Table 2 shows that the Cronbach's alpha and composite reliability of the perceived intensity of emotional distress construct are 0.793 and 0.792, respectively, for the ill intention scenario; and 0.808 and 0.816, respectively, for the good intention scenario. These results indicate acceptable reliability for the items in the perceived intensity of emotional distress construct.

Table 2 also indicates that the Cronbach's alpha and composite reliability of the moral affect construct are 0.898 and 0.906, respectively, for the ill intention scenario; and 0.927 and 0.932, respectively, for the good intention scenario. These results suggest acceptable reliability for the items in the moral affect construct.

Validity Tests

The average variance extracted (AVEs) of the perceived intensity of emotional distress construct are 0.553 and 0.592 for the ill and good intention scenarios, respectively, indicating convergent validity. Table 2 shows that the squared root values of the AVEs are larger than the

correlation between the perceived intensity of emotional distress and moral affect constructs for both the ill and good intention scenarios, suggesting discriminant validity.

The AVEs of the moral affect construct are 0.709 and 0.775 for the ill and good intention scenarios, respectively, suggesting convergent validity. Further, the square root values of AVEs are greater than the correlation between the perceived intensity of emotional distress and moral affect constructs, indicating discriminant validity.

Table 2: Reliability and Inter-Construct Correlations

Panel A: Ill Intention				
	Cronbach's Alpha	Composite Reliability	Inter-Construct Correlations	
			Intensity	Affect
Distress	0.793	0.792	**0.744***	
Affect	0.898	0.906	0.491	**0.842***
Panel B: Good Intention				
	Cronbach's Alpha	Composite Reliability	Inter-Construct Correlations	
			Intensity	Affect
Distress	0.808	0.816	**0.769***	
Affect	0.927	0.932	0.533	**0.880***

Square root of average variance extracted (AVEs)
Distress = Perceived Intensity of Emotional Distress, Affect = Moral Affect

Test of Mediating Effect (Hypothesis 1)

We test the mediating hypothesis using the causal indirect effect approach (Muthen, 2011; VanderWeele & Vansteelandt, 2009). The results reveal that moral affect mediates the effect of perceived intensity of emotional distress on responsibility assessment (β = 0.187 [all the coefficients were unstandardized coefficients.], p = 0.002, Table 3, Panel A), providing support for hypothesis 1 for a breach with an ill intention. However, moral affect does not mediate the relationship between perceived intensity of emotional distress and responsibility assessment (β = -0.046, p = 0.267) for breach with a good intention.

Table 3: Results of Hypotheses

Panel A: Test of Mediation										
	IV	MV	DV	1) IV→MV		2) MV→DV		3) IV+MV→DV		Mediation
				β	p-value	β	p-value	β	p-value	
Ill intention	Distress	Affect	Resp	0.375	0.000	0.499	0.000	0.187	0.002	Supported
Good intention	Distress	Affect	Resp	0.618	0.000	-0.082	0.297	-0.051	0.286	Not Supported

Panel B: Test of Moderation					
	IV	DV	IV→DV		Moderation
			β	p-value	
Ill intention	AffCon	Resp	-0.110	0.457	Not Supported
Good intention	AffCon	Resp	0.118	0.008	Supported

IV=Independent Variable, MV=Mediating Variable, DV=Dependent Variable
Distress=Perceived Intensity of Emotional Distress, Affect=Moral Affect, Resp=Responsibility
AffCon=Moderation between Moral Affect and Consideration of Consequences

Test of Moderating Effect (Hypothesis 2)

Hypothesis 2 states that consideration of consequences strengthens the effect of moral affect on responsibility assessment, regardless of the nature of the perpetrator's intent. Since the fit indices (i.e., χ^2, CFI, RMSEA, and SRMR) are not available for the moderated mediation analysis, we use the Akaike Information Criterion (AIC) (Brown, 2006; Byrne, 2011) to assess the model fit. AIC is a comparative fit measure which suggests that a model with a smaller value has a better fit. This study examines two models: the first model comprises only the main effect of the moderating variable on the dependent variable (responsibility assessment), and the second model consists of both the main effect and the interaction between moral affect (mediator) and consideration of consequences (moderator) on responsibility assessment. The AIC value of the model without the interaction term is 4457.310. When the interaction term is included, the AIC value decreases to 4456.963, indicating that the model with the interaction term has a better fit. The results ($\beta = -0.106$, $p = 0.468$) do not support hypothesis 2 for an information security breach with an ill intention.

In the case of a breach with a good intention, the AIC value of the model without the interaction term is 4534.789. This value decreases to 4527.577 after the interaction term is introduced, suggesting improved model fit. The results indicate that consideration of consequences strengthens the relationship between moral affect and responsibility assessment ($\beta = 0.118$, $p = 0.008$, Table 3, Panel B), supporting hypothesis 2 for a breach with a good intention.

Conclusion

Discussion of Findings

This study uses two hypothetical scenarios suggesting an information security breach either with an ill or good intention to examine hackers' responsibility assessment of the breach. The findings show that hackers recognize the emotional distress of the victims when a perpetrator harbors ill intention. The victims' emotional distress elicits moral affect (i.e., feelings of regret, sorrow, shame, and guilt), causing our hacker participants to view the information security breach as unacceptable and holding the perpetrator responsible for the breach. This is consistent with prior research (e.g., Buon et al., 2013; Martin & Cushman, 2016; Phillips & Shaw, 2014) findings on judgment of an act as morally unacceptable and punishable when a perpetrator harbors an ill intention which causes harmful consequences to the victims. Our

hacker participants may consider a breach with an ill intention as an out-group act and deem such an act as undesirable (Bissett, 2003; Chiesa et al., 2009). In the case where a perpetrator has a good intention for engaging in a breach, the extent of their moral affect is attenuated, leading to reduced responsibility assessment, despite awareness of the victims' emotional distress. In the absence of an intention to cause harm to a victim, hackers may view a perpetrator's act as an in-group act and consider the breach as morally acceptable (Bissett, 2003; Chiesa et al., 2009). Therefore, hackers are less likely to hold a perpetrator responsible for a breach with a good intention. Further, our hacker participants' moral affect (i.e., feelings of regret, sorrow, shame, and guilt) may be attenuated when they evaluate a breach without any intention to cause emotional distress to the victims. Hence, accentuating our hacker participants' focus on a perpetrator's good intention may mitigate perceptions of the harmful consequences of a breach. Hackers may also focus on the potential benefits of a breach with a good intention (e.g., improving systems security) which may outweigh the harmful consequences of the breach. Subsequently, they are less likely to hold a perpetrator responsible for the breach despite their awareness of the victims' emotional distress.

Additionally, our findings reveal that the ill intention of a breach is more important than consideration of consequences of a breach with an ill intention in our hacker participants' responsibility assessment. This observation is consistent with prior research (e.g., Monroe & Reeder, 2011). Hackers may recognize the victims' emotional distress and become motivated to behave in a prosocial and equitable manner when a perpetrator harbors an ill intention (Haidt, 2003; Killen & Smetana, 2015). In the case of a breach with a good intention, consideration of consequences directs the hackers' attention to the victims' emotional distress. While a perpetrator may not have any intention to cause harmful consequences to the victims, the act causes emotional distress to the victims (Cushman, 2008). Direction of attention to the victims' emotional distress results in increased responsibility assessment (Young & Saxe, 2011).

Contributions

Our research shows that the nature of a perpetrator's intention for engaging in an information security breach determines our hacker participants' response to the breach. While hackers may not approve of a perpetrator's engagement in a breach with an ill intention, they may be tolerant of a perpetrator engaging in a breach with a good intention. Thus, effective handling of information security breach issues requires discernment of an act either with an ill or good intention. Lack of a conflict between an act with an ill intention and the consequences of the act suggests lack of a valid justification for making such an act morally acceptable. In the case of a breach with a good intention, hackers may believe that they engage in the activity to help improve systems security; subsequently, they are likely to perceive this activity as morally acceptable and continue to engage in the act. Directing attention to the victims' emotional distress due to an information security breach might help to discourage this behavior.

Limitations and Suggestions for Future Research

This study has some limitations. First, we use one question to measure our hacker participants' consideration of consequences and responsibility assessment, respectively. Future research can develop comprehensive measures of these constructs to examine whether similar results are obtained. Second, since this study involves a survey, future work can design an experimental study to enhance understanding of the process of and factors influencing the hackers' responsibility assessment of information security breaches. Third, this study examines only one type of consequences; that is, the victims' emotional distress. Future research can

investigate hackers' reaction toward an information security breach that leads to disastrous financial consequences. Research can also provide insight into evaluators' (hackers or jurors) responsibility assessment of a company in an information security breach. Finally, future work can shed light on whether hackers assess responsibility in favor of their in-group (i.e., a breach with a good intention) and explore whether consideration of consequences may attenuate the effect of in-group bias on moral judgment.

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DECISION SCIENCES INSTITUTE
Reviewing the Relationship Between Organizational Culture and Strategy

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ABSTRACT

Using a value-based definition of organization culture, a relationship between culture and strategy is supported based on the qualities of strategy being reflective of values, shared by the collective and distinguishing one organization from another. The history and corporate actions of Uber is presented to motivate and illustrate the relationship.

KEYWORDS: Organizational Culture, Strategy

INTRODUCTION

During a tumultuous 2017, Travis Kalanick, the co-founder and CEO of Uber, resigned leadership of the ride sharing service company (Reilly, Fortune, 2018). Under Kalanick's leadership, Uber was the target of sexual harassment allegations, a negative social media campaign, and a U.S. Department of Justice criminal investigation. Dara Khosrowshahi took over as CEO of the technology giant and began a deliberate effort to reverse the negative perceptions of the brand. In a television advertisement airing mid-2018, Khosrowshahi made the following statement:

"I want you to know just how excited I am to write Ubers next chapter with you. This begins with new leadership and a new culture and you're going to see improvements to our service with better pickups and ride quality for both riders and drivers. One of our core values as a company is to always do the right thing and if there are times when we fall short we commit to being open taking responsibility for the problem and fixing it."

-- Dara Khosrowshahi, CEO, Uber

A key point of this statement is the focus on changing the *culture* of Uber. Under Kalanick's leadership, the culture of Uber has been described as entrepreneurial, or a growth at all costs (Khosrowshahi, Uber, 2018). This is consistent with the aggressive growth strategy pursued by the firm since inception. However, while Khosrowshahi has discussed the culture change of the firm several times, the strategy of the firm has not been addressed. How will a shift in culture affect the strategy of the firm? Is a strategy change necessary to affect culture?

These questions motivate a much broader topic – what is the relationship between organizational culture and strategy? Khosrowshahi himself argues the “forward-leaning, fearless approach” type of culture has contributed to the success of the aggressive growth strategy. In this example, it appears the culture directly influences strategy.

However, it may be argued that the strategy of the firm determines the culture. A key component of strategy is the impact the strategy has on resource allocation (Bourgeois & Brodwin, 1984). If the company hopes to implement a diversification strategy and diverts additional resources to R&D, then the strategy has signaled a high value ranking of innovation. The value of innovation then may craft a culture of teamwork and collaboration. Alternatively, if a company implements an aggressive growth strategy, then resources may be diverted to meeting short-term sales targets. This resource allocation may lead to an organizational culture that is less concerned with long-term consequences.

In this paper, we will discuss the concepts of organizational culture, strategy, and the relationship between culture and strategy in terms of shared values. We seek to open a discussion of how these concepts can be used to assess or leverage one another.

LITERATURE REVIEW

Organizational Culture

Culture is defined as “the collective programming of the human mind that distinguishes the members of one human group from those of another. Culture, in this sense, is a system of collectively held values.” (Hofstede, 1980; p. 24). Organizational culture is the culture specific to an organization and it enables “the differentiation of organizations along the lines of dominant values guiding organizational behaviors” (Leidner & Kayworth, 2006; p. 360). This description suggests organizational culture is not only a set of values important to a group, but a combination of these values to distinguish one group from another.

The term "organizational culture" (also referred to as "corporate culture") entered the research field in 1965 in textbooks by both Bass and Schein independently (Schein, 1996). While the early measurement of organizational culture had been focused primarily on individual characteristics and how they matched or conflicted with the social norms of the organization, the research evolved to include more intergroup phenomena and leadership implications (Schein, 1996). The concept of organizational culture was advanced significantly by Geert Hofstede in the early 1980s through the extensive study of culture, at both the national, organizational and individual levels. Hofstede defines culture as "the collective programming of the human mind that distinguishes the members of one human group from those of another. Culture, in this sense, is a system of collectively held values." (Hofstede, 1980; p. 24). A value is "a broad tendency to prefer certain states of affairs over others" (Hofstede, 1980; p. 19).

This view of a value-based organizational culture definition is supported in prominent management research. Straub and colleagues (2002) postulated shared values were the central and distinguishing characteristic of culture. In 2006, the organizational culture construct was reviewed through a meta-analysis conducted by Leidner and Kayworth (2006). This seminal work describes organizational culture as enabling “the differentiation of organizations along the lines of dominant values guiding organizational behaviors” (Leidner & Kayworth, 2006; p. 360).

This description supports the concept that organization culture is not simply a list of values the group may hold, but a ranking of those values. Certain organizational culture values may be hidden, even from the group itself, until there is a conflict in which the group participants must choose between two mutually exclusive values. This conflict can arise between stakeholders and technology (Leidner & Kayworth, 2006; Kappos & Rivard, 2008). For example, an organization may value both security and cooperation as part of the organizational culture. However, if a technology, such as an intranet, which is designed to encourage collaboration and information sharing amongst departments, is presented, the technology may be contrary to the value of security. Therefore, the values of security and cooperation are pinned against each other, meaning the organization must rank one of these values as higher than the other in the face of this new technology.

Strategy

Strategy has been defined by multiple researchers in several different contexts. In the field of business management, Henry Mintzberg (1987) defined strategy as a plan, a ploy, a pattern, a position and a perspective. The notion of strategy as perspective suggests a relationship with organizational culture. In Mintzberg's perspective definition, strategy is how the organization perceives the world and the organization's role in the world. He likened the strategy of an organization to the personality of an individual. In this way, the strategy of an organization is "built right into it". The character of an organization leads the organization to act and respond in a certain way to stimuli. Mintzberg noted that other fields have used other concepts to capture this notion. In particular, sociologists refer to the "ideology" of a society, military theorists refer to the "grand strategy" of armies, and anthropologists refer to the "culture" of a society.

This organizational personality embodies the organizational culture and values of the collective (Mintzberg, 1987). For example, if a company values innovation and the first-mover advantage, then the company may be an aggressive risk taker and devote resources and attention to research and design. Another example is if a company values safety, then the company may accentuate safe working environments and infrastructure.

Chen, Mocker, Preston, and Teubner (2010) adopted the perspective definition when defining strategy as, "a shared organizational perspective on setting and meeting organizational goals" (Chen et al., 2010, p. 236). Following these researchers, strategy is defined as the shared organizational perspective on setting and meeting organizational goals based on the organization's culture and values.

Relationship between organizational culture and strategy

Following Husted and Allen (2007), classic literature (Child, 1972; Hambrick & Mason, 1984; Prahalad & Bettis, 1986; Andrews, 1987) and the more contemporary theory, the resource-based view (RBV) of the firm (Barney, 1991), elicit a relationship between strategy and organizational culture. This relationship is based on the qualities of strategy as: 1) reflective of values, 2) shared by the collective, and 3) distinguishing one organization from another.

<u>Reflective of Values</u>

Corporate values historically have been listed as a fundamental pillar of corporate strategy (Andrews, 1987), but these values were later de-emphasized by other researchers (Porter, 1979). The RBV presented by Barney (1991) brought values back into the spotlight by linking

strategy and values through the concept of organizational culture. Barney specifies the strategy of a firm is formed by the external perception of the business environment and the internal resources of the organization. One of the key resources of the organization, in the fact that it is valuable and difficult to imitate, is organizational culture, which is rooted in the dominant values and beliefs of the organization (Barney, 1991).

Strategic choices are made through an evaluative process (Guth & Tagiuri, 1965; Child, 1972; Hedberg & Johsson, 1977, Prahalad & Bettis, 1986, Geletkanycz, 1997). The decision maker considers his or her cognitive base (perceptions about the future, alternatives, or consequences) and his or her values (Hambrick & Mason, 1984). As Hambrick and Mason (1984) point out, values are an important element in organizational strategy; “a decision maker can arrive at a set of perceptions that suggests a certain choice, but discard that choice on the basis of values” (Hambrick & Mason, 1984; p. 195). Therefore, a strategy is derived partially from the consideration and ranking of values. This value ranking is reflective of the value ranking within the organizational culture.

The connection between values and strategy has been empirically supported as well (Geletkanycz, 1997; Kotey & Meredith, 1997; Husted & Allen, 2007). Geletkanycz (1997) tested the effects of managerial values on the strategic choices for an organization. He found the national cultural values of individualism and short-term orientation covary with certain strategic decisions and policies. Kotey and Meredith (1997) tested a similar relationship between values and strategy when they focused on the link between managerial values and organizational strategies. Kotey and Meredith (1997) measured the personal values of small business owners, in terms of entrepreneurial and conservative values, and found specific strategies, in terms of proactive or reactive strategies, are associated with these values. Husted and Allen (2007) found similar results by looking at the corporate responsibility values of a firm and the strategy of the firm. Husted and Allen (2007) use the RBV to hypothesize the relationship between strategy and values and found the organizations with a high value for social responsibility were much more likely than other firms to engage in a socially responsible strategy.

Guth and Tagiuri (1965) summarize the relationship between values and strategy best by stating, "It is quite clear, on the basis of both observation and of systematic studies of top management in business organizations, that personal values are important determinants in the choice of corporate strategy" (p. 123). This concept is consistent with the values-based definition of organizational culture. Strategy is indicative of organizational values and are therefore related to organizational culture.

Shared by the Collective

According to the shared perspective view of strategy, a key component of strategy is the collective feature of strategy. Following this definition, the strategy cannot only be dictated to the organization from the board room, but, in fact, is shared by the members of the organization. Mintzberg (1987) describes this well when discussing the concept, "Strategy is a perspective shared by the members of an organization, through their intentions and/or by their actions. In effect, when we are talking about strategy in this context, we are entering the realm of the collective mind – individuals united by common thinking and/or behavior" (p. 17). Mintzberg is not alone in specifying strategy as collectively shared; Guth and Tagiuri (1965) define strategy as shared when they say strategy is, “an explicit and shared set of goals and policies defining what the company is to achieve and become in the future and how it must operate in order to reach its goals” (p. 127).

The cultural model of strategy formation, offered by Bourgeois and Brodwin (1984), further supports the shared perspective view strategy. Bourgeois and Brodwin (1984) provided the metaphor of upper management playing a coaching role in the organization. The coach may give general direction but then the strategy is taken up by the members of the organization to fulfill the goal. The shared by the collective component of strategy is supported later by Hart (1992) in the discussion of strategic vision and shared values. While top management motivates and inspires the strategy, the strategy centers on the shared perspective and values of organizational members.

By defining strategy as a group-level phenomenon, researchers must consider the perceptions of strategy by organizational members to assess the strategy, and therefore the values of an organization. Perceptions are how individuals assign meaning to their environment (Taylor & Fiske, 1978), so organizational members' perceptions of strategy indicate the way members assign meaning to the strategy of the organization.

Distinguish an Organization

Organizational culture is defined as shared values that distinguish one group from another (Hofstede, 1980; Leidner & Kayworth, 2006). Shared values are ranked according to priority, creating a unique value hierarchy that distinguishes one organization from other organizations with different value hierarchies. As Hedberg and Johsson (1977) discussed, one of the purposes of a strategy is to be an ordering system that maps information into perspectives or worldviews. Roth, Schweiger, and Morrison (1991) posited these worldviews are the dominant general management logic, based on the schemas of the top managers. The schemas are unique to each manager but are reflective of the values, theories, and propositions of the managers.

Empirical research supports the concept that the strategy of an organization differs from another organization in terms of values. For example, in the empirical work of Kotey and Meredith (1997), two distinct strategies were measured, proactive strategies and reactive strategies. Proactive strategies involve initiative-taking and value more integration and risk. Reactive strategies tend to follow the market leaders and do not value innovation greatly. The researchers admit the activities involved with each strategy may intermingle, but a "proactive-reactive continuum" (Kotey & Meredith, 1997; p. 39) exists, which is used to distinguish organizations.

The idea of strategy distinguishing an organization is revisited by Mahoney and Pandian (1992) in their discussion of the RBV and strategic management. As the RBV explains, the strategy of the firm is the distinctive competencies of the organization. These competencies are defined by the rules and routines of the organization and may be based on the values of the organization. The idea of strategy distinguishing the organization is particularly true when considering the information technology (IT) capability of an organization. Bharadwaj (2000) discusses IT capabilities under the RBV lens and finds organizations differentiate themselves on the basis of their IT capabilities. An organization that values IT capabilities, and the strategic value IT provides for the organization, employs a superior IT capability strategy. The superior IT capability strategy is consistent with the value placed on IT and is shared by the collective. Bharadwaj found that organizations may be identified and differentiated based on strategy, such as a superior IT capability strategy.

CONCLUSION

The discussion above supports a relationship between organizational culture and strategy, but the nature of the relationship is still unclear. For example, recall the case of Uber. The aggressive growth strategy was necessary for the firm to survive in the competitive industry of mobile applications, where buyer power is high and the threat of newcomers to the industry is high (Standard & Poor, 2018). This strategy may have attracted, or nourished, a “Hobbesian environment… in which workers are sometimes pitted against one another and where a blind eye is turned to infractions from top performers.” (Isaac, New York Times, 2018). The culture, therefore, reflected the value ranking of growth and revenue targets above integrity.

Yet, one may also argue the culture of the firm led to the aggressive strategy of the firm. Uber was founded by Travis Kalanick and Garrett Camp, who were described as serial entrepreneurs that needed to rebuke conventional wisdom regarding consumer transportation to be successful. As reported by CNN Money, the company was threatened with legal action in several cities during the expansion (Petroff, 2017) forcing the owners and employees to challenge existing market structures. It is possible the organizational culture, which highly ranked the value of innovation, led to an aggressive strategy.

While previous literature can be used to support the relationship between organizational culture and strategy, more research is needed identifying the nature and strength of this relationship. This conceptual understanding is the first step toward understanding the phenomenon of the culture-strategy relationship. Thoughtful, deliberate research design and modeling is necessary to further a consistent theory of systematic effects on organizational culture and strategy.

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Risk Assessment of Small Unmanned Aircraft System (sUAS) Operations

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ABSTRACT

The rapid growth of the Small Unmanned Aircraft System sector raises questions about the risk of accidents and incidents in National Airspace System (NAS). The purpose of this research is to propose a process to analyze the Federal Aviation Administration (FAA)'s UAS sighting data using cluster analysis to classify sUAS encounter incidents into different groups based on a set of selected variables. The identified clusters help researchers understand the nature, characteristics, and risk factors of incidents, based on which a risk assessment model can be developed to predict the risk of incidents and collision in NAS.

KEYWORDS: Small Unmanned Aircraft System, risk assessment, cluster analysis, National Airspace System, safety

INTRODUCTION

Small Unmanned Aircraft System (sUAS) is an emerging sector of the aerospace industry and the sUAS market was projected to reach $1.61 billion in 2015 (Visiongain, 2015). The Federal Aviation Administration (FAA) defines sUAS as "a small unmanned aircraft, weighing less than 55 pounds, and equipment necessary for the safe and efficient operation of that aircraft" (FAA, 2016a, p. 42065). sUAS can be used either for recreational or business purposes. The demand for sUAS has grown rapidly. As of September 2016, the FAA has granted the exemption for more than 5500 petitions to allow sUAS to be used for non-recreational purposes, and more than 406,000 people have registered to use sUAS for hobby; and the number will continue to grow (FAA, 2016b). The FAA expects about 1.9 million additional sUAS to be used for hobby in 2016 (FAA, 2015).

In June 2016, the FAA issued the new Small UAS Rule (part 107), which requires sUAS to be registered and sUAS pilots to have the remote pilot airman certificate and pass the FAA approved test if the sUAS is used for business or work. If used for recreational purposes, the sUAS over 0.55lbs must be registered but the operator does not need any permission from the FAA to fly (FAA, 2016c). In order to ensure the safety of sUAS operations in National Airspace System (NAS), the FAA explicitly requires sUAS to stay under 400 feet above ground level (ABL), at speed of no faster than 100 mph, away from airports, and operate during daylight hours. When a sUAS is flown within 5 miles of an airport, the operator must provide the airport and air traffic control tower with prior notice (FAA, 2016a).

Safety of integrating UAS into NAS is one of the FAA's top priorities (FAA, 2016b). Despite strict procedures and regulations issued by the FAA, not all UAS operators adhere to these rules. There have been a number of incidents, in which manned aircraft's pilots and air traffic controller reported their encounters with sUAS in the restricted airspace. Specifically, the UAS sighting report shows that there is 1346 UAS encounter incidents reported from November 2014

to January 2016 (FAA, 2016d). This high number of sightings of sUAS violating the FAA-defined regulations raises questions about the reliable separation of sUAS and manned aircraft needed to ensure safety in the NAS (Gettinger & Michel, 2015).

When a sUAS operates above 400 feet AGL, intentionally or unintentionally, it increases the risk of collision between the sUAS and manned aircraft. Similarly, the collision may occur when a sUAS operates near airports, in which manned aircraft fly at low altitudes while on final approach and during take-off (Gettinger & Michel, 2015). While this risk can be mitigated by methods such as see-and-avoid, in most circumstances flying sUAS below 400 feet AGL or flying more than 5 miles away from an airport will provide necessary separation and consequently avoid the risk of collision (Logan, Bland, and Murray, 2011).

As the number of sUAS used for hobby continues to grow, the number of sightings of violating sUAS will likely to increase; on average, the FAA receives more than 100 incident reports per month (FAA, 2016d). The higher the number of sUAS encounter incidents, the higher the risk of collision in NAS. This raises some important questions: What happens? How do these incidents happen? Why do they happen? How to prevent them from happening again? While the use of sUAS for non-recreational purposes can be controlled at some extent, it is much harder to enforce the rules to individuals using sUAS for fun since they are not required to go through any safety training, to pass any test, or to get the permission from the FAA to fly. Accordingly, in order to find the solution for this problem, it is critical to have a deeper understanding in similarities and differences of these violations and how they occurred.

The purpose of this research is to propose a process for identifying risk factors for sUAS operations in NAS. Specifically, this process can be used to analyze the FAA's UAS sighting data using cluster analysis to classify sUAS encounter incidents into different groups based on a set of selected variables in the dataset. First, data will be collected from the FAA's UAS sighting database. Then, even narratives will be coded into specific variables using two coders with expertise and experience in sUAS and aviation safety, followed by the reliability and validity assessment to ensure the quality of the data. In the next step, a two-step cluster analysis will be performed to classify sUAS encounter incidents into different clusters; each cluster represents a group of incidents sharing common characteristics and risk factors. These clusters will be interpreted, compared, and profiled to provide more details of these risk factors.

LITERATURE REVIEW

The rapid growth of the sUAS sector attracts more attention from the industry. However, the literature on sUAS operations in NAS is limited and inadequate, especially from the recreational sUAS perspective. There seem to be two major trends in sUAS literature. The first trend focuses on see-and-avoid methods. In a NASA research project, McAdaragh et al. (2014) highlighted the importance of the human element in visual line-of-sight operation, which is critical for sUAS not equipped with altitude reporting devices to comply with altitude restrictions. In another study, Williams and Gildea (2014) also emphasized the importance of altitude estimation by a visual observer and how this visual observer could help avoid mid-air collisions between a sUAS and manned aircraft. Loffi et al. (2016) tested the ability of manned aircraft's pilots in visually detecting the distance with a sUAS in visual meteorological condition (VMC) and the time needed to avoid a collision. The results showed that pilots overestimated their distances to a sUAS and did not have adequate time to recognize and respond to the sUAS.

The second trend focuses on risk assessment aspect of sUAS operations in NAS. Atkin (2010) studied risk minimization for sUAS in urban regions. Major causal factors are identified including lost link, in-flight upset, loss of sense-and-avoid, loss of operator situational awareness, and component failure. In another study, Awad (2013) developed crash models for UAS in two scenarios: mid-air collision and ground collision. The mid-air collision model evaluates the impact of VMC at day and night time on the collision incidents. The ground collision model evaluates the effects of factors such as aircraft failure rate, aircraft wingspan, glide angle, and population density on the risk likelihood. However, the study does not differentiate between sUAS and regular sized UAS. Similarly, Sahawneh (2016) developed mathematical models for collision detection and risk estimation for sUAS equipped with a sense-and-avoid system. While the models are proven to be working, the study is limited to the sense-and-avoid technology that can keep the sUAS remain clear and avoid collision with other air traffic.

Overall, although these studies provide interesting findings in the safety of sUAS operations in NAS, they are limited to see-and-avoid methods by the pilots or sense-and-avoid technology. In addition, risk assessment models are developed to predict the collision likelihood for very specific and controlled scenarios, in which sUAS are assumed to have already violated the altitude restriction and entered the restricted airspace. What missing in the literature is the classification of sUAS encounter incidents and how to prevent them from happening again.

There are only two industrial reports that analyzed the UAS sighting data. Gettinger and Michel (2015) analyzed 921 sUAS incidents using descriptive statistics and showed that 90.2% of sUAS encounters occurred above 400 feet AGL and 58.8% of sUAS encounters occurred near airports where UAS operations are prohibited. The Academy of Model Aeronautics (AMA) conducted a similar analysis of UAS sightings, using 582 reports of UAS encounters between August 2015 and January 2016. The report indicated only 3.3% of sUAS encounters were considered “near misses” or “close call”. In addition, the report also noted that the data contained reports of objects other than sUAS, including balloons, birds, or jet pack (AMA, 2016). While these reports provide an overview of UAS encounter incidents using simple descriptive statistics for single variables, they do not establish classification of these incidents based on a variety of related variables and develop profile for each group, a needed base to identify causes and develop effective mitigation strategies.

METHODOLOGY

In order to meet these objectives, this research proposes the following steps in data collection and analysis to ensure the validity of the results.

Data Collection and Preparation

Data will be collected from the FAA’s UAS sightings reports between October 2016 and September 2017 (FAA, 2018). The total sample size is 2094 cases. The data includes four variables: event date and time, city, state, and event report narrative. The report narrative is qualitative data presenting observations by pilot, air traffic controller and citizen in regard to sUAS encounters with manned aircraft, helicopters, and airports (FAA, 2016b). The data is anonymous and has no personal or identification information of the individuals reporting the incidents. Hence, there is no concern of ethical issues.

Two data sets will be combined into one data file and sorted by date and time. MS Excel will be used for data exploration and preparation purpose. In order to ensure the usability of the data, the data will be examined carefully to identify unusable or irrelevant data including

- False alarm events are events in which the encounter with sUAS was reported but then marked false alarm. These events will be deleted from the data.
- Since this research focuses on sUAS, any sightings of other objects will be deleted.
- Any reports that have too much missing information, which make them less meaningful, will be deleted.

Data Coding

Since even narratives in the sighting data are qualitative and unstructured, it is important to filter the data and code it into separate variables for the analysis purpose. First, event narratives will be examined carefully to identify important variables for analysis. Second, the data will be coded to these identified variables.

A preliminary analysis of the data suggests the following variables. The list of variables will be examined and validated before the coding process.

- Incident date
- Incident time
- Incident location
- UAS type
- Number of involved UAS
- UAS color
- Type of incident
- Violation detail
- Injury or hazards
- Incident altitude
- Airport
- Distance from airport
- Type of manned aircraft
- Manned aircraft operation
- Distance from manned aircraft
- Evasive action
- Law enforcement notification

Code Reliability and Validity Assessment

Since the data is coded from event narratives, it is important to ensure the reliability and validity of the data. Data reliability refers to the extent to which data consistently represents what is intended to measure (Hair et al., 2010). In order to test the reliability, a second coder will be asked to recode a sample of data randomly selected from the dataset (Bazeley, 2013). The coders must have understanding of sUAS operations and aviation safety. Then the codes will be compared, and Cohen's Kappa coefficients will be used to evaluate the inter-coder reliability of the codes (Landis and Koch, 1977; Cohen, 1960; Fleiss, 1981; Gwet, 2014). Kappa coefficients will be interpreted following the general guidelines by Fleiss (1981). Specifically, a Kappa coefficient above 0.75 indicates an excellent level of agreement; a coefficient between 0.4 and 0.75 indicates a fair to good level of agreement; and a coefficient below 0.4 indicates a poor level of agreement. If the inter-coder reliability is not satisfactory, the codes will be revised and the reliability assessment will be repeated.

Data validity refers to the extent to which data correctly represents what is intended to measure (Hair et al., 2010). The validity will be assessed through the auditing process, in which a set of criterion codes will be set in advance. Then the actual codes will be compared with the criterion codes, and Kappa coefficients will be used to evaluate the agreement between these codes

(Crittenden and Hill, 1971; Bazeley, 2013). The process will continue until the validity is satisfactory.

Additional Data Collection

In order to identify clusters, additional information may be needed, for example, the size of the airport, size of manned aircraft, color, and operation type, etc. The data will be useful for cluster comparison and cluster profiling. Based on the name of the airport and aircraft type indicated in the report, these additional data will be collected from external sources.

Data Analysis

Variable Selection

Classification of sUAS encounter incidents will be performed based on their commonalities in various variables. Based on the literature review, a selected set of variables will be identified for this purpose. A preliminary list of these variables includes incident altitude, distance from manned aircraft, distance from airport, airport size, manned aircraft size, etc. The variables will be reviewed and finalized by subject matter experts in sUAS and aviation safety.

Cluster Analysis

Cluster analysis is a multivariate statistical technique that classifies objects based on a set of user-selected variables (Hair et al., 2010). First, missing values and outliers will be examined and handled. And then, the multicollinearity assumption will be evaluated to meet the requirement of the test, and the data will be standardized as needed. Cluster analysis will be performed in two steps.

At Step 1, a hierarchical cluster analysis will be conducted using SPSS 24 to identify the number of cluster based on the selected variables. Hierarchical cluster analysis is a stepwise clustering procedure that combines the objects into clusters. The result is the dendrogram showing the formation of the clusters. In this step, the Ward's method will be used as the clustering algorithm to generate clusters that are homogenous and relatively equal in size, and squared Euclidean distance will be used to measure the similarity (Milligan, 1979; Jain et al., 1999; Hair et al., 2010).

At step 2, a non-hierarchical cluster analysis will be conducted to fine-tune the cluster solution identified in step 1. Non-hierarchical method has an advantage of being able to "better optimize cluster solutions by reassigning observations until maximum homogeneity within clusters is achieved" (Hair et al., 2010, p.531). K-means algorithms will be used to partition data into "a user-specified number of clusters and then iteratively reassign cases to clusters until a numerical goal related to cluster distinctiveness is met" (Hair et al., 2010, p.485).

Cluster Validation

The cluster validity will be assessed by comparing the clusters based on variables that have a theoretically based relationship to the clustering variables but are not included in the cluster solution. MANOVA test will be used for this purpose. First, the criterion validity variables will be selected as dependent variables (for example, incident time of day, hazard, location, etc.). Second, assumptions for MANOVA (independence, homoscedasticity, normality, linearity and

multicollinearity) will be tested. Then, the multivariate and univariate testing will be performed to compare group differences in regard to the criterion validity variables. If the results show the effect of cluster solution on these dependent variables, then it can be concluded that there is enough evidence of criterion validity.

Cluster Profiling

The meanings of clusters will be interpreted by analyzing the cluster size and the pattern of cluster means and mean-centered values of selected variables including characteristic variables and risk factors. These groups will be presented with selected names and characteristics; each group represents incidents with common characteristics and risk factors. Qualitative data will be examined to provide further explanation for the cluster results.

CONCLUSIONS

This research promises both theoretical and practical contributions to the field of sUAS operations and safety. From the theoretical perspective, the proposed process fills the gap in the literature by identifying risk factors for sUAS operations in NAS. The research will use the FAA's UAS sighting data, which takes into account the large number of sUAS used for hobby; something has been missing in the current sUAS literature. The cluster analysis will classify sUAS encounter incidents into groups based on their common characteristics and risk factors, which provide a big picture of what violations and how they happen as a high number of sUAS integrate into NAS.

From the practical perspective, the results of this process will provide the FAA and stakeholders a clear picture of safety concerns when more users purchase and fly sUAS for hobby. The high number of sightings of sUAS violating the FAA's sUAS procedures and regulations may increase the risk of collision in NAS. The clusters will allow the FAA to understand the nature, characteristics, and risk factors for each group of incidents, based on which they develop necessary mitigation strategies to prevent further violation of the FAA's sUAS rules and regulations. They can also be used as the base to identify causes of sUAS encounter incidents and develop a risk assessment model to predict the risk of incidents and collision in NAS.

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DECISION SCIENCES INSTITUTE
Risk Management for Funds: A Decision Theoretic Approach

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ABSTRACT

The aim of this paper is to develop an integrated portfolio optimization framework that is consistent with empirically documented investor behaviour as well as market practice in the asset management industry. We develop a top-down approach where risk measures as well as benchmarks of investment funds can be linked to features of behavioural theories such as Prospect Theory. We show how a risk budgeting and risk management process that is consistent with Behavioral Portfolio Theory can be developed.

KEYWORDS:: Risk Management, Portfolio Selection, Decision Theory.

JEL classification: G11, D81, C11.

INTRODUCTION

In theory, investors knowledgeable of their risk aversion should choose their portfolios by either maximizing return for a given risk or minimizing risk for a target return. Within the standard portfolio framework, risk is typically measured with the standard deviation of returns. There are two issues with this approach. First, empirical evidence points out that investors' behaviour is not consistent with Expected Utility. Research by (Bruhin et al, 2010) indicates that 80% of individuals distort probabilities as suggested by (Kahneman & Tversky, 1979;1992). This behaviour is also in line with recent decision theoretic research on behaviour under ambiguity, when there is uncertainty concerning the probabilities (Gilboa & Schmeidler, 1989; Schmeidler, 1989). Second, in practice, most of the investments are managed by asset management companies that act as agents for the investors. This creates a layer of asymmetric information, as the investor does not directly observe, neither the skills, nor the effort of the asset manager. Issues related to fund delegation problems and asymmetry of information are closely related (Stracca, 2005) to the current EU regulation for mutual funds, where the board is responsible for the supervision of the risk management process and the contracts with the service providers of the fund.

In principle, the Board members should devise rules that are consistent with preferences exhibited by the investors. This implies that they have to develop risk management principles and compensation rules. Risk principles are discussed in (CMRA, 2008). Besides broad governance principles and the focus on non-market risks (operational, etc.), the document indicates that the main risk consists in deviations of the fund's performance from client expectations. In principle, the benchmark return of the fund should be in line with client expectations as well as the risk profile of the fund. The asset manager's task is then to limit downside risk with respect to the benchmark.

There is also a greater awareness that risk management should be integrated with portfolio optimization (CMRA, 2008). In a sense, risk management generates alpha. This implies that the risk budgeting process should be integrated with the portfolio optimization. In the standard mean-

variance framework, a benchmark is selected on the efficient frontier, and the manager has a constraint on the tracking error variance (TEV). The manager has a constraint on the TEV and is supposed to maximize alpha under this constraint (Berkeelar et al, 2006). The Risk Management department also fixes limits on the Value at Risk (VaR). Again, there are a few issues with this approach. First, as shown by (Admati & Pfleiderer, 1997) the existence of a benchmark is inconsistent with expected utility. Second, returns are not normally distributed (Embrechts et al, 2002).

Research in Decision Theory and Behavioural Economics documents that individuals evaluate risk with respect to a subjective reference level. Experimental evidence by (Kahneman & Tversky, 1997;1992) suggests that investors analyse losses and gains with respect to a benchmark in a non-linear way. Moreover, investors are loss averse which implies that losses with respect to the reference level are penalized heavily. Moreover, investors transform the so-called objective probabilities in an inverse S-shaped way (Prelec, 1998; Bruhin et al*,* 2010). Finally, investors consider different asset classes as individual portfolios, a phenomenon called Mental accounting. This is an instance of the heuristics used by individuals (Gilovich et al, 2008). (Shefrin & Statman, 2000) develop a framework that is consistent with empirically documented investor behaviour. Their framework rationalizes the existence of different asset classes and investment styles. Moreover, return distributions are analysed along three dimensions: Security, Aspiration and Potential. Aspiration indicates what the investor expects. Security, implies limits on losses and potential indicates that an investor pays for small probabilities of very high payoffs.

The aim of this paper is to develop an integrated risk management framework that is consistent with empirically documented investor behaviour. Within our framework, a subjective benchmark is determined by the subjective reference level of the investors. The subjective benchmark is then mapped on risk factors to determine the relevant market or return-based benchmark. The setting of risk limits can then be set as a function of the loss aversion of investors. Constraints are typically set in terms of VaR, but recent evidence points out that expected shortfall is more robust and reduces the incentives for the managers to take extreme risks not measured by VaR (Basak & Shapiro, 2001). Moreover, VaR is not sub-additive which is an issue essentially when different sub-compartments of the fund are managed by different managers. Sub-additivity, of course, depends on the type of portfolio considered and can be tested by econometrically analyzing the tails of the distributions (Garcia et al*,* 2007).

Risk decomposition is typically implemented through a marginal risk decomposition. First, note that VaR has the property that if each subposition is multiplied by a given constant , then the total VaR increases by this given constant. This property based on Euler's law enables us to measure marginal (sometimes called incremental) contributions by portfolio positions (Tasche, 2008; Kalkbrener, 2005). If we evaluate the derivative of VaR with respect to each portfolio position and weigh the latter by the respective position, we get the total value of VaR. We can thus evaluate the portfolio adjustments that respect the VaR constraints and determine the respective contributions to VaR. For simple frameworks with a few assets the marginal VaR calculations are straightforward, but for realistic environments a risk mapping has to be implemented. The latter consists in mapping risk properties on representative asset classes.

Although the risk budgeting approach is well-known and is part of market practice, recent developments that suggest approaches consistent with return statistics are less known. As already alluded to, when the tails of the return distributions are too heavy, VaR is not sub-additive and cannot be used in the risk budgeting process. In that case coherent risk measures such as shortfall measures (Acerbi, 2002) can be used to develop a coherent risk budgeting process (Dorfleiter et

al, 2008). Such an approach can then be used to develop an integrated risk management and portfolio optimization process that is consistent with leptokurtic return distributions.

In our framework, risk will be analyzed in terms of deviations with respect to a benchmark, the latter being either return-based or model-based. The measures that will be considered are actually deviation measures as the reference level is not fixed. There is, however, a clear and simple mapping between deviation measures and risk measures. Bertsimas *et al* (2004) have suggested shortfall measures as risk measures to be used in an optimizing framework. Shortfall measures evaluate deviations with respect to the benchmark under extreme market movements. We show how that measure can be used as a risk management tool and in the risk budgeting process.

Risk budgeting presumes that risk can be consistently aggregated. The total risk measured has to equal the sum of the different measured risks of the sub-components taking into account diversification effects (Kalkbrener, 2005). In order to be effective in a risk aggregation process, a measure needs to respect some of the coherence axioms (Atzner et al, 1999), notably positive homogeneity and sub-additivity. The Euler principle can then be used to measure the marginal contributions to risk of the different sub-components (Tasche, 2008). The shortfall measure is sub-additive and positively homogeneous and there thus exists a linear diversifying capital allocation. These characteristics enable the board to set a top-down risk management process making the sure the total risk budget is respected.

Our roadmap is the following. We start with a short overview of experimentally documented investor behaviour. We then analyse the portfolio delegation problem of the investor, which is an institutional feature of the asset management industry. This leads to the conclusion that the choice of the benchmark is an important risk management that can be linked to investors' subjective aspiration levels. We then discuss the types of measures to be used to create a top-down risk budgeting approach that is consistent with an investor's aggregate risk target. Finally, we discuss the application of the top-down optimization process.

INVESTOR BEHAVIOUR

Standard Markowitz portfolio theory presumes that investors are EU maximizers with a concave Bernouilli utility function. The decision theoretic and behavioral economics literature, however, highlights that most individuals' behavior is not consistent with the EU hypothesis. Recent experimental evidence is provided in (Bruhin et al, 2010). (Kahneman & Tversky, 1979; 1992), document that individuals evaluate gains and losses with respect to a subjective reference level. Their so-called value function is concave on gains and convex on losses. Moreover, investors are strongly averse to losses. This has led to the following well-known specification:

$$v(w-\overline{w}) = \begin{cases} (w-\overline{w})^{\alpha} & if \quad w \geq \overline{w} \\ -\lambda(w-\overline{w})^{\beta} & if \quad w < \overline{w} \end{cases} \tag{1}$$

Where *w* and $\overline{w}$ respectively denote the realized wealth and the subjective reference wealth level. λ is the loss aversion parameter and is typically calibrated to 2.25. α and β are generally calibrated to 0.88.

Investors also transform observed probabilities and the way these probabilities are distorted is well-documented (Tversky & Wakker, 1995; Wakker, 2010; Prelec, 1998). Investors typically apply inverse S-shaped functions, called probability weighting functions, to the cumulative probability distribution. Recent research indicates that such behavior could stem from a kind of ambiguity aversion. Frameworks to treat ambiguity have been developed by (Gilboa & Schmeidler, 1989;

Schmeidler, 1989). Those authors suggest that DMs maximize EU under the worst case scenario given sets of probability distributions. (Schmeidler, 1989) shows that relaxations of the independence axiom lead to a preference representation with respect to a non-additive set measure. This model is known as the Choquet Expected Utility (CEU) model. (Ghirardato et al, 2004) suggest to model behavior in the face of ambiguity with a weighted $(\alpha, 1-\alpha)$ combination of the worst and the best scenarios. This has led to the $\alpha - MEU$ approach where α is interpreted as a parameter of ambiguity aversion. Recently, (Amarante, 2009) shows that $\alpha - MEU$ can be mapped on CEU representations. Finally, a last dimension that is often forgotten in the literature, is that DMs also typically consider prospects in different mental accounts. This opens the door for multiple investment styles and funds. This provides an explanation of the asset Allocation Puzzle (Canner et al, 1997). The academic literature, however, has faced difficulties to integrate those behavioral aspects into an operational portfolio optimization framework and this is the task we try to solve here.

(Shefrin & Statman, 2000) develop a portfolio optimization approach that is consistent with empirically documented behavior. They argue that there are three dimensions that matter for the DM: *potential*, *aspiration* and *security*. *Aspiration* indicates the level of wealth expected or desired by the DM. *Security* refers to the desire to limit losses with respect to the aspiration level. Finally, *potential* indicates that DMs want to invest a fraction in assets that have a very small probability of very high payoffs such a lottery tickets. This is in line with the well-documented fact that DMs buy insurance as well as lottery tickets. The three dimensions are linked to different behavioral aspects of prospect theory. Besides behavioral aspects, institutional features are also important to take into account and are actually conditioned by behavioral features. (Verlaine, 2016) provides a detailed analysis of this topic. As investors are deviating from the standard rationality paradigm, they are not investing their money directly but delegate the investment to managers, an issue analyzed in the next section.

THE PORTFOLIO DELEGATION PROBLEM

As the optimal contracts with the asset managers bear a close relationship with the risk management of the fund, behavioral aspects also influence the optimal contract. There has been an interest, quite recently, in the delegation issues in portfolio management. For a good overview consult (Stracca, 2005). The delegation problem is typically modelled through a Principal-Agent relationship. The investor is the Principal and the Agent is the Asset Manager. The portfolio delegation literature focuses on contractual issues. In a first step, the investors face a set of Managers and have to select the good ones that have the skills to generate outperformance. In a second step, the contract and the compensation rules have to incentivize the Manager to spend maximal effort to generate outperformance. The investors are thus supposed to structure the contract in such a way that 3 conditions be respected. First, the managers with superior skills are selected. Second, the contract incentivizes the Asset Manager to generate risk-adjusted outperformance once the contract is signed. Finally, the risk-sharing between the investor and the Asset Manager should also be optimal.

Formally, the maximization problem takes the following form.
In the first order the Principal maximizes his expected utility given by :

$$\begin{aligned} &Max_f\, EU\big((1+R) - f(R)\big) \\ &with\ R = w\big(S(e)\big)R_p \end{aligned} \tag{2}$$

He thus maximizes expected utility of gross return minus the fees. But in order to hire a manager he also needs to be sure that the expected utility of the return is higher than what he gets if he simply invests in a passively managed fund. Hence, the following participation constraint:

$$EU\left(1+R-f\left(R\right)\right)\geq EU\left(1+R_u\right) \tag{3}$$

So basically, the EU of the gross net of fees return has to be higher than what the investor gets when he invests in an Exchange Traded Funds, for instance.
The manager also maximizes utility and faces a participation contraint.

$$e,w\left(S\right)=\arg\max\left[EU\left(f\left(R\right)\right)-h\left(e\right)\right] \tag{4}$$

So the manager chooses an optimal effort level and portfolio combination so that he maximizes EU of fees perceived minus his disutility of effort *h(e)*. However, the following participation constraint

$$EU\left(f\left(R\right)-h(e)\right)\geq U^{*} \tag{5}$$

indicates that he is only working for the investors if the expected utility of the fee minus disutility of effort is higher than the utility he gets in another job.
Different fee functions have been suggested, but they all face the drawback that, due to the fact that there is no direct relationship between effort spent by the manager and portfolio return, it is extremely difficult to make sure the manager spends effort and that the returns are due to luck or hidden risks. Basically, there are two types of contracts, linear and non-linear, which we analyse below.

The linear compensation contract takes the following form:

$$\begin{aligned} &f\left(R\right)=C+B\left(R-b\right)\\ &with\ C,B>0 \end{aligned} \tag{6}$$

b is a subjective benchmark that is known in advance and it can be either stochastic or fixed. Our approach implies the evaluation of this subjective benchmark for a prospect theory type decision maker and then the choice of a investment fund becnhmark that has the same expected return. Typically Mutual Funds are benchmarked with a stochastic market based benchmark, generally given by an index that reflects the strategy of the fund. Hedge Funds, however, are mostly benchmarked with an absolute target which is given by the Hurdle rate. Hedge Funds often also have so-called High-water mark clauses which specify that past losses with respect to the benchmark have to be made up before the variable fees are paid. As shown by (Brown & Goetzmann, 2003) this creates path dependent option like features which are difficult to analyse within this framework. Within the linear contract framework, a higher B induces the manager to spend more effort but also to take more risk which will increase the required flat payment C.

In the standard agency setting, there is a trade-off between risk sharing and effort inducement.
However, in a portfolio delegation framework this kind of contract doesn't induce the manager to work harder. The manager has complete control over his response to signals (his information). This is known as the 'irrelevance result'. This result holds irrespective of whether the contract contains a benchmark. A benchmark, unless it is the optimal conditional portfolio, is a distorting factor.

The non-linear compensation contract has also been suggested as an optimal compensation rule:

$$f(R) = C + B(R-b)^2 \quad with \quad C, B > 0 \tag{7}$$

Here, compensation depends in a quadratic way on the relative performance compared to a benchmark. It can induce the manager to undertake more effort. However, if the manager is allowed to respond to the signal in a nonlinear way, the 'irrelevance result' still holds. Hence, restrictions have to be imposed on the manager's trading set. This is an interesting result in terms of industry regulation.
Finally, linear vs. non-linear asymmetric contracts

$$f(R) = \begin{cases} \mathrm{C} + \mathrm{B(R - b)} \text{ if } \mathrm{R} > \mathrm{b} \\ 0 \text{ if } \mathrm{R} < \mathrm{b} \end{cases} \tag{8}$$

Symmetric contracts penalize negative outcomes in the same way as they reward positive outcomes, while for convex contracts the marginal reward is higher the better the performance compared to a benchmark. Symmetric linear contracts are typical of the (regulated) hedge fund industry, whereas call-option contracts are more widespread in the hedge fund industry.

The irrelevance result and the fact that restrictions on the trading set have to be imposed rationalizes the recourse to risk management and risk limits. The Board's responsibility in terms of risk management is thus to select a benchmark that is in line with the risk profile of the fund and determine the risk limit or limits of the fund or positions. The foregoing developments imply that the Board has to develop a top-down approach to the risk management and measurement and this is the issue that we aim to address.

The function of the benchmark is also to distinguish performance related to systematic risk factors from performance due to superior selection skills. From an operational viewpoint, the role of the benchmark is also to control the deviation of the portfolio with respect to the benchmark. As pointed out in (CMRA, 2008), the main risk is that the performance will fall short of the benchmark. Finally, benchmarks are also often used to compare fund performance to the benchmark. Correct benchmarking is an issue and (Sensoy, 2009) suggests that approximately 35% of benchmarks are not in line with the risk profile of the fund.

Deviations from the benchmark are typically controlled through the trading error variance (TEV). This is in line with the quadratic compensation rule above. If we apply the expectation operator to the quadratic compensation rule we get:

$$\begin{aligned} E[f(R)] &= C + BE\left[(R-b)^2\right] \\ &= C + B \times TEV \end{aligned} \tag{9}$$

And the compensation thus depends on the TEV. Even though this approach is quite used in practice, the TEV evaluates positive and negative deviations from the benchmark in the same way.

We argue that the benchmark selection should be integrated with the risk management process and be linked to empirically documented risk behavior. As the benchmark measures risk-adjusted performance, the benchmark should be in line with the reference risk measure and be used to determine the global risk exposure of the fund. For instance, if the global exposure of the fund is measured with the Value at Risk (VaR, henceforth), then the benchmark's expected return should be in line with the risk implied by the VaR. The expected return of the benchmark will be

determined by an equilibrium asset pricing model. If returns are normally distributed, the VaR being the product of volatility with a multiplying factor, the benchmark could be selected by construction of an efficient frontier in the mean-variance space and by determining the equilibrium expected return for the respective volatility of the funds risk profile.

The multivariate normality of returns, however, has been questioned by Embrechts *et al.* (2002). This has led to the application of new risk measures, notably VaR and Expected Shortfall (ES). The benchmark should thus be deduced from equilibrium relationship between return and one of the chosen risk measures. The choice of the risk measure, however, depends on the aggregation properties and here the notion of coherency of the risk measure plays a major role.

RISK MEASURES AND AGGREGATION

(Artzner et al., 1999) derived the axioms that a well-behaved risk measure should respect. . A coherent risk measure $\rho(X)$ is a real valued function defined on the space of real-valued random variables which satisfies the following axioms:

- Translation invariance: $\forall c \in \Re, \rho(X+c) = \rho(X) - c$
- Sub-additivity: $\forall X, Y \ \rho(X+Y) \leq \rho(X) + \rho(Y)$
- Positive homogeneity: $\forall \lambda \geq 0, \ \rho(\lambda X) = \lambda \rho(X)$
- Positivity: $X \geq 0, \ \rho(X) \leq 0$

All those axioms have a specific interpretation. Translation invariance, also called cash-invariance, implies that the risk can be interpreted in terms of capital requirements. If an investor puts the amount $\rho(X)$ of cash in the portfolio, the portfolio becomes riskless given the risk measure used ρ. Positivity, of course, just implies that a higher payoff profile has less risk. A measure that satisfies both axioms is called a monetary measure of risk (Föllmer & Scheid, 2008). Positive homogeneity means that an increase in all the portfolio positions by λ also leads to a linear increase in the risk involved. This axiom has actually been questioned on the grounds of liquidity risk. Finally, sub-additivity which is probably the most important axiom implies that the risks of a portfolio are less than the sum of individual risks. A well-behaved risk measure should thus model diversification effects.

This last property is actually important to decentralize the task of managing the risks arising from a collection of different positions. Separate risk limits can be set for different positions or sub-compartments making sure that the risk of the aggregate position is bounded by the sum of individual risk limits. With that respect, it is well-known that VaR defined as

$$VaR_{\alpha}(X) = \inf\left\{m \in \Re \middle| P[X+m] < 0 \leq \alpha\right\} \tag{10}$$

is not sub-additive.
Expected shortfall given by

$$ES_{\lambda} = \frac{1}{\lambda}\int_0^{\lambda} VaR_{\alpha}(X)d\alpha \tag{11}$$

is a coherent risk measure and can be used as an effective risk measure to set decentralized risk limits. ES also has other interesting properties in terms of manager control and robustness. As highlighted by (Basak & Shapiro, 2001), risk limits in terms of VAR may lead to portfolio concentrations and increases of extreme risks. ES measures can also be deduced from robust decision making in the face of uncertainty (Föllmer & Schied, 2004). The development of coherent

risk measures has also led to research on coherent capital allocation which is of particular interest here.

Coherent capital allocation has been a research topic since the seminal work of (Artzner et al, 1999). The first major contribution to the issue of coherent economic capital allocation was provided by (Denault, 2001). More exactly, the problem addressed is the following. Adding different business units or sub-portfolios leads to diversification effects, thus the sum of the risks of the subcomponents is larger than the risk of the sum of the subcomponents. However, the benefits of risk reduction due to the portfolio composition have to be divided among the different subcomponents. Denault applied concepts from cooperative game theory to a coherent approach to the allocation of risk capital.

(Kalkbrener, 2005) develops an axiomatic approach based on subadditive and positively homogeneous risk measures. The suggested axiomatization presumes that the risk capital allocated to a subportfolio *i* depends exclusively on the distribution of *i* and the distribution of the whole portfolio, not on the decomposition of the rest. The axiomatization of Kalkbrener is based on the assumption that capital allocated to subportfolio P_i only depends on P_i and the aggregate portfolio *P*, but not on the decomposition of the rest of the portfolio.

$$P - P_i = \sum_{i \neq j} P_j \tag{12}$$

The capital is thus represented by a function $\Lambda(P_i, P)$. If we consider an aggregate risk measure $\rho(P)$, fixed by a decision maker for instance, then Λ is a capital allocation with respect to $\rho(P)$ whenever

$$\Lambda(P, P) = \rho(P) \tag{13}$$

hence when the capital allocated to the aggregate portfolio equals the risk capital of the aggregate portfolio.

Kalkbrener suggests three axioms for capital allocations. First, linear aggregation makes sure that the sum of the risk capital of the sub-portfolios equals the risk capital of the aggregate portfolio. Second, there are some diversification effects. Third, continuity ensures that small portfolio adjustments have a limited impact of the risk capital of the sub-portfolios. Those axioms uniquely characterize capital allocations. Also, for a given risk measure ρ there exists a capital allocation Λ_ρ that satisfies the linear aggregation and diversification axioms if and only if ρ is sub-additive and positively homogeneous, that is ρ satisfies:

$$\begin{aligned} \rho(P_i + P_j) &\leq \rho(P_i) + \rho(P_j) \\ \rho(\alpha P_i) &= \alpha \rho(P_i), \ \forall \alpha \geq 0 \end{aligned} \tag{14}$$

Kalkbrener proves that the existence of directional derivatives of ρ at a portfolio *P* is a necessary and sufficient condition for Λ_ρ to be continuous at *P*.

Kalkbrener then shows that:

- If there exists a linear, diversifying capital allocation Λ with respect to ρ, then ρ is positively homogeneous and sub-additive.
- If ρ is positively homogeneous and sub-additive then Λ_ρ is a linear, diversifying capital allocation with respect to ρ.

One of the challenges is to develop a top-down risk management process consistent with institutional features and loss aversion as well as probability weighting. For this, specific properties of the risk measures are needed.

PREFERENCES AND SHORTFALL MEASURES

The foregoing developments warrant the recourse to alternative risk measures such as expected shortfall. Although this type of measures have been known for some time, they have not been used in practice till recently. (Bertsimas et al, 2004) were the first to analyse the use of shortfall measures in an optimizing framework. Recall, that our aim is to develop a portfolio optimization approach that is consistent with investor behaviour exhibiting loss aversion and probability weighting. As discussed earlier, (Shefrin & Statman, 2000) suggest that such an investor maximizes his portfolio along three dimensions *potential*, *aspiration* and *security*. *Aspiration* indicates the level of wealth expected or desired by the DM. *Security* refers to the desire to limit losses with respect to the aspiration level. Finally, *potential* indicates that DMs want to invest a fraction in assets that have a very small probability of very high payoffs such a lottery tickets. Note that the *potential* dimension can be implemented through Core-Satellite approaches, where most of the investments are concentrated in a standard fund and a very small fraction of the investment is invested in satellites of Hedge Funds. We thus concentrate on the *aspiration* and *security* dimension. *Aspiration* then determines the benchmark of the fund, while *security* implies downside restrictions of deviations with respect to the benchmark.

Let's now consider a vector of returns R, with mean

$$E(R) = \mu \tag{15}$$

and a vector of portfolio weights **ω**. As we will concentrate on risk measurement, the mean return will be fixed at a target aspiration rate.

$$E\left[R^T \omega\right] = R_p \tag{16}$$

We could now minimize over **ω** the (1-α) confidence level

$$VaR_\alpha(\omega) := \mu^T \omega - q_\alpha\left(R^T \omega\right), \ \forall \alpha \in (0,1) \tag{17}$$

where $q_\alpha\left(R^T \omega\right)$ is the α-quantile of the distribution of the portfolio return $R^T \omega$. A natural approach of portfolio optimization would thus consist in maximizing VaR_α as a function of portfolio weights. As VaR_α is not a convex function of portfolio weights this leads to computational difficulties (see Lemus *et al.* (1999)).

Issues with sub-additivity also lead us to use shortfall to impose limits on deviations with respect to the benchmark. We thus suggest to minimize the shortfall at the risk level α:

$$s_\alpha(\omega) := \mu^T \omega - E\left[R^T \omega \middle| R^T \omega \le q_\alpha\left(R^T \omega\right)\right], \ \forall \alpha \in (0,1) \tag{18}$$

$s_\alpha(\omega)$ basically measures the expected losses below the expected return that might occur whenever the portfolio drops below the α-quantile. Given those results we are led to focus on shortfall minimization.

It is interesting to discuss the properties of the shortfall risk measure. As shown by Bertsimas *et al.* (2004) whenever returns are elliptically symmetrically distributed, the shortfall measure is proportional to the standard deviation. It is thus equivalent to minimize volatility or shortfall.
As discussed in the next section shortfall measures have "good" aggregation properties that can be used in a risk budgeting process.

RISK BUDGETING PROCESS

The risk measure originally introduced by (Artzner et al,. 1999) was not expected shortfall but Tail Conditional Expectation

$$TCE_\alpha(\omega) = -E\left[R^T\omega \middle| R^T\omega \le q_\alpha\left(R^T\omega\right)\right] \tag{19}$$

Which is a coherent risk measure.

As shortfall is to be used in portfolio optimization it integrates the expected return and shortfall can be expressed as the following way:

$$s_\alpha(\omega) = \mu^T\omega + TCE_\alpha \tag{20}$$

Due to this mean-adjustment expected shortfall violates translation invariance and positivity.
Shortfall also has very useful mathematical properties. Most notably, an important issue for portfolio optimization is that it is convex in the portfolio weights ω.
Moreover:

- $s_\alpha(\omega) \ge 0\ \forall\omega and\ \alpha \in (0,1)$. $s_\alpha(\omega)$equals 0 for some ω and α if and only $R^T\omega$ is constant with probability 1.
- $s_\alpha(\omega)$is positively homogeneous : $s_\alpha(\lambda\omega) = \lambda s_\alpha(\omega),\ \forall\lambda \ge 0$
- If the density of returns is continuous: $\nabla_\omega s_\alpha(\omega) = \mu - E\left[R \middle| R^T\omega \le q_\alpha\left(R^T\omega\right)\right]$

Those are actually the properties needed to develop a linear diversifying capital allocation process. The properties are also useful to optimize portfolios.

Shortfall can be estimated quite easily. Consider a sample of T returns of the portfolio ω. The return at date t is given by $r_t(\omega)$and the returns can be sorted in increasing order:

$$r_1(\omega) \le r_2(\omega) \le \ldots \le r_T(\omega) \tag{21}$$

Consider $K = [\alpha T]$, the number of returns below a certain level, the non-parametric estimator of $s_\alpha(\omega)$can be represented thus:

$$s_\alpha(\omega) = \omega^T\mu - \frac{1}{K}\sum_{j=1}^{K} r_{(j)}(\omega) \tag{22}$$

Sometimes α is too small and extreme value theory (EVT) can be used to extrapolate outside the observed sample. In order to optimize the portfolio the following mean-shortfall optimization can be solved.
Minimize $s_\alpha(\omega)$
subject to $\omega^T\mu = r_p\ and\ e^T\omega = 1$
where e is a column vector of ones.
Bertsimas et al. (2004) show that the minimum α-shortfall frontier is convex. In presence of a riskless asset the minimum shortfall is defined from:
Minimize $s_\alpha(\alpha)$
Subject to $\omega^T\mu + (1 - e^T\omega)r_f = r_p$

(Tasche, 2000) has shown that the minimum shortfall frontier in the $(r_p, s_\alpha(\omega))$ space, with $r_p \geq r_f$, is a ray starting from the point $(r_f, 0)$ and passing through the particular point $(r_p^*, s_\alpha^*(\omega))$ with $r_p^* \geq r_f$.

The optimal solution satisfies

$$\mu_j - r_f = \beta_{j,\alpha}(\omega_\alpha)(r_p - r_f), \quad j = 1,...,n \tag{23}$$

With

$$\begin{aligned} \beta_{j,\alpha}(\omega) &= \frac{1}{s_\alpha(\omega)} \times \frac{\partial s_\alpha(\omega)}{\partial \omega_j} \\ &= \frac{\mu_j - E\left(R_j \middle| \omega^T R \leq q_\alpha(R^T\omega)\right)}{\omega^T \mu - E\left(\omega^T R \middle| \omega^T R \leq q_\alpha(R^T\omega)\right)} \end{aligned} \tag{24}$$

$\beta_{j,\alpha}$ is called the shortfall beta and can be interpreted as the relative change in shortfall when varying the weight of asset j. Note that as with the standard beta.

$$\sum_{j=1}^{n} \omega_j \beta_{j,\alpha}(\omega) = 1 \tag{25}$$

This is a very useful property as it gives a decomposition of the portfolio shortfall into individual assets' contributions. Note that $\beta_{j,\alpha}$ depends on α and this may be used to quantify the empirically observed fact that components of the market or portfolio become more dependent on the market when the latter is more volatile.

OVERVIEW OF THE TOP-DOWN RISK MANAGEMENT PROCESS.

Consider a board of directors that supervises the management of a fund with different asset classes. These asset classes can be managed by different asset managers. As discussed in section 4 and 5, the first foremost element of the risk management process is the right choice of a benchmark. Typically, the board then chooses either a market index that is the most representative of the aggregate investment strategy of the fund, or a return-based benchmark. For Mutual Funds different models could be used, but market standard has become the (Carhart, 1997) 4-factor or (Fama & French, 1993) 3-factor model. Carhart's model is used extensively as it encompasses the Fama-French model. The specification is the following:

$$r_{it} = \alpha_i + \beta_{rm,i} rm_t + \beta_{hml,i} hml_t + \beta_{smb,i} smb_t + \beta_{pr1y,i} pr1y_t + \varepsilon_{it} \tag{26}$$

Where smb and hml denote returns on portfolios that proxy for common risk factors associated with size and book-to-market, respectively. The term pr1yt is the return difference between stocks with high and low returns in the previous year. This term accounts for passive momentum strategies. r_{it} is the fund's before-expense return in month t in excess of the 30-day risk-free interest rate. The alpha is supposed to capture the fund's before-fee risk adjusted performance. Of course, the benchmark would be given by an expected return with zero alpha.

The benchmark expected return can now be used to determine the expected return $\mu(\omega)$ of the shortfall measure

$$s_\alpha(\omega) = \mu(\omega) - E\left[R^T\omega \middle| R^T\omega \leq q_\alpha(R^T\omega)\right] \tag{27}$$

We write the expected return as a function of the portfolio weights rather than $\omega^T \mu$ as in our delegation framework the expected return is not directly a function of our portfolio but is indirectly related to the risk of the fund. Once the benchmark is chosen the board has to fix a confidence level α for the calculation of the TCE. The confidence level could actually be related to behavioural aspects such as the security dimension of (Shefrin & Statman, 2000). The weights of the "portfolio" are given by the weights of the respective asset classes of the fund. The board can now fix a shortfall target and given the positive homogeneity and sub-additivity properties as well as the continuity of the shortfall measure, we can apply Euler's (Tasche, 2008) Theorem to the measure to deduce:

$$s_\alpha(\omega) = \sum_{j=1}^{n} \omega_j \times \frac{\partial s_\alpha(\omega)}{\partial \omega_j} \tag{28}$$

More exactly:

$$\mu\ (\omega) - E\left(\omega^T R \middle| \omega^T R \le q_\alpha\left(R^T \omega\right)\right) = \sum_{j=1}^{n} \omega_j \times \left[\mu_j - E\left(R_j \middle| \omega^T R \le q_\alpha\left(R^T \omega\right)\right)\right] \tag{29}$$

The shortfall is thus given by the weighted sum of the different asset classes' shortfall contributions. This implies that the Board can now fix a target shortfall and determine the portfolio weights and shortfall risk limits for the different asset classes. Shortfall can thus be used as risk budgeting tool. The total risk budget is fixed by the Board in terms of shortfall, then the different risk budgets can be determined for the different asset classes, making sure the sum of the risk budget equals the target risk budget.

The notion of shortfall beta is also very useful. The property that

$$\sum_{j=1}^{n} \omega_j \beta_{j,\alpha}(\omega) = 1 \tag{30}$$

is actually a direct result of the Euler property. As shortfall beta measures the marginal contribution to risk compared to total risk, it can be used as a performance attribution tool and integrated to portfolio optimization as we can relate estimates of alpha to marginal contributions to risk.

CONCLUSION

This paper develops a portfolio optimization framework that is consistent with recent evidence concerning investor behavior. The approach developed in the paper is also consistent with practice in the Asset management industry, namely the existence of benchmarks and risk management constraint. The shortfall measures discussed could in principle be calibrated for different degrees of loss aversion. The aggregation properties enable us to fix a target on the shortfall and then risk budget different asset positions. The existence of shortfall betas provides a tractable way to optimize the portfolio. Future research will focus on implementations and calibrations for investor behavior.

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DECISION SCIENCES INSTITUTE
Setting Bin Quantities for 2-Bin Kanban Systems

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ABSTRACT

The 2-bin inventory model has been well-known as a visual version of the basic (Q, r) model for inventory control. Visual control has been a hallmark of the JIT movement in industry toward simplification and transparency. The equal bin variation of the 2-bin idea, although prevalent in application, has not been thoroughly analyzed in the research literature. We provide a complete analysis of 2-bin Kanban and derive a simple closed form expression for the minimum total cost bin size subject to a specified customer service level, and extend it to the case of n-equal-bins, n>2.

KEYWORDS: Inventory management and coordination, Health care operations

INTRODUCTION: THE TRADITIONAL 2-BIN (Q, r) APPROACH

The scientific literature on inventory management typically describes 2-bin systems as a special case of the well-researched (*Q, r*) system; e.g., see Miltenburg and Wijngaard (1991) and the texts from leading authors such as Silver, Pyke, and Peterson (1998, p. 238, p. 363) and Starr (2004, pp. 533-534). Given an expected demand rate of *D* units/period, an order of quantity *Q* is placed whenever the inventory reaches the reorder point, *r*. As described by these (and other) authors, the 2-bin system is a "visual" version of (*Q, r*) with two bins: the first bin (called the working bin) of capacity *Q*, and the second bin (called the reserve bin) of capacity $r = DL + ss$, where *L* is the lead time until the order is received, and *ss* is the desired safety stock. We assume here throughout that safety stocks are computed in the conventional manner; i.e., given the distribution of demand during lead time, $F(\cdot)$, and a desired customer service level, *CSL*, we choose *ss* so that $F(DL + ss) \geq CSL$.

This control policy specifies that when the working bin is depleted, an order is issued to replace it and is expected to arrive *L* periods later. The quantity of the working bin is fixed, possibly set to the *EOQ* quantity; the reserve bin quantity is set to *r*, the estimated expected demand during lead time, *DL*, plus any planned safety stock, *ss*. When the replacement order is received, the reserve bin is to be filled (to level *r*) and the remaining received quantity is to be placed into the working bin. This approach has long been touted for its visual simplicity (e. g., see Brown, 1977, pp. 250-254; Welch, 1983).

This 2-bin approach is recommended only when lead time *L* is sufficiently short or *Q* is sufficiently large, i.e., only when $DL = r \leq Q$ holds. Otherwise, we cannot guarantee that the received quantity will replenish total inventory above the reorder point. As Silver et al. (1998) point out, a possible procedure then would be to reorder when the *inventory position* reaches level *r*. Here inventory position at time *t* is defined as on-hand inventory plus open orders minus

backorders as of time *t*. Although monitoring inventory position solves the problem, it introduces more complexity by requiring continuous monitoring of open replenishment orders, mitigating the desired visual simplicity. Thus, the recommendation typically has been to limit 2-bin systems when lead times are sufficiently short.

LITERATURE REVIEW: 2-BIN KANBAN

For decades, the so-called 2-bin inventory system has been a well-known replenishment system for high volume, low cost components in manufacturing (e.g., see Brown, 1977). More recently it has become popular in hospitals for controlling the inventory of disposable incidentals (see Landry and Beaulieu, 2013 for a historical perspective). It is also seen in the retail trade in the stocking of displays of items for sale. It is widely popular because it requires no sophisticated information system and no perpetual inventory record keeping, and is consistent with the fundamental principles of JIT: it is simple, functional, and visually intuitive.

Whereas the scientific literature describes 2-bin systems as having two unequal sized bins as specified above, there is a great deal of empirical evidence (case studies like Bélanger, Beaulieu, Landry, and Morales , 2018, and web sites, as listed below), that shows the prevalent simplification found in practice is to have both bins contain the same quantity. Such “2-equal-bin” systems have been commonly referred to as “2-bin Kanban” systems (Landry and Beaulieu, 2013; Moons, Waeyenbergh, and Pintelon, 2018). Evidence of the widespread adoption of this “2-equal-bin” interpretation in industry can be found in Oracle Corporation’s support literature for their worldwide MRP users (See Oracle ***MRP User's Guide*****,** Release 12.1.) Another industrial example is found in the case study by Childerhouse, Aitken, and Towill (2002) of a UK Lighting manufacturer. Their study examined how the subject company reorganized its logistics chains whereby high volume suppliers were managed via a 2-bin Kanban approach.

The growing attention given to logistics process improvements for hospitals is well documented (e.g., see Denton, B.T. (ed.), *Handbook of Healthcare Operations Management*, and Hall, R. (ed) *Handbook of Healthcare System Scheduling*). The popularity of the 2-bin Kanban approach in hospitals can be found in the health care trade literature (e.g., Kaczmarek, 2015) and verified at a number of web sites used by hospitals to train their medical staffs. Notable examples include:

1. “2 Bin Training Video” https://www.youtube.com/watch?v=WULe9bg31ps
2. “ Two Bin Supply System at St Clair Hospital" https://www.youtube.com/watch?v=yjSwwPF5BUU
3. “Inventory Management Solutions: 2-Bin Kanban - Cardinal Health” https://www.youtube.com/watch?v=bRgcMaTmHCU
4. “Kanban Training: What is the Two Bin Kanban?” https://www.youtube.com/watch?v=I3bURj1oM_k
5. “Martin Health System - Blue Bin Demand Flow Process” https://www.youtube.com/watch?v=A5Y_3NuN5Ng

In viewing these training videos, it becomes apparent that these hospitals have changed the traditional 2-bin (Q, r) approach by making the size of both bins equal. In a recent study by Rosales, Magazine, and Rao (2015), the authors describe how the 2-equal-bin approach is prevalent in hospitals where large numbers of medical supplies need to be efficiently (and simply) managed. Other case studies describing 2-bin Kanban implementations in hospitals

include Landry and Beaulieu (2010) and Landry, Beaulieu, Roy (2017) who describe a Canadian hospital's logistics improvements including an $850,000 2-bin Kanban system, Aguilar-Escobar, Bourque, and Godino-Gallego (2015) who describe operations improvements (including 2-bin Kanban) in a Seville hospital, and Persona, Battini, and Rafele (2008) who describe 2-bin Kanban application by two hospitals in Italy.

But Why Two Equal Bins?

In hospital settings, medical supplies are typically withdrawn from stock and reordered by medical technicians who are not necessarily trained in inventory management, making simple visual control systems appropriate. Implementing the aforementioned (Q, r) version of the 2-bin approach runs the risk that when a replenishment order is received, the reserve bin, due to worker error, is not replenished but rather all of the replenishment is assigned to the working bin. Replenishing the reserve bin to its full value might also be complicated by the need to count remaining quantities which introduces additional labor cost and also becomes a source of error. Such mistakes increase the risk of stocking out in the next cycle. The 2-equal-bin interpretation eliminates the need to refill the reserve bin each time a replacement is received. We simply continue using the bin in use until it empties. Here the order quantity and reorder point are identical, so when a delivery arrives, the container in which it arrives can automatically serve as the second bin. In a 2-equal-bin system the two parameters r and Q are the same; when the quantity on hand reaches level B (the bin quantity), an order for B units is placed. The equal-bin approach thus further simplifies implementation because there is now only a single parameter. Moreover, it facilitates first-in-first-out cycling of inventory (important in hospitals and whenever items are perishable).

As mentioned above, the 2-equal-bin approach is typically appropriate in both manufacturing and health care applications (hospitals) for managing the point-of-use (POU) inventory of supply items. In manufacturing, the point of use may be an individual work center; in a hospital, it would be an individual nursing unit. Typically, SKUs are held in a central storage facility and disbursed to the individual POUs by a material handling staff; or the SKUs may be supplied directly from an outside vendor as in the "stockless delivery" approach described by Rivard-Royer, Landry, and Beaulieu (2002). The material handler(s) tour the facility, visiting POUs, delivering replacement stock, and noting empty bins. Thus, once a bin becomes empty the total lead time to replenish it includes the time until it is first recognized (by the handler) as empty, plus the time for the handler to return to central storage, pick the SKU from stock, and finally deliver it to the POU. Modern applications of this model are now able to reduce this lead time through use of RFID technology (See Landry and Beaulieu, 2010, for detailed description of how this technology is being applied to complement 2-bin systems.)

MOTIVATION

All of the empirical evidence cited above confirms the wide usage of 2-equal-bin inventory control systems in practice. Yet the issue of how to set these (equal) bin sizes has been only seldom raised and never resolved. As Rosales et al. (2015) point out in their study of the hospital environment, the bin quantity for a given SKU was determined by applying a management-defined target level of inventory turns given estimated mean demand. Bin quantity determination was not in the scope of their investigation; but as they conclude, this would be an important issue for further research. Olson (2014) draws a similar conclusion in his study of the 2-bin Kanban implementation at the Walter Reed National Military Medical Center, where he concludes that an economic analysis similar to EOQ might be worthy of future research. The

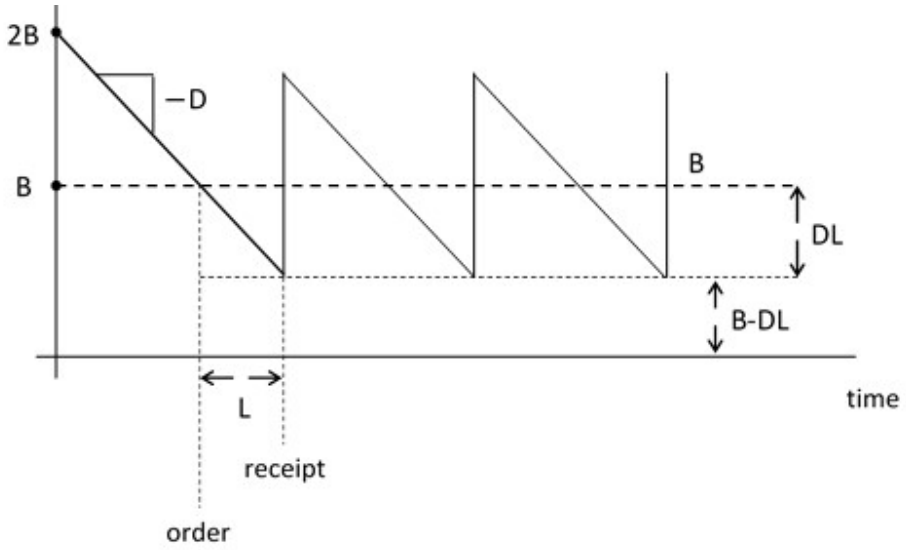
notion of setting bin quantities according to some target level of inventory turns is also reported by Miltenburg et al., (1991, p.118) as they write, "*The order quantity is an amount sufficient to satisfy x weeks of usage, where x is specified by management*." A possible alternative would be to set the order quantity to the familiar economic order quantity (*EOQ*). We show here that setting bin quantities in either of these ways is an unnecessary over-simplification and will lead to higher-than warranted total cost. We provide an analysis showing how the economic lot quantity concept can be applied when the order point and replenishment quantities are made identical to the bin quantity. The impact of efficient inventory management of disposable SKUs for hospitals is not trivial; they constitute as much as 17% of total expenses (Olson, 2014; Patrick, 2014), and it is not uncommon for hospitals to manage hundreds of such items and to distribute them to numerous nursing units across different departments (Rosales, Magazine, and Rao, 2015). Providing an understanding of the effect of bin sizes and a complete economic analysis is the motivation for this study.

The rest of this work is organized as follows. The next section develops the economic bin quantity for the 2-bin Kanban model comparing its total cost to the traditional (Q, r) 2-bin approach. As shown, the total cost of 2-bin Kanban is higher than that achieved with the traditional model. One can interpret this as the added cost for the improved simplicity and reduction of the risk for errors that it provides. The following section extends the analysis to the case of n bins, $n \geq 2$. Having more than two bins may often be more suitable when the item takes up excessive space and/or when the lead time is relatively long (i.e., when $L > B/D$). (Typically, shorter lead times occur when the source of supply is an internal central stockroom as opposed to an outside supplier.) Next we provide numerical examples illustrating how the various results can be applied, and a straight-forward procedure for management for determining bin quantities and number of bins when a visual equal bin approach is desired. The final section summarizes and identifies potentially fruitful further research.

THEORETICAL MODEL: THE ECONOMIC 2-BIN KANBAN MODEL

Figure 1 plots the average inventory behavior of a 2-bin Kanban system. As the figure shows, after an initial setting of *2B* units, inventory depletes at an expected rate *D* until inventory level *B* is reached at which time an order for *B* units is placed and expected to arrive *L* time units later.

Figure 1: Average Inventory Behavior under a 2-bin Kanban System



After this first cycle, the system converges to the steady state behavior whereby the expected value for minimum inventory is $MinI = B - DL$, and the expected value for the maximum inventory is $MaxI = B + B - DL = 2B - DL$, so that the mean inventory can be computed by

$$\text{Average Inventory} = \frac{MinI + MaxI}{2} = \frac{(3B - 2DL)}{2}.$$

Let *S* denote the fixed cost to replenish a bin, *c* be the unit cost, and *h* the periodic percent inventory holding cost. (S is assumed non-trivial. When the supplier is an outside vendor, transport and handling costs will be incurred; if replenishment comes from a storage facility, labor cost for replenishment workers is incurred.) Given these parameters, we can express the expected value of total relevant cost for the 2-equal-bin system, TC_2, as a function of *B*:

$$TC_2(B) = \frac{(3B - 2DL)}{2}ch + \frac{DS}{B}, \qquad (1)$$

where the first term on the rhs of (1) represents average periodic inventory holding cost (including holding the implicit safety stock of B-DL units) and the second term is the average periodic fixed replenishment costs. In addition, we have the constraint $B \geq DL + ss$ to assure that the appropriate customer service level (CSL) is met. Assuming normally distributed periodic demand with standard deviation σ, z_α is the point on the standard normal distribution such that $P\{Z > z_\alpha\} = \alpha$, and recalling that L is the lead time until delivery, yields $ss = z_{CSL}\sigma\sqrt{L}$. Thus, when $B > DL + ss$, the 2-bin Kanban approach affords the added stockout protection of $B - DL - z_{CSL}\sigma\sqrt{L}$ units of safety inventory. Note that the comparable expected total periodic cost for the (*Q, r*) model (including a safety stock of *ss*) is

$$TC_{Q,r}(Q) = \frac{Q}{2}ch + \frac{DS}{Q} + (ss)ch. \qquad (2)$$

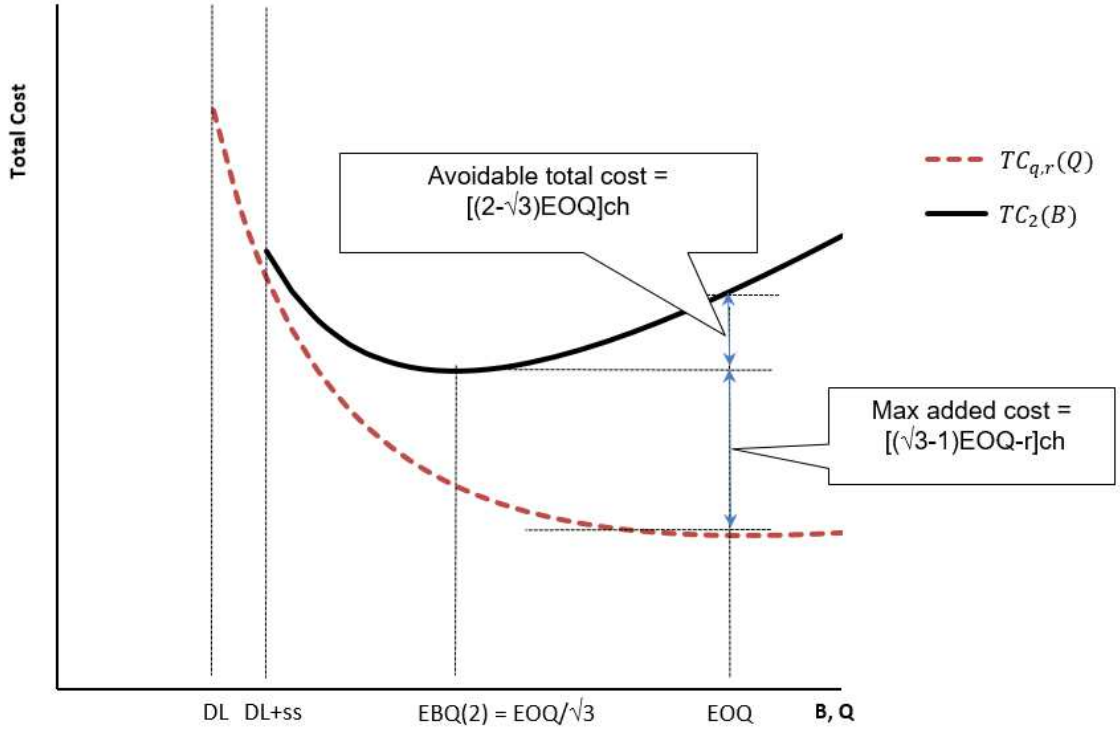
Taking the first derivative of (1) and setting it to zero yields the economic bin quantity for the 2-bin Kanban system, $EBQ(2)$:

$$EBQ(2) = \sqrt{\frac{2DS}{3ch}}. \quad (3)$$

Since $\frac{d^2TC_2}{dB^2} > 0$, $EBQ(2)$ is the value of *B* which minimizes average total relevant costs. Note this is $1/\sqrt{3} \approx 0.577$ as much as the traditional $EOQ = \sqrt{\frac{2DS}{ch}}$ derived by finding the value which minimizes $TC_{Q,r}$ in equation (2).

As shown in Figure 2, selecting the bin size to *EOQ* (and not *EBQ(2)*) can incur avoidable total cost, which is obviously parameter dependent. The conclusion here is that given that we are using a 2-bin Kanban system, then setting *B = EOQ* leads to avoidably excess total cost.

Figure 2: The Economic Bin Quantity (EBQ) Cost Model



The figure illustrates that the $TC_{Q,r}$ cost curve is only relevant for $Q \geq DL$ and that the TC_2 total cost curve is only relevant for $B \geq DL + ss$. Thus, because of the convexity of $TC_2(B)$, whenever $EBQ(2) < DL + ss$, the lowest cost choice for *B* is $DL + ss$. As a result, the appropriate specification for selecting the optimum bin size, *B*, is

$$B = \max\{EBQ(2), DL + ss\}. \quad (4)$$

Remark 1: If the objective is to minimize inventory (without regard for fixed costs to order) then we set $B = DL + ss$.

This would be appropriate in manufacturing when JIT is the goal and setup costs are minimal. Given the limited alternatives offered in the literature, a materials manager may easily be tempted to choose a bin size equal to the economic order quantity. See, for example, Rossetti, Buyurgan, and Pohl (2012, p.257). The next remark quantifies the economic implication of using $B = EOQ$ instead of $B = EBQ(2)$ as a bin size in a 2-bin system.

Remark 2: The avoidable total cost shown in Figure 2 can be computed by

$$TC_2(EOQ) - TC_2\big(EBQ(2)\big) = \left\{\frac{3ch}{2}\sqrt{\frac{2DS}{ch}} + DS\sqrt{\frac{ch}{2DS}} - DLch\right\} - \left\{\sqrt{6DSch} - DLch\right\}$$
$$= \big(2-\sqrt{3}\big)\sqrt{2DSch}$$
$$= (0.268)TC_{EOQ,DL}(EOQ), \qquad (5)$$

which may also be expressed as $(0.268)EOQ \cdot ch$. In equation (5) the value $\sqrt{2DSch}$ is equation (2) evaluated at $Q = EOQ$ with $ss = 0$. The implication here is clear: in deciding to use the visual 2-bin Kanban system, setting the bin quantity to the traditional *EOQ* leads to significant excess total cost (over 25% of the relevant total cost in the traditional EOQ model).

Remark 3: Assume that $EBQ(2) \geq DL + ss$. Then using the conventional 2-bin (Q, r) configuration with *EOQ* and a safety stock *ss* is always less costly than using a 2-equal-bin configuration.

This follows by noting that the 2-equal-bin configuration is the conventional 2-bin (Q, r) configuration with the constraint $Q = r$.

Remark 3 tells us that the total cost of inventory using a 2-bin Kanban system is always greater than using the conventional (Q, r) 2-bin model. The maximum cost difference is $TC_2 - TC_{Q,r} = \big[\big(\sqrt{3}-1\big)EOQ - r\big]ch > 0$. This assumes no operational errors (as described earlier). One can think of this as the added cost for system simplification and stock keeping error reduction.

EXTENDING TO n EQUAL BINS

The analysis provided above shows that it is not necessary to limit application of 2-equal-bin systems to cases when lead times are "short;" i.e., when $L < {}^{(EBQ(2)-ss)}/_{D}$. Rather than resorting to tracking inventory position, we can simply set $B = \max\{EBQ(2), DL + ss\}$ and continue having a fully visual system. But there is also another option, which will be shown in the section to follow to be economically optimal if $EOQ > (DL + ss)/\sqrt{2}$.
Rather than increasing B to at least $DL + ss$, we can maintain visual control (i.e., avoid tracking inventory position) by increasing the number of bins. It is equivalent to tracking inventory position because an empty (missing) bin represents an open replenishment order. Additionally, in many cases it may be more practical to set the bin quantity B based on efficient container quantity for transport. With more bins we can tolerate longer lead times and smaller bin sizes, but at the cost of more inventory.

Optimum Bin Quantity Given the Number of Bins

We can generalize the analysis for the 2-bin Kanban case to the case $n > 2$ to determine the optimum bin (container) quantity as follows. Note that an order will be placed every time a bin is emptied which is exactly the same moment that the inventory position reaches $(n-1)B$. Therefore, the expected value for minimum inventory is $MinI = (n-1)B - DL$, and the expected value for the maximum inventory is $MaxI = B + (n-1)B - DL = nB - DL$. The mean inventory can be computed by

$$\text{Average Inventory} = \frac{MinI + MaxI}{2} = \frac{((2n-1)B - 2DL)}{2}. \quad (6)$$

Thus total relevant cost is then

$$TC_n(B) = \frac{((2n-1)B - 2DL)}{2}ch + \frac{DS}{B}, \quad (7)$$

which upon setting the derivative with respect to *B* equal to zero yields the economic bin quantity given n:

$$EBQ(n) = \sqrt{\frac{2DS}{(2n-1)ch}} = \frac{EOQ}{\sqrt{(2n-1)}}. \quad (8)$$

A check of the second derivative will confirm that this is a global minimum for $TC_n(B)$ in (7).

Since every order is placed when the inventory position is at $(n-1)B$, it is necessary that $(n-1)B \geq DL + ss$ in order to meet the CSL. As a result, the appropriate specification for selecting the optimum bin size, *B*, is

$$B = max\left\{EBQ(n), \frac{DL + ss}{(n-1)}\right\}, n \geq 2. \quad (9)$$

In order to understand how to find the optimal number of bins and bin sizes for a given problem efficiently, it is first necessary to investigate the total cost functions given in expression (7) and their minima. The next theorem shows that if $B = EBQ(k)$ for some *k* (*i.e.*, $EBQ(k) > (DL + ss)/(k-1)$, implying that $EBQ(k)$ is feasible), then $B = EBQ(m)$ is feasible for all $m \geq k$.

Theorem 1: Assume that $EBQ(n) \geq \frac{(DL+ss)}{n-1}$. Then $EBQ(n+1) \geq \frac{(DL+ss)}{n}$.

Proof: The expression $EBQ(n) = \sqrt{\frac{2DS}{(2n-1)ch}}$ implies that

$$EBQ(n+1)\sqrt{\frac{2n+1}{2n-1}} = EBQ(n) \geq \frac{(DL + ss)}{n-1}$$

where the inequality holds by hypothesis. Multiplying this expression by $\frac{n-1}{n}$ yields

$$EBQ(n+1)\left(\frac{n-1}{n}\right)\sqrt{\frac{2n+1}{2n-1}} \geq \frac{(DL+ss)}{n}.$$

Since $\left(\frac{n-1}{n}\right)\sqrt{\frac{2n+1}{2n-1}} < 1$ for $n \geq 1$,

$$EBQ(n+1) > EBQ(n+1)\left(\frac{n-1}{n}\right)\sqrt{\frac{2n+1}{2n-1}} \geq \frac{(DL+ss)}{n},$$

as was to be shown.

Two immediate consequences of this theorem are given by the following corollaries. The first corollary uses the result in Theorem 1 to determine when $EBQ(n)$ is feasible for any number of bins, $n \geq 2$. The second corollary uses the result in Theorem 1 to show that if $EBQ(n)$ is feasible for some n, then the difference in the minimum total cost decreases monotonically to 0 as the number of bins increases.

Corollary 1: If $EBQ(2) \geq DL + ss$, then expression (9) reduces to

$$B = EBQ(n), \qquad n \geq 2, \tag{10}$$

that is, whenever $EBQ(2)$ is feasible, then so is $EBQ(n), n > 2$.

Corollary 2: If $EBQ(n) \geq \frac{DL+ss}{n-1}$, then

$$TC_{k+1}(EBQ(k+1)) - TC_k\big(EBQ(k)\big) = \left[\sqrt{2k+1} - \sqrt{2k-1}\right]TC_{EOQ,DL}(EOQ), k \geq n. \tag{11}$$

This shows that $TC_{k+1}(EBQ(k+1)) - TC_k\big(EBQ(k)\big)$ monotonically decreases to 0 in *k*.

According to expression (9), if $EBQ(n) < \frac{DL+ss}{n-1}$, then $B(n) = \frac{DL+ss}{n-1}$. Substituting this into $TC_n(B)$ yields

$$TC_n\left(\frac{DL+ss}{n-1}\right) = \frac{DLch}{(2n-2)} + \frac{(2n-1)}{(2n-2)}ch(ss) + \frac{(n-1)DS}{(DL+ss)}. \tag{12}$$

Equation (12) is useful in proving the following, which shows how to select an optimum number of bins in the case that $EBQ(k) < \frac{DL+ss}{k-1}, 1 \leq k \leq m$, for some *m*.

Theorem 2: $TC_{n+1}\left(\frac{DL+ss}{n}\right) > TC_n\left(\frac{DL+ss}{n-1}\right)$ if and only if $EOQ > \frac{DL+ss}{\sqrt{n(n-1)}}$.

Proof: $TC_{n+1}\left(\frac{DL+ss}{n}\right) - TC_n\left(\frac{DL+ss}{n-1}\right) > 0$ implies from (12) that

$$-\frac{ch(DL+ss)}{2n(n-1)} + \frac{DS}{(DL+ss)} > 0.$$

This can be rewritten as

$$\frac{2DS}{ch} > \frac{(DL+ss)^2}{n(n-1)}.$$

Taking the square root of both sides and recognizing the left hand side as the *EOQ* completes the proof. The proof of the converse is similar.

Noting that in Theorem 2, the sequence $\frac{1}{\sqrt{n(n-1)}}$ is monotonically decreasing in *n* leads to the following.

Corollary 3: If $EOQ > \frac{DL+ss}{\sqrt{n(n-1)}}$, then

$$TC_n\left(\frac{DL+ss}{n-1}\right) < TC_{n+1}\left(\frac{DL+ss}{n}\right) < TC_{n+2}\left(\frac{DL+ss}{n+1}\right) < \cdots.$$

We can now state our main result: there are only two candidates for n for the n-equal-bin quantity.

Theorem 3: The least cost equal-bin solution occurs at either $EBQ(2)$ or $\frac{DL+ss}{n-1}$ for some $n \geq 2$ which satisfies the condition of Corollary 3.

Proof: Theorem 1 implies that there is a smallest *n* for which $EBQ(n)$ is a feasible equal-bin solution, and thus partitions the set $\{EBQ(k), k \geq 2\}$ into the set of infeasible equal-bin values, $\Gamma = \{EBQ(k), 2 \leq k \leq n, n \geq 1\}$, which is null if $n = 1$, and the set of feasible equal-bin values, $\{EBQ(k), k \geq n+1, n \geq 1\}$. Because of the convexity of $TC_n(B)$ in equation (7), the optimum equal-bin values are $\frac{DL+ss}{k-1}$ for $2 \leq k \leq n$. By Corollary 2, $TC_n\big(EBQ(n)\big) < TC_k(EBQ(k))$ for $k > n$. Consequently, if $EBQ(2)$ is a feasible equal-bin value, then it is the least cost equal-bin solution. Thus if we can show that

$$TC_n\left(\frac{DL+ss}{n-1}\right) < TC_{n+1}\big(EBQ(n+1)\big), \tag{13}$$

for $n \geq 2$, then the theorem will follow.

Let N be the largest value of n such that $EBQ(N) \in \Gamma$, implying that $EBQ(N) \leq \frac{DL+ss}{N-1}$, and $EBQ(N+1) \geq \frac{DL+ss}{N}$. Upon substitution of the values of $EBQ(N)$ and $EBQ(N+1)$ from equation (8), these two constraints can be rewritten as

$$\frac{(2N+1)}{2N^2}\frac{(DL+ss)^2 ch}{D} \leq S \leq \frac{(2N-1)}{2(N-1)^2}\frac{(DL+ss)^2 ch}{D},$$

or more simply as

$$S = c_1 \frac{(DL+ss)^2 ch}{D}, \tag{14}$$

where

$$LL = \frac{(2N+1)}{2N^2} \leq c_1 \leq \frac{(2N-1)}{2(N-1)^2} = UB, \tag{15}$$

and LL (UL) indicates the lower (upper) bound. Define

$$f(N) = TC_N\left(\frac{DL+ss}{N-1}\right) - TC_{N+1}\big(EBQ(N+1)\big)$$

$$= \left(\frac{2N-1}{2N-2}\right)(DL+ss)ch + \frac{(N-1)DS}{(DL+ss)} - \sqrt{2(2N+1)DSch}, \tag{16}$$

Substituting S in equation (14) into (16) yields

$$f(N) = \left[\left(\frac{2N-1}{2N-2}\right) + c_1(N-1) - \sqrt{2(2N+1)}\sqrt{c_1}\right](DL+ss)ch, \tag{17}$$

so that the sign of $f(N)$ will be negative when

$$f(N) = \left[\left(\frac{2N-1}{2N-2}\right) + c_1(N-1) - \sqrt{2(2N+1)}\sqrt{c_1}\right] < 0, \tag{18}$$

or equivalently

$$f(N) = (N-1)^2c_1^2 - (2N+3)c_1 + \left(\frac{2N-1}{2N-2}\right)^2 < 0. \tag{19}$$

The zeros of $f(N)$ are real, distinct, and occur at

$$c_1 = \frac{2N+3}{2(N-1)^2} \pm \frac{\sqrt{4N+2}}{(N-1)^2}. \tag{20}$$

Some algebra shows that the lower zero, $c_1 = \frac{2N+3}{2(N-1)^2} - \frac{\sqrt{4N+2}}{(N-1)^2}$, is smaller than LL in expression (15) while the upper zero, $c_1 = \frac{2N+3}{2(N-1)^2} + \frac{\sqrt{4N+2}}{(N-1)^2}$, is greater than UL in expression (15). As a quadratic function of the artificial variable c_1, $f(N)$ achieves a minimum between the zeros in expression (20), and therefore $f(N) < 0$ for all $LL \leq c_1 \leq UL$. By Corollary 2,

$$TC_N\left(\frac{DL+ss}{N-1}\right) < TC_{N+1}\big(EBQ(N+1)\big) < TC_{N+2}\big(EBQ(N+2)\big) < \cdots,$$

and Theorem 3 follows. The next corollary shows how to determine the optimal number of bins when $EBQ(2)$ is not feasible.

Corollary 4: If $EBQ(2) < DL+ss$, then the optimum number of bins, n_{opt}, can be determined from Theorem 3 by

$$n_{opt} = \left\lceil \frac{1+\sqrt{1+4((DL+ss)/EOQ)^2}}{2} \right\rceil, \tag{21}$$

where $\lceil\cdot\rceil$ is the ceiling function.

Optimum Number of Bins Given the Bin Quantity

Whenever the bin quantity is predetermined, say B_0, the minimum number of containers, n_{min}, can be selected so as to minimize inventory (and therefore total cost) subject to assuring a desired level of customer service, CSL. Assuming that lead time demand follows a normal distribution, with mean *DL* and variance σ_L^2, the value of $n \geq 2$ can be easily determined by

$$n_{min} = \left\lceil \frac{DL + ss}{B_0} + 1 \right\rceil = \left\lceil \frac{DL + \mathrm{F}^{-1}(CSL)\sigma_L}{B_0} + 1 \right\rceil, \tag{22}$$

where $\mathrm{F}(\cdot)$ denotes the cumulative probability distribution for a standard normal distribution.

ILLUSTRATIVE EXAMPLES

In order to demonstrate the use of these results, consider a decision maker who wishes to use n-equal-bins to achieve a visual system. The mean daily demand is $D = 8$ units with a standard deviation of daily demand $\sigma_D = 3.12$ units, the lead time $L = 3$ days, and the CSL is to be at least 90%. The cost structure includes a unit cost of $c = 300$ dollars, an annual holding cost of $h = 12\%$ of the unit cost to hold a unit for a 365 day year, and a fixed order cost of $S = 3$ dollars.

The decision maker would first check to see if $EBQ(2) > DL + ss$. Since $EBQ(2) = 12.74$ and $DL + ss = 8(3) + 6.93 = 30.93$, $EBQ(2)$ is not a feasible 2-bin Kanban quantity, and so equation (21) can now be used to determine the optimum number of bins

$$n_{opt} = \left\lceil \frac{1 + \sqrt{1 + 4((DL + ss)/EOQ)^2}}{2} \right\rceil = \left\lceil \frac{1 + \sqrt{1 + 4\left(\frac{24 + 6.93}{12.74}\right)^2}}{2} \right\rceil = \lceil 1.988 \rceil = 2,$$

which yields the optimum bin size of $\frac{DL+ss}{1} = 30.93$.

Table 1 shown below contains relevant data supporting this decision for $2 \leq n \leq 7$.

Table 1: Example Computations for the n-Equal-Bins Problem

n	EBQ(n)	$(DL + ss)/(n-1)$	B	$(DL + ss)/\sqrt{n(n-1)}$	Annual Total Cost
2	12.74	30.93	30.93	21.87	2.734
3	9.87	15.46	15.46	12.63	3.308
4	8.34	10.31	10.31	8.93	4.179
5	7.35	7.73	7.73	6.92	4.949
6	6.65	6.19	6.65	5.65	5.638
7	6.12	5.15	6.12	4.77	6.267

We have already determined that $EBQ(2) < DL + ss$ as shown in the first row of this table where $n = 2$. Now noting that $EOQ = 20.06$, the smallest value of n for which Corollary 3 holds is $n = 2$. As can be seen, this is also where the annual cost is minimized.

To demonstrate the impact of lead time on the optimal number of bins given the same cost structure as described above, Table 2 shows the values of $(DL + ss)/\sqrt{n(n-1)}$ as lead time varies from 1 day to 15 days.

Table 2: Values of $(DL + ss)/\sqrt{n(n-1)}$ for Selected Lead Times

	n						
L	2	3	4	5	6	7	8
1	8.48	4.90	3.46	2.68	2.19	1.85	1.60
2	15.31	8.84	6.25	4.84	3.95	3.34	2.89
3	21.87	12.63	8.93	6.92	5.65	4.77	4.13
4	28.28	16.33	11.55	8.94	7.30	6.17	5.34
5	34.61	19.98	14.13	10.94	8.94	7.55	6.54
6	40.87	23.59	16.68	12.92	10.55	8.92	7.72
7	47.08	27.18	19.22	14.89	12.16	10.27	8.90
8	53.25	30.74	21.74	16.84	13.75	11.62	10.06
9	59.39	34.29	24.25	18.78	15.34	12.96	11.22
10	65.51	37.82	26.74	20.72	16.91	14.30	12.38
11	71.60	41.34	29.23	22.64	18.49	15.62	13.53
12	77.68	44.85	31.71	24.56	20.06	16.95	14.68
13	83.73	48.34	34.18	26.48	21.62	18.27	15.82
14	89.77	51.83	36.65	28.39	23.18	19.59	16.97
15	95.80	55.31	39.11	30.30	24.74	20.91	18.11

To determine the optimal number of bins for a given lead time, say $L = 6$, Theorems 2 and 3 along with Corollary 3 indicate that the decision maker should find the first value in the corresponding row that is smaller than $EOQ = 22.06$. For $L = 6$, this occurs in the column for $n = 4$. For each lead time, the optimal number of bins is indicated by the shaded selection.

To determine the optimal bin size, the result is $(DL + ss)/(n-1)$ for $n \geq 3$. In the special case of $n = 2$, it is also necessary to determine if $EBQ(2) > DL + ss$. If so, $EBQ(2)$ is the optimal quantity; otherwise $(DL + ss)/(n-1) = DL + ss$ is optimal.

Confirmation of the optimal number of bins is shown in Table 3 where the total cost of Equation (7) is computed for each combination of lead time and bin number. The minimum cost value for each lead time is once again indicated by the shaded selection. These are exactly the same selections made in Table 2.

Table 3: Total Annual Cost Behavior for Selected Lead Times

	n						
L	2	3	4	5	6	7	8
1	2.980	4.076	4.968	5.738	6.427	7.056	7.638
2	2.734	3.308	4.179	4.949	5.638	6.267	6.849
3	2.984	2.998	3.520	4.169	4.849	5.478	6.060
4	3.361	2.975	3.246	3.682	4.183	4.718	5.271
5	3.786	3.069	3.158	3.447	3.816	4.226	4.659
6	4.231	3.222	3.162	3.340	3.612	3.933	4.280
7	4.687	3.406	3.219	3.306	3.502	3.753	4.036
8	5.148	3.610	3.309	3.319	3.452	3.647	3.877
9	5.611	3.826	3.421	3.362	3.440	3.588	3.775
10	6.075	4.050	3.547	3.426	3.456	3.563	3.713
11	6.539	4.279	3.684	3.504	3.492	3.562	3.680
12	7.002	4.512	3.827	3.594	3.542	3.580	3.669
13	7.464	4.747	3.977	3.693	3.603	3.611	3.675
14	7.926	4.984	4.130	3.797	3.673	3.653	3.693
15	8.386	5.222	4.286	3.906	3.749	3.704	3.722

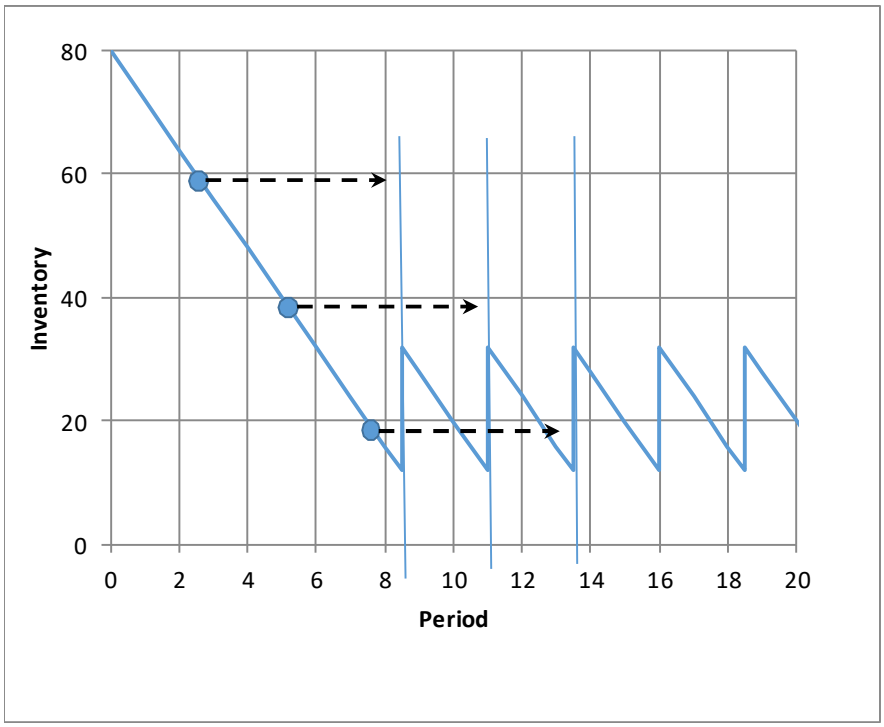
The choice of using n-bins instead of 2-bins will be the optimal economic choice if $EOQ > (DL + ss)/\sqrt{2(2-1)} = (DL + ss)/\sqrt{2}$; however, the inventory on hand will appear to be a 2-bin Kanban system to workers using a visual system, as described next.

In order to illustrate the expected inventory behavior of an n-equal-bin system, Figure 3 shows the expected inventory level over time for the 4-equal-bin system in the preceding example with $L = 6$. Beginning with inventory of four bins of 19.25 units, when the first bin empties at time $t = 2.5$ a replacement bin of 19.25 units is ordered arriving 6 periods later at time 8.5. Subsequent bins are emptied and reordered every 2.5 periods. The equilibrium average inventory is $\frac{((2n-1)B-2DL)}{2} = 22$ units. In general, the inventory level for an n-equal-bin system can be expressed using the floor function $\lfloor \cdot \rfloor$ as:

$$I(t) = nB - Dt + \max\left\{0, B\left\lfloor \frac{t-L}{\frac{B}{D}} \right\rfloor\right\} \tag{23}$$

Figure 3 also demonstrates that the inventory on hand will typically appear to be a 2-bin Kanban system to workers using a visual system. The unseen inventory position fluctuates between $(n-1)B$ and nB.

Figure 3: On Hand Inventory Behavior for a 4-Bin Visual System



DISCUSSION

It is frequently suggested that so-called "C items," often referred to as the "trivial many," represent the appropriate target class of items for applying a visual system approach for controlling inventory. C items are often described as those whose annual usage dollars (AUD) reside in the lowest quintile with respect to AUD for all stock keeping units (SKUs), yet often comprise up to 50% of the total number of SKUs. We would not recommend automatically designating a 2-bin Kanban approach for all C items or limiting the approach to only C items. The central assumptions validating the analytical results here are continuous, constant and stationary expected demand. Consistent with the recommendation of Bijvank and Vis (2017), our recommendation is to use the 2-bin method only for non-bulky multi-usage disposable supply items. For hospitals, this would exclude perishable items such as blood and medicines, and non-disposable items such as surgical instruments. Basic inventory management approaches for such cases can be found for example in Federgruen, Prastacos, and Zipkin (1986), Katsaliaki .and Brailsford (2007), and Prastacos (1984)

Finally, note that the typical recommendation for applying the 2-bin model (the Q,r version) has been to limit it to items with short lead times. We have shown here that this is not necessary; one can accommodate long lead times either by increasing the bin size or the number of bins.

Based on the results derived here, we provide a straight-forward procedure for determining bin quantities and number of bins when a visual equal bin system is desired. After calculating $EBQ(2)$ from Equation (3) or simply $EBQ(2) = .577EOQ$.

1. *If a 2-equal-bin system is desired, then set* $B = max\{EBQ(2), DL + ss\}$ *to achieve minimum total cost.*

2. *If a specific bin quantity* B_0 *is desired, then to achieve minimum total cost set* $n = \left\lceil \frac{DL+ss}{B_0} + 1 \right\rceil$.

3. *If a least cost n-equal-bin system is desired, then:*
   3.1 If $EBQ(2) \geq DL + ss$, *then*
   set $B = EBQ(2), n = 2.$
   3.2 If $EBQ(2) < DL + ss$, *then*
   set $n = \left\lceil \frac{1+\sqrt{1+4((DL+ss)/EOQ)^2}}{2} \right\rceil$ *and*
   set $B = \frac{DL+ss}{n-1}$.

It is advisable to periodically review all the firm's inventory items to see if those currently controlled via a 2-bin system should remain so and if the 2-bin approach should be applied to any new items.

FINAL REMARKS

In this paper we have examined the 2-bin Kanban model for inventory control, a special case of the well-known (Q, r) system with two bins. A total cost model was developed that includes holding and replenishment costs. The minimum total cost bin size/reorder point was derived subject to a specified customer service level to constrain backorder costs. An extension of the problem to the case of n-equal-bin, n > 2, was then provided. Somewhat surprisingly, it was shown that in the general n-equal-bin system that the optimum bin size can occur at only two possible values, which may be easily computed based on problem parameters. Simple conditions were then given that describe which of these two values is optimum, thus completely solving the general problem.

As we have shown, there is significant empirical evidence that the 2-bin Kanban model is widely used in hospitals as well as in industrial settings because it removes the chance of worker error in replenishing the reserve and working bins. In spite of this popularity in practice, the 2-equal-bin system has not been analyzed in the research literature, implying that this is a situation where practice has led research. This paper has provided the practice of inventory management a straightforward comprehensive approach on how to specify bin-based visual control systems.

Future Research

The 2-bin Kanban inventory control system has an interesting similarity to the familiar Kanban system for production control. Both systems make use of fixed batch transfer quantities. The major difference is that Kanban is a procedure for controlling production when we have a series of capacitated resources. An interesting and perhaps productive line of future research would be to apply an analogous economic approach (as described here for EBQ) for the production coordination problem addressed by Kanban systems.

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Single-Point Manufacturing Resilience: A Simulation Study and Initial Results

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ABSTRACT

There have been numerous studies related to supply chain multi-point network fluctuations in response to real or perceived demand shocks in the system. Starting with the classic work in the bullwhip phenomenon, it is well known that poor visibility of downstream demand can cause increasing fluctuations in orders upstream. Many researchers have followed this initial work with increasingly complex studies to determine optimal remediation strategies. There has also been considerable research related to improving a single manufacturing facility, one of the many points in a typical supply chain network. However, there is little work performed on determining the impact of demand shocks for a single facility. While there has been an attempt to determine optimal mitigation strategies for shifting bottlenecks, or for scheduling a bottleneck resource, there are no known studies that test the resiliency of a set of processes within a single operations facility, whether manufacturing or service. This paper uses a complex simulation approach to model various types of single point manufacturing facilities with different sets of typical operating attributes. The results indicate how quickly a manufacturing facility can return to steady state conditions after a one-time, limited duration, demand increase. Such infrequent shocks can be the result of marketing promotions, short-term pricing discounts, weather phenomenon, or even disruptions caused by terrorist attacks on another similar facility.

KEYWORDS: manufacturing, resilience, simulation, demand variability

INTRODUCTION

The main objective of this paper is to provide the foundation for understanding the effects of short-term demand shocks in a single-point manufacturing facility across a spectrum of operating attributes. While there have been numerous studies and articles related to supply chain networks with multiple points and the effect of fluctuations in response to real or perceived demand shocks in the system, there is little work done on such fluctuations within a single manufacturing facility. We note that in the classic work in the bullwhip phenomenon, sometimes called “system or industrial dynamics,” it is well known that poor visibility of downstream demand can cause increasing fluctuations in orders upstream. (See Forrester (2007) for a review of the past literature). Many researchers have followed this initial work with increasingly complex studies to determine optimal remediation strategies.

Considerable research exists that focuses on improving a single manufacturing facility. However, there is little work performed on determining the impact of demand shocks for a single facility. While there has been an attempt to determine optimal mitigation strategies for shifting bottlenecks, or for scheduling a bottleneck resource, there are no known studies that test the resiliency of a set of processes within a single operations facility, whether manufacturing or

service. This paper uses a complex simulation approach to model various types of single point manufacturing facilities with different sets of typical operating attributes.

We note that infrequent shocks can be the result of marketing promotions, short-term pricing discounts, weather phenomenon, or even disruptions caused by terrorist attacks on another similar facility.

The objective of this study is to lay the groundwork for future studies of increasing complexity in various types of settings, both manufacturing and services. In particular, this study examines the impact of single demand shocks on a single operating facility for short period, with various operating conditions tested. We look for the overall impact of the delays caused by the shock, as well as the length of time required for an operating system to recover.

In the manufacturing arena, short-term demand shocks on a factory due to weather related issues can cause spikes in demand, like for portable power generators immediately before and after major storms. Analogies in the service sector also exist. For example, the resilience of an emergency department of a hospital is of high interest and importance, since major events may cause long back-ups to providing needed treatments to injured or ill patients. Beyond the necessary use of triage to prioritize the incoming patients, there can be other remediation methods used to reduce the return to steady state operations, as well as initial design decisions that increase resilience. This initial study provides some insight into those design decisions.

LITERATURE REVIEW

There is much literature that focuses on the performance of manufacturing systems under different design parameters. Additionally, there is a good deal of literature that addresses supply chain network resilience. However, a major gap exists in the literature for resilience at single-point manufacturing facilities. In the following sections, a sample of the relevant literature is presented.

Resilience in the Supply Chain

The earliest work that can be attributed to the concept of supply chain resilience is Jay Forrester's work on Industrial Dynamics, later called System Dynamics. (See Forrester, J., 1961.) Forrester provides a detailed perspective on related work over the next fifty years in Forrester, 2007.

There have been number articles and studies that refer specifically to supply chain network resilience in recent years. Scholten & Schilder, 2015, for example, discuss the importance of collaboration for high performing and resilient supply chains. Supply chain readiness and recovery is further discussed by Chowdhury & Quaddus, 2016. Birkie,et. al, 2017, specifically address how to mitigate disruptions in the supply chain and the importance of resilience capabilities in mitigating disruptions. Their research indicates that supply chain complexity can be helpful in mitigating disruptions.

Process Design Attributes

Manufacturing systems with high flow dominance have been extensively analyzed from both an assembly line perspective, and batch production perspective, the latter sometimes called flow shops. Bitran, G. & Dasu, S.,1992, provide a comprehensive review of open queueing network models of manufacturing systems.

Hillier and Boling, 1967, developed analytic models for studying the performance of assembly lines when no setup times occurred during production. They considered lines composed of up to five sequential machines, using exponential service times and finite buffer capacity. They were the first to consider limited buffer capacity in these scenarios and showed that a “bowl phenomenon” existed for optimal assignment of service times to machines. They determined that optimal assignment of tasks should result in higher task times in the earlier and later machines in the line.

Smunt and Perkins, 1985, later showed that the improvements in output rate from using the bowl service time distribution degraded rapidly once task time variance was reduced to more realistic levels, and, thus, practically, balancing assembly lines was still the best approach in practice.

Considerable research followed on production processes that were in-between pure flow lines and random job shops. The intent of this research and practice was to reduce random flows found in job shops by grouping machines together in a quasi-assembly line, called cells. The intention is to allow the production of small batches of many products with reduced setup times. See Wemmerlov & Hyer,1989, for a survey of cellular manufacturing users in the U.S. Suresh and Meredith, 1994, provide a comprehensive understanding of cellular manufacturing systems and the use of remainder cells, which are machines that are left over from the cellular design.

In the random job shop area, Jackson, 1957, 1963, provided the first analytic approaches for studying dynamic job shop performance. A comprehensive review of queuing models analyzing job shop performance can be found in Bitran and Dasu,1992.

The implementation of cellular manufacturing results in process configurations that share design characteristics common to both flow shops and job shops. Garza and Smunt,1991, measured of flows between cells and illustrated the negative impact of variations from purely sequential flows on system performance. Monahan and Smunt, 1989, studied processes with nearly sequential routings under a variety of product-process characteristics. Smunt & Ghose, 2016, presented a way to measure flow dominance on a continuum from 0.0 to 1.0, which was not scale dependent. They illustrated comparative performance for a wide variety of process scenarios across the continuum of this flow dominance measure.

While these past studies have addressed either multi-point network resilience or single-point manufacturing performance, there is little discussion in the literature that focuses on how a single manufacturing facility may respond to short-term demand shocks. The research presented here provides some preliminary results for understanding single-point manufacturing resilience.

DEVELOPMENT OF THE MANUFACTURING MODEL AND EXPERIMENT

Manufacturing system performance has mainly investigated two extremes of flow dominance, i.e. the routes taken by a job through the factory for complete processing. Purely sequential routings and totally random routings are the extremes. With increasing use of automated manufacturing technology and cellular manufacturing, we see that it is now possible to realize many of the efficiencies of flow lines for the production of low-to- medium volume products. The result is a process design that has characteristics of both a flow shop and a job shop. We define our experimental characteristics in the next section.

Process Characteristics

Four characteristics of a manufacturing process are considered, including flow dominance (FD), operation time utilization (UTIL), setup time (SU), and job size (JS).
Flow dominance is defined as the proportion of jobs going from one machine to another. A high level of flow dominance characterizes flow lines - all jobs follow the same routing through the process. At the other extreme, job shops typically have low flow dominance since jobs may have many different routings. When flow dominance is low, it is more likely that short-term bottlenecks will occur since the routing is more random. We utilize a measure described in Smunt & Ghose, 2016, to specify flow dominance based upon entropy theory.

It is well-known that setup time influences system performance. High machine setup times tend to increase the severity of bottlenecks. Low setup times, resulting from faster changeovers, worker method improvements, or dedicated equipment to produce families with similar processing requirement (cellular manufacturing), results in the ability to economically produce a large variety of parts without the need for large finished-goods inventory.

Job sizes interact with setup times since lower job sizes require more setups, thus increasing total system utilization.

Finally, we use operation time utilization to vary the load on the process. When operation time utilization is lower, the impact of setup times and other disruptions should have less impact than when the operation time utilization is higher.

Demand Characteristics

Demand stability refers to the consistency of the overall load on the system. We model unstable demand by temporarily increasing the load, a situation we refer to as a demand shock. Demand shocks may be the result of marketing promotions, short-term pricing discounts, weather phenomenon, or even disruptions caused by terrorist attacks on another similar facility.
We are particularly interested in the system's ability to return to its steady state condition following a demand shock that causes an overload in capacity utilization. A short-term shock resulting in less than 100% utilization would produce a relatively quick change to another steady state level, and is, therefore, of less interest to us. Rather, we are concerned with the process attributes that effect long response times under short-term, high-load conditions.

In this experiment, we use two different levels of shocks – 133% of the normal demand level for two periods and 200% of the normal demand level for two periods.

Simulation Experiment – Design

A comprehensive factory simulation model was developed and coded in SIMSCRIPT. (More detailed information for the base simulation model design can be seen in Smunt an Ghose, 2016.) Using this model, we conducted an initial experiment to determine the impact of a demand shock and the resulting resilience of the manufacturing facility based upon the time for the mean flow time (MFT) of the production to return to steady state levels.

The experimental product-process factors and their levels are shown in Table 1. The experiment utilized a full factorial design and allowed demand to experience periodic shocks.

Ten (10) repetitions of each combination of factor levels each were tested for a total of 9,000 runs. To eliminate transient state effects, the simulation for each combination was initialized for 5,000 hours of simulated factory time. Following initialization, performance statistics were gathered for forty periods of 320 hours each, so that a time series of performance measures could be observed. Additional intervals between the batches were not utilized in this experiment because serial correlation is of interest in this setting. Since we want to test the ability of the system to return to steady-state conditions after the demand shock, it is important to track performance criteria as they first increase and then decrease.

In this experiment, we define utilization from three perspectives: 1) operation utilization - the percent of machine time spent producing units, 2) setup utilization - the percent of machine time that is nonproductive due to required changeovers between production of different product types, and 3) total utilization - operation utilization plus setup utilization. We set average operation utilization at 60% and 70%. Total utilization varied with job size and the setup time. (We verified that operation utilization of either 60% or 70% was a steady-state condition after 5,000 simulated hours.) At 60% operation utilization, the manufacturing process' total utilization ranged from 70% to 90% - typical values in practice and in prior research studies of job shops. These total utilization levels result in interesting and realistic conditions. For example, total utilization levels reaching into the high 90's percentages result in a near-explosive queueing condition, thus the system will exhibit increasing flow times that would not be acceptable in real world applications. Below a total utilization level of 70%, the system has a large capacity to take on additional demand input, so testing lower utilization levels is not needed or interesting. However, we did observe that at a 70% operation utilization, the total utilization reached 100% in some situations. Note that for every combination of factor levels tested, the operation utilization remains at either 60% or 70% for each work center.

Setup times are deterministic and are specified in terms of the setup ratio, which we define as the ratio of the desired setup time to a base setup time. Pilot experiments revealed that a base setup time of 3.0 hours yields reasonable levels of total utilization.

Each job requires six separate tasks for completion. Jobs are processed in shortest operation time priority, with no capacity limit on the WIP inventory that may develop ahead of each work center.

FACTOR	Level 1	Level 2	Level 3	Level 4	Level 5
FD (Flow Dominance)	0.00	0.23	0.50	0.76	1.00
SU (Setup Time)	0.25	0.50	0.75	-	-
UTIL (Operation Utilization)	60%	70%	-	-	-
JS (Job Size)	25	100	175	250	-
DS (Demand Shock)	1.33	2.00			

Table 1: Simulation Experiment Factor Levels

Example routings for the products produced on the simulated factory for the high and intermediate flow patterns can be seen in Smunt & Ghose, 2016.
In the high dominance case (FD = 1.00), each product type starts at work center 1 and ends at work center 6 after sequentially using each work center in between.

At the other extreme, the low flow dominance case (FD = 0.00) has twelve work centers. We originally set the routings so that each product type uses six of these work centers in random order. Each work center is used as the first, second, etc. task in the sequence. A work center is used only once for each product type.

The intermediate flow dominance levels are variations of the FD=1.00 case. Intermediate conditions may occur as firms move from a process layout to more automated manufacturing. It is unlikely that a firm will completely change its flows from a jumbled order to a pure flow shop in one step.

For any combination of factor levels, job arrival rates are adjusted so that operation utilization remains at either 60% or 70%.

RESULTS

Results of initial experiments that test a single-point manufacturing facility's resilience are discussed in this section. Demand is increased by either 1.33 or 2 times the steady-state demand for two periods, which effectively overloads the facility during this time.
Figure 1 shows the Mean Flow Time (MFT) longitudinal results for the five levels of flow dominance tests, from 0 to 1, where 0 represents a pure job shop (low flow dominance) and 1 represents a pure flow shop (high flow dominance). In these experiments, there was unlimited buffer capacity between the work centers and the average operation utilization (UTIL) is set at 60%. We can see that the systems with the most random flows, FD =0.00, the effect of a demand shock is most apparent when looking at the peak MFT. The ability of the systems to return to steady state, however, is the same for all FD levels.

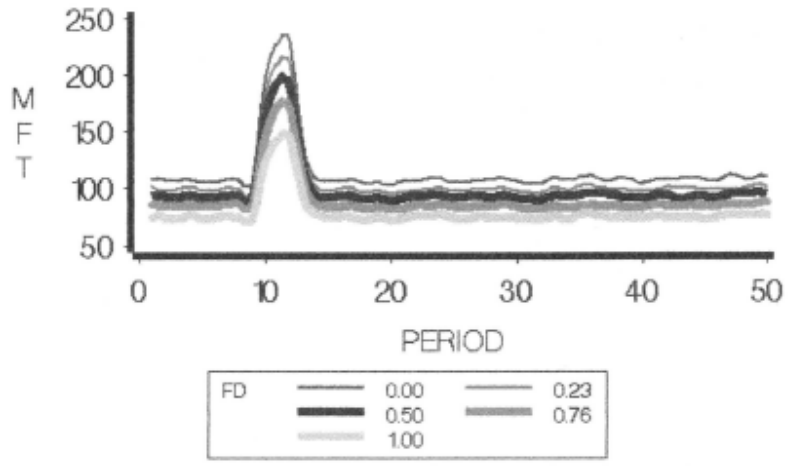

Figure 1: MFT Resilience – By Flow Dominance; DS = 1.33; UTIL = 60%

The longitudinal results for MFT in Figure 2 use the same parameters as in Figure 1, except that the demand shock (DS) is at the higher level of 2 times the average demand. The MFT peak is much higher with this increase surge level, and most FD levels experience approximately the same peak. It is also seen that the time to respond to steady state is longer with the higher surge level.

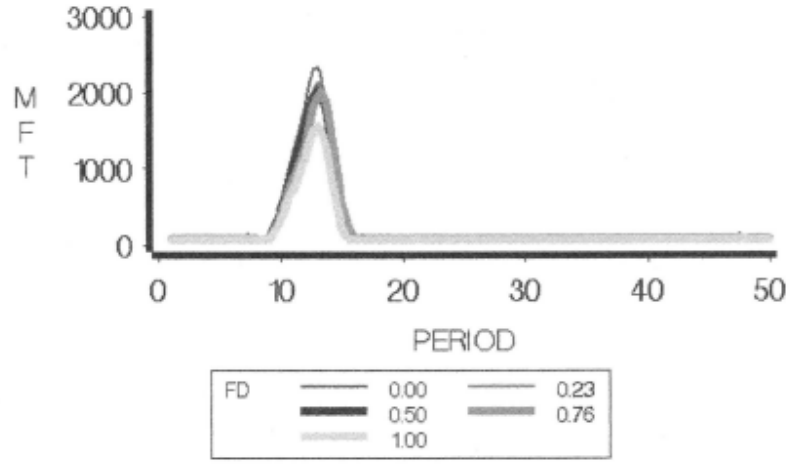

Figure 2: MFT Resilience – By Flow Dominance; DS = 2.00; UTIL = 60%

Figure 3 plots the MFT results over time for the lower levels of DS and UTIL. The impact of increasing setup times in the system is significant. Both steady state and peak MFTs are much larger as the setup times increase. The ability of the system to return to steady state levels with high setup times is less, thus high setup times reduce resiliency. The impact of flow dominance is also interesting to note since the peak MFTs are lower for higher flow dominance conditions.

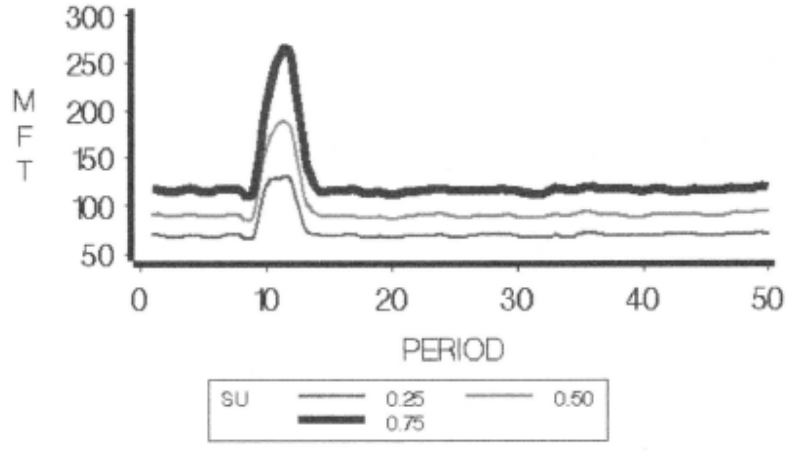

Figure 3: MFT Resilience – By Setup; DS = 1.33; UTIL = 60%

Figure 4 shows similar MFT results to Figure 3, except that DS = 2.00. The impact of increasing the short-term total utilization level results in greatly increased peak MFTs for all setup levels. Differences in peak MFT due to setup levels are now minimal, since it is the increased total utilization percentage caused by the higher demand shock dominates the systems' (non) resilience.

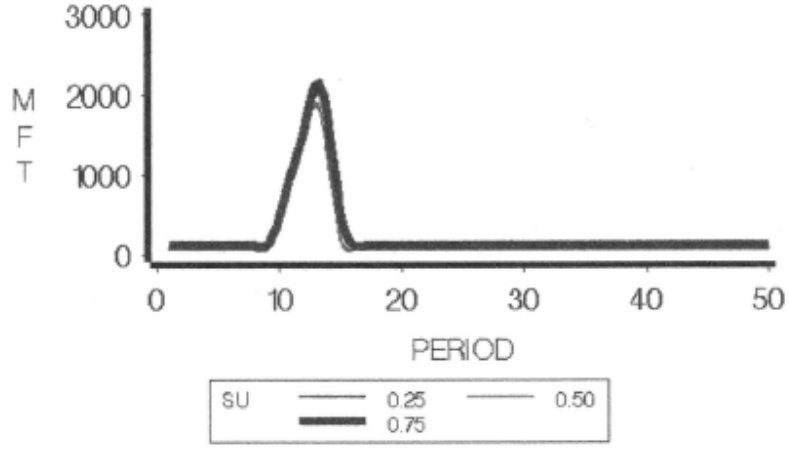

Figure 4: MFT Resilience – By Setup; DS = 2.00; UTIL = 60%

Figure 5 presents the MFT resilience perspective for various levels of job sizes. While it is true that both steady state and peak MFTs are larger as job size increases, there appears to be no relative negative impact on resilience to operating a system with higher job sizes. In fact, the marginal increase in MFT for the peak is lower for large job sizes than for low job sizes.

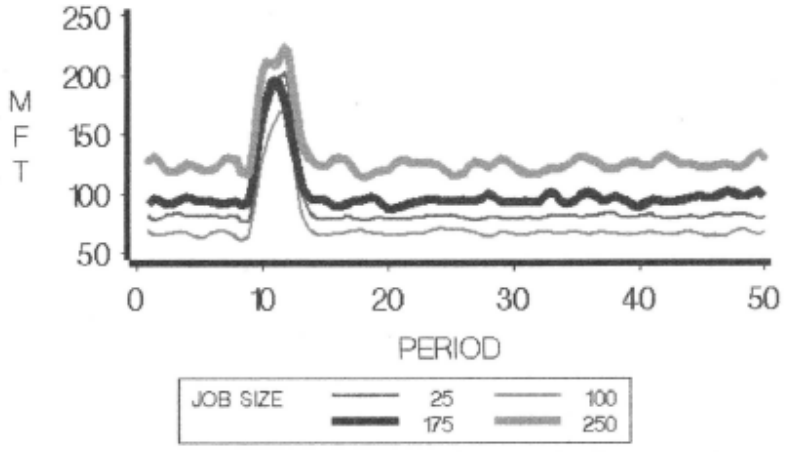

Figure 5: MFT Resilience – By Job Size; DS = 1.33; UTIL = 60%

When increasing DS to 2.00, the effect of job sizes is minimal. MFT peaks are much higher for all levels of job sizes.

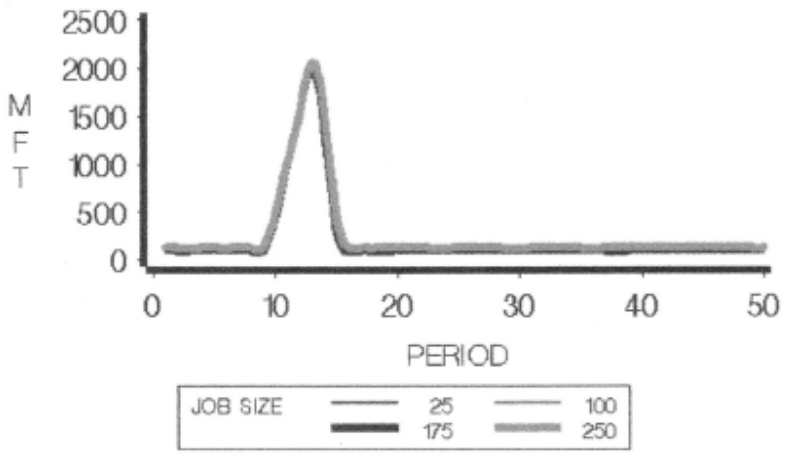

Figure 6: MFT Resilience – By Job Size; DS = 2.00; UTIL = 60%

Finally, in Figure 7, we look at the double impact of high levels of DS and UTIL across all levels of FD. What can be seen is that the systems essentially explode with the higher demand surge and overall operation utilization levels, and never return to steady state during the 50 periods of the simulation.

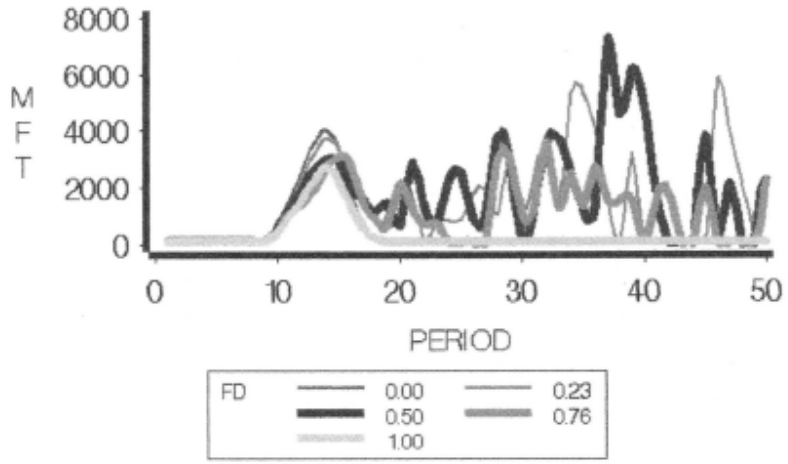

Figure 7: MFT Resilience – By Flow Dominance; DS = 2.00; UTIL = 70%

CONCLUSIONS AND FUTURE RESEARCH

A comprehensive simulation experiment was conducted to investigate factors that affect resilience of single-point manufacturing facilities. The results indicate how quickly a manufacturing facility can return to steady state conditions after a one-time, limited duration, demand surge and potential design factors to consider for adding resilience to systems.

While these results are mainly focused on manufacturing operations, especially due to the testing the impact of setup times in a batch manufacturing mode, similar experiments can be designed to determine resilience in service settings. Designing resilient emergency departments, for example, should be of great interested due to high likelihoods of external events that may cause huge surges in capacity needs.

Future research will encompass additional testing of operating conditions and various other structures of demand surges. One important design consideration is the amount of buffer inventory available within the manufacturing system. The study discussed here allowed unlimited buffer capacities, but modern production systems are moving towards very low levels of work-in-process inventory. It is likely that limited inventory buffers will exacerbate system resilience. Future experiments will also need to examine various levels of demand surges, as well as the length of time of such surges. Finally, modifications to provide ways to increase resilience will need to be tested, for example, the use of parallel processing capabilities or smart control systems.

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DECISION SCIENCES INSTITUTE
Smart Multitasking with Smartphones

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ABSTRACT

Research has shown that people use smartphones in a way that encourages constant multitasking. While previous studies have determined that multitasking with technology has a negative impact on performance of a primary task, we examine how constant task switching specifically with mobile devices affects users. Our experiment examines discretionary task interleaving with smartphones and the effects this has on performance. The results demonstrate that while any amount of multitasking negatively affects performance on a primary task, these effects are lessened when switching at a breakpoint between subtasks rather than during a subtask.

KEYWORDS: Multitasking; Smartphones; Breakpoints

INTRODUCTION

Multitasking can be categorized in two different ways: internal versus external. External interruptions cause someone to switch tasks due to an interruption in the environment (Miyata & Norman, 1986), such as receiving a text message. In contrast, internal interruptions, occur when someone is interrupted due to their own thought processes (Miyata & Norman, 1986), for example someone remembers to respond to an outstanding email. An internal interruption is "a self-initiated switch away from a task prior to its completion" (Jin & Dabbish, 2009). These are also referred to as "voluntary, discretionary task interleaving between independent tasks" (Payne, Duggan, & Neth, 2007). External interruptions and internal discretionary task switching occur at about the same frequency (Gonzalez & Mark, 2004).

People are constantly multitasking whether at work or at school. Employees switch tasks often, and experience internal and external interruptions at about the same rate (Czerwinski, Horvitz, & Wilhite, 2004; Gonzalez & Mark, 2004; Dabbish, Mark, & González, 2011). Dabbish et al. (2011) found that in the workplace the organizational environment, individual differences, and external interruptions explain self-interruptions. Studies focusing on multitasking with technology have also largely focused on students. Surveys of college students have found that multitasking with technology including emailing, texting, and social networking is widespread during classroom and study time (Jacobsen & Forste, 2011; Junco, 2012; Junco & Cotten, 2012). These results have also been supported through direct observation. Despite the presence of an observer, middle school, high school and college students were found to remain on task for an average of ten minutes total out of fifteen, and were on task without a break for an average of just 5.61 minutes at a time (Rosen, Carrier, & Cheever, 2013).

Recent studies have shown that the timing of external interruptions may have different effects on performance of the primary task depending on when the interruption occurs (Adamczyk & Bailey, 2004; Iqbal & Bailey, 2005; 2007; 2008). Some studies have tried to mitigate the negative impacts of interruptions by placing them at breakpoints (Iqbal & Bailey, 2008; Okoshi, Ramos, Nozaki, Nakazawa, Dey, & Tokuda, 2015a).

Although there has been recent research examining the effects and prevalence of multitasking with technology in general, fewer studies have specifically studied multitasking with mobile devices. However, people are using these devices and they are being used in a way that encourages multitasking behaviors (Oulasvirta, Tamminen, Roto, & Kuorelahti, 2005; Böhmer, Hecht, Schöning, Krüger, & Bauer, 2011; Oulasvirta, Rattenbury, Ma, & Raita, 2012). Multitasking on mobile devices has received some research attention in recent years (Ho & Intille, 2005; Okoshi, Ramos, Nozaki, Nakazawa, Dey, & Tokuda, 2015b; Okoshi et al., 2015a). Users download numerous apps on their smartphones and some are constantly interrupting users (Ho & Intille, 2005). Performance effects of multitasking on mobile devices may not be the same as computer-based multitasking. Adepu and Adler (2016) found that users performed the same task better on desktop computers than on smartphones, though they preferred their smartphones for that task. Larger screen sizes can enhance performance.

In addition to receiving interruptions which force a user to multitask, often people choose to multitask from one app to another. However, research in the area of discretionary multitasking has received less attention. Similarly, while computer-based multitasking has been studied, less research has focused on mobile-based multitasking and its performance implications. This research examines the timing and performance effects of discretionary task interleaving on smartphones.

LITERATURE REVIEW

Performance Effects of Multitasking

Hembrooke and Gay (2003) found that multitasking with laptops during a classroom lecture negatively impacted performance. A later study expanded on that concept and examined how multitasking with different technologies affected an assessment of a series of three typical lectures (Wood, Zivcakova, Gentile, Archer, De Pasquale, & Nosko, 2012). This study found that social based technologies, such as Facebook and instant message, had the most negative impact.

The negative effects of multitasking with some technologies may fluctuate with their popularity. For example, one study found instant messaging to be a popular form of multitasking which led to negative effects (Levine, Waite, & Bowman, 2007). Later studies performed after instant messaging was no longer popular did not find the same negative effects, but found multitasking with other forms of technology that were used more often, and for social purposes to be harmful. For example, surveys of college students have found that multitasking with Facebook or texting is negatively correlated with GPA (Jacobsen & Forste, 2011; Junco, 2012; Junco & Cotten, 2012). Similarly, another study found that students who texted or accessed Facebook at least once during the fifteen minutes they were observed were more likely to have a low GPA (Rosen et al., 2013).

Bowman et al. (2010) did not find that multitasking with technology negatively impacted the

performance of a primary task. However, they did find that multitasking increased the length of time to complete the task. These findings were contradicted by Adler and Benbunan-Fich (2012). Their study found that medium levels of multitasking helped participants finish a larger amount of the primary task, but that any amount of multitasking negatively impacted accuracy on the primary task. This may be due to the fact that in the study by Adler and Benbunan-Fich (2012) the primary task was timed, while the experiment performed by Bowman et al. (2010) was untimed.

A person's perception of task importance can also affect performance when multitasking (Coens, Reynvoet, & Clarebout, 2011). Participants in this study who were told that the secondary task was more important performed better on the secondary task than on the primary task. Participants who were told that both tasks were equally important performed better on the secondary task than participants who were told that the primary task was more important. Janssen et al. (2012) also found that people perform differently depending upon the priority of the tasks.

When Do People Multitask and its Performance Implications

Many studies that have examined when people multitask have not focused on discretionary multitasking, which involves task switches prompted by the user, but rather they focus on external interruptions (Dabbish et al., 2011). However, some experiments involving external interruptions can help predict when people are most likely to multitask when given a choice.

McFarlane (2002) compared four methods of interruption: immediate, negotiated, mediated, and scheduled. Participants in the immediate category received interruptions immediately when they occurred. Participants in the negotiated category were given control over when they would respond to the interruptions. Participants in the mediated category were interrupted at times of lower workload as judged by the application. Participants in the scheduled category received interruptions every 25 seconds. The negotiated category was the most successful category. Although the timing of the task switches was not recorded, the fact that it led to the best performance suggests that people waited for an opportune time to respond to interruptions.

Salvucci and Bogunovich (2010) determined that people tended to respond to interruptions at a moment of lower workload when given a choice. A time of lower workload is a point in the primary task when the participant would not need to remember any information about the primary task when returning after an interruption.

In one study where participants were allowed to multitask at their own discretion, people preferred to switch at subtask boundaries (Payne et al., 2007). Participants were presented with two similar tasks with hard and easy versions. People in this experiment preferred to switch tasks at the completion of a subtask.

Several experiments have been done to determine the most opportune time to interrupt people who are using technology. These studies have all demonstrated that interruptions at breakpoints are the least disruptive to the user by comparing the cost of disrupting participants at different points in a task (Adamczyk & Bailey, 2004; Iqbal & Bailey, 2005; 2008). These experiments have involved users completing a task on a computer, and being disrupted at predetermined best times (at breakpoints between subtasks), at predetermined worst times (during a subtask), and at random times.

Adamczyk and Bailey (2004) report that participants experienced more frustration and annoyance when the interruptions were at random and worst times. Participants also rated these disruptions as less respectful of their primary task than disruptions at best times. However, differences in resumption lag (the time between responding to the interruption and resumption of the primary task) were not significant. Iqbal and Bailey (2005) contradict the previous findings about resumption lag. In their experiment, resumption lag was significantly higher for random and worse cases than for best cases.

Iqbal and Bailey (2007) divide breakpoints into three categories: coarse, medium, and fine. For example, in a task involving document editing, “Fine may be switching paragraphs; medium may be switching documents; and coarse may be switching to an activity other than editing.” Iqbal and Bailey (2008) interrupted participants at coarse, medium, and fine breakpoints with interruptions related to the primary task and interruptions unrelated to the primary task. Participants reported preference for related material at fine and medium breakpoints and unrelated material at coarse breakpoints. They also reported that resumption lag differed based on the relevance of the interruption content. Furthermore, they found that scheduling notifications at breakpoints, rather than having them occur immediately, reduced frustration and reaction time.

Other research has found that the timing of an interruption can affect the length of time it takes to complete the interrupting task. Fischer et al. (2011) interrupted users using their phones in natural environments throughout a two week period and found that interrupting tasks take longer to acknowledge and complete when participants were interrupted at a random time rather than at the end of another task (such as after hanging up from a phone call). Their findings did contradict Iqbal and Bailey (2008) in that their participants did not give random interruptions a worse rating than interruptions at the end of another task.

How Mobile Devices are Used

Several studies have demonstrated that people use mobile devices in a way that is habit forming and facilitates multitasking. When navigating typical urban environments, people pay attention to their mobile devices in short bursts of four to eight seconds (Oulasvirta et al., 2005). Smartphone use throughout the day is more spread out, with one study finding participants spending an average of 59.23 minutes on their mobile devices per day and each session lasted an average of 71.56 seconds (Böhmer et al., 2011).

Smartphones are also used for a longer portion of the day than laptops. Oulasvirta et al. (2012) found that people use smartphones for an average of 160 minutes per day as opposed to 87 minutes per day on a laptop. They also found that unlike laptops, smartphone usage is habit forming. This study looked for smartphone usage sessions that qualify as Short Duration and Reward Based (SIRB). This is defined as a session that is less than 30 seconds in duration that provides some emotional reward. Smartphone sessions were found to be significantly more likely to qualify as SIRB than laptop sessions, which lead to habit forming behaviors. Oulasvirta et al. (2012) suggest that this is because smartphones are more readily available than laptops. They found several characteristics of habitual smartphone use. These habits increase the overall time spent using smartphones because they lead to other smartphone based activities.

More people are now becoming distracted with their smartphones. This can occur in many situations, such as in the classroom (Bradstreet Grinols & Rajesh, 2014). With interruptions from phones becoming normal occurrences, designers need to think about ways to manage these

interruptions (Tolmie, Crabtree, Rodden, & Benford, 2008). Böhmer et al. (2014) found that a multiplex design, where people can be alerted to a call through a small partial-screen notification while working on their primary task worked best. Nagata (2003) found that anticipated interruptions led to better performance in web-based tasks, particularly on a mobile device.

Many websites that were once used solely on computers now have mobile versions or apps. Kalkbrenner and McCampbell (2011) conducted a survey comparing smartphone use vs. standard phone use and found that 88% of respondents felt that smartphones led to an increase in their productivity compared with 42.8% of regular phone owners. Having many apps on one's phone increases people's multitasking. As computers became faster, cheaper, and more powerful, user multitasking occurred more frequently. Similarly, smartphones are become more commonplace and people can open multiple apps simultaneously and task switch.

While multitasking can occur between smartphones and other media and multitasking is prevalent with smartphones when driving (Liu, Cao, Tang, He, & Wen, 2017), we concentrate exclusively on multitasking on mobile devices from one smartphone-based app to another in order to a) compare the results to computer-based multitasking and b) understand more about the ways in which people multitasking on a mobile devices and its effects on performance.

HYPOTHESES

When given a choice about when to respond to an interruption, people tend to choose a time in between subtasks when they will not need to remember information about the primary task (Salvucci & Bogunovich, 2010). People also experience frustration when forced to task switch during a subtask instead of in between subtasks (Adamczyk & Bailey, 2004). People perform better with negotiated interruptions (McFarlane, 2002). If given a choice, people will prefer to switch tasks at a time that is more convenient, such as during a breakpoint rather than during a subtask. Therefore, we hypothesize:

H1: People will have more task switches at breaks between subtasks than during subtasks on mobile devices.

Multitasking has been demonstrated in various studies to negatively impact performance on a primary task. Some studies have found a negative correlation between GPA and multitasking in class or while completing school work (Jacobsen & Forste, 2011; Junco, 2012; Junco & Cotten, 2012; Rosen et al., 2013). Other studies have found that multitasking has a direct impact on performance of the primary task (Hembrooke & Gay, 2003; Adler & Benbunan-Fich, 2012; Wood et al., 2012). Although these studies have not specifically focused on the effects of multitasking with mobile devices, other studies have shown that smartphones are used in a way that specifically encourages multitasking habits and behaviors (Oulasvirta et al., 2005; Böhmer et al., 2011; Oulasvirta et al., 2012). Therefore, we predict:

H2: People who multitask with mobile devices will have worse performance on the primary task than those who do not multitask.

As mentioned above, task switches negatively impact performance on a primary task. This impact can be affected by several factors, including the timing of the task switch. While using technology, interruptions during a subtask can be more detrimental than interruptions in between subtasks (Adamczyk & Bailey, 2004; Iqbal & Bailey, 2005; 2008). When people are

interrupted at a subtask, they experience less frustration (Adamczyk & Bailey, 2004) and less time lag when returning to the primary task (Iqbal & Bailey, 2005). Similarly, with discretionary task interleaving there can be better and worse times to choose to interrupt oneself. Therefore, we propose:

H3: Task switches during a subtask on a mobile device will negatively affect performance on the primary task more than task switches in between subtasks.

MATERIALS AND METHODS

In order to examine when people task switch and its effects, we created a primary task and secondary task that participants were able to choose to switch to.

Primary Task

For the primary task we created an app-based math puzzle called Math Squares. The puzzle consisted of a grid of three rows and three columns of the numbers that formed equations using addition and subtraction. Each of the numbers one through nine was used in the grid exactly once. At the start of the puzzle, the answers to each of the equations were displayed at the end of each row and column. The goal of the task was to fill in the numbers on the grid to create accurate equations. Three numbers were displayed by default to help participants get started. See Figure 1 for a screenshot of the Math Squares puzzle.

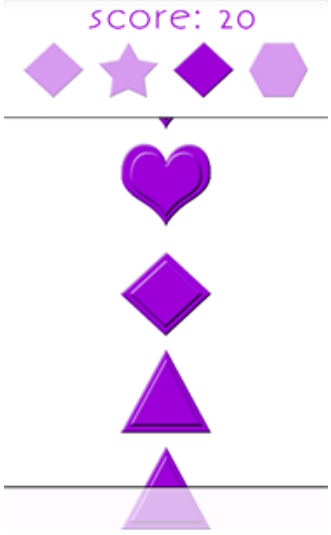
The Math Squares puzzle was designed as the primary task for several reasons. The puzzle requires concentration to find the correct answer, but only involves basic skills like addition and subtraction. Multiple puzzles could be completed in the ten minute time limit so that participants would be able to task switch both in the middle of completing a puzzle and in between puzzles.

Figure 1: Screenshot of Math Squares Puzzle

Secondary Task

For the secondary task, we created an app-based game called Match-It. At the top of the phone screen, four shapes were displayed in a row. Other shapes scrolled down the middle of the screen. The goal of the game is to tap the scrolling shapes in the order of the pattern at the top of the screen. See Figure 2 for a screenshot of the Match-It game.

Figure 2: Screenshot of the Match-It game



The Math Squares puzzle was designed as the primary task since it requires concentration to find the correct answer similar to performing some kind of homework related task. The Match-It game was designed as the secondary task because of its similarity to popular games available in the Google Play store that can be played quickly. Our goal was to mimic the user who is working on something, such as homework, but switches to play a game as is common nowadays.

Participants

Participants were recruited through Amazon's Mechanical Turk, an online platform that allows task creators (known as requesters) to pay workers to complete online tasks known as Human Intelligence Tasks (HITs). Requesters are able to hire a large number of workers from around the world for relatively low pay. This allows researchers using Mechanical Turk to inexpensively recruit more participants from a diverse pool of candidates (Horton, Rand, & Zeckhauser, 2011; Berinsky, Huber, & Lenz, 2012; Mason & Suri, 2012). Research has shown that although workers are paid small amounts of money for doing short tasks, they are often intrinsically motivated and complete the HITs for personal enjoyment (Buhrmester, Kwang, & Gosling, 2011). The reliability of research using Mechanical Turk has been found to be on par with research conducted using traditional methods. In fact, Mechanical Turk participants performed better on online attention checks in three different studies when compared with an undergraduate subject pool of students (Hauser & Schwarz, 2015). Studies can also be done using a wider and more diverse pool of candidates than recruitment on college campuses (Buhrmester et al., 2011; Horton et al., 2011; Berinsky et al., 2012; Mason & Suri, 2012). For

better accuracy of results, the requester can also specify qualifications for completing a HIT, such as the number of HITs a worker has previously completed, and their prior approval rating. Requesters can choose to reject a HIT and not pay the worker if the HIT was not completed accurately (Mason & Suri, 2012).

For this study, a HIT was created on Mechanical Turk. $1.00 payment was given for approximately twenty to twenty-five minutes of work on the experiment. To incentivize accurate results, the person with the highest score was given an additional reward of $5.00. Participants were given forty minutes to complete the HIT so that they would not feel rushed. In order to ensure that our participants would take the tasks seriously, workers had to have previously completed at least 500 HITS at 95% approval rate by the previous requesters. Because the directions were written in English, participation was also restricted to English speaking countries.

After accepting a consent form, participants were given a link to access the experiment via an Android phone. After installing the app and beginning, participants were given a questionnaire regarding their demographic information. Participants were then presented with tutorials for the primary and secondary tasks. Both tutorials included written instructions for how to complete the task as well as two minutes of practice time for each of the tasks.

After the tutorials, instructions were provided to explain the rules of the experiment. The directions were as follows:

1) You will be given ten minutes to complete the math puzzle as many times as you can.
2) After you submit each completed puzzle, a new puzzle will appear. You will not find out your score until the end of the experiment.
3) Your goal is to complete as many puzzles as you can accurately. The participant with the highest number of complete wins will receive an additional $5.00.
4) You may switch to the Match-It game at any time. You can play the Match-It game as often as you want.
5) Please do not use a calculator.
6) Please do not close this app, or engage in any other activities during the ten minutes. If you receive a phone call, please do not answer it. If this app is closed, you will not be able to continue with the experiment, and you will not be paid.

In the experiment itself, participants had ten minutes to complete a primary task and were given the opportunity to switch to a secondary task at any time. Once the experiment was completed, participants were given a post-questionnaire regarding their performance during the experiment.

One hundred and eighty three participants completed the experiment. Two participants were not able to complete the experiment due to technical difficulties with their phones and had to be removed. One additional participant was removed who had 53 switches. We chose to remove this participant, since the range of switches for all other participants was between 0 and 13, and 53 was way above the average and not representative of typical participants but an outlier. The data of the remaining 180 participants (108 male and 72 female) was analyzed.

Since the experiment was through Mechanical Turk and therefore remote (we could not see the participants), a few safeguards were put in place to ensure that participants were not switching to other apps on their phone and were completing the experiment with full concentration and commitment:

1) The app was designed so that if the participant attempted to navigate away from the app

on their phone, they were prompted to abandon the experiment or to continue. After abandoning the experiment, the app was made inaccessible.
2) The post-experiment questionnaire asked participants if they had used a calculator, left the experiment at any time and asked them to self-rate their effort on a scale of one to five. The directions in the questionnaire ensured participants that they would be paid regardless of their answers.

No participant reported using a calculator. Four participants (2%) reported leaving the experiment at some time, and six participants (3%) rated their effort as a one (from a scale from 1 – 5), which we felt indicated they did not put in much effort to try and complete the task with the best results possible. We considered removing these 10 participants, but removing them from the results did not change the significance of the analysis so we left them in.

We also allowed users to leave comments, many of which indicated that they enjoyed the experiment and put effort into completing it. Some comments include: “It was awesome playing the puzzle”, “I wanted to do as best I could on the math game so I could win the bonus.”, “Nice game. Hope you release it for Android.”, and “good hit..brain heating”.

Pre- and Post-Questionnaires

Participants were given a pre- and post-questionnaire on their smartphone before and after the experiment. Since the experiment as well as the questionnaires was completed on a smartphone we asked mostly closed-ended questions with choices to limit the amount of typing on the phone that would be necessary.

In the pre-questionnaire, participants were asked questions related to their frequency of game use and multitasking patterns on phones. In the post-questionnaire they were asked the questions described previously on their effort, whether they used a calculator, and left the experiment at any point.

Experiment

For ten minutes, participants played the Math Squares puzzle as many times as possible. Underneath the puzzle there was a button to submit a puzzle and receive a new one, a button allowing the participant to switch to the Match-It game, and a timer showing the remaining time. Each Math Squares session had to take a minimum of thirty seconds to keep participants from randomly filling in the grid and submitting. If the user attempted to close the app by clicking on the home or recent apps buttons, a popup would appear asking the user to confirm their desire to abandon the experiment. This was done to prevent people from using other applications on their phones instead of participating in the experiment. Participants could switch to the Match-It game at any time. During the Match-It game, the timer was stopped to ensure that everyone would spend ten minutes playing the Math Squares puzzle in order for performance to be compared accurately.

Measures

During the experiment the following data were captured:

1) *Complete Wins*: The number of Math Squares puzzles completed correctly, with all six numbers filled in accurately.

2) *Total Switches*: The number of times that the user switched from the Math Squares puzzle to the Match-It game.
3) *Between Switches*: The number of times the user switched to the Match-It game in between finishing one Math Squares puzzle and starting the next puzzle.
4) *During Switches*: The number of times the user switched to the Match-It game after starting a Math Squares puzzle but before submitting the puzzle.
5) *Average Score per Match-It Game*: Participants were given one point each time they tapped the correct shape. The total number of points was recorded and averaged together.
6) *Average Seconds per Match-It Game*: The total number of seconds played for each Match-It game was recorded and averaged at the end.

RESULTS

Participants

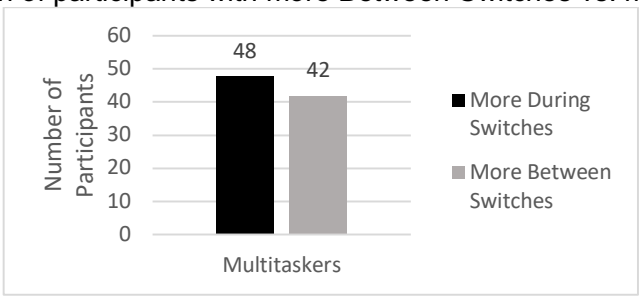
The 180 participants' data was analyzed for demographic information. In regards to ethnicity: 111 (61.67%) were Caucasian, 38 (21.11%) were Asian/Pacific Islander, 14 (7.78%) were Hispanic/Latino, 13 (7.22%) were Black/African American, 3 (1.67%) were Middle Eastern, and 1 (0.56%) identified as "other". The breakdown of age is as follows: 106 (58.89%) were 18-30, 54 (30%) were 31-40, 15 (8.33%) were 41-50, 2 (1.11%) were 51-60, and 3 (1.67%) were 61 or older.

Of the 180 participants, 78 (43.33%) of the participants were monotaskers, participants who did not switch during the experiment, while 102 (56.67%) were multitaskers, participants with at least one switch. The number of switches among multitaskers ranged from one to thirteen with a mean of 2.9. Of the multitaskers, 32 (31.37%) switched only one time while the remaining 70 participants (68.63%) had two or more switches. Participants completed an average of 5.8 Math Squares puzzles, and had an average of 3.07 Complete Wins. Participants spent an average time of 16.43 seconds on each Match-It game and 119.17 seconds on each Math Squares puzzle.

Test of Hypothesis 1

In order to determine whether participants would choose to task switch more frequently at breakpoints between subtasks rather than during a task, we compared Between Switches and During Switches for the 102 multitaskers. 42 participants had more Between Switches than During Switches, and 48 had more During Switches than Between Switches (see Figure 3). There were 12 participants who had an equal number of Between Switches and During Switches. A sign test shows that there were no significant differences between the number of Between and During Switches for participants ($z=0.63$, $p=0.53$), therefore H1 is not supported.

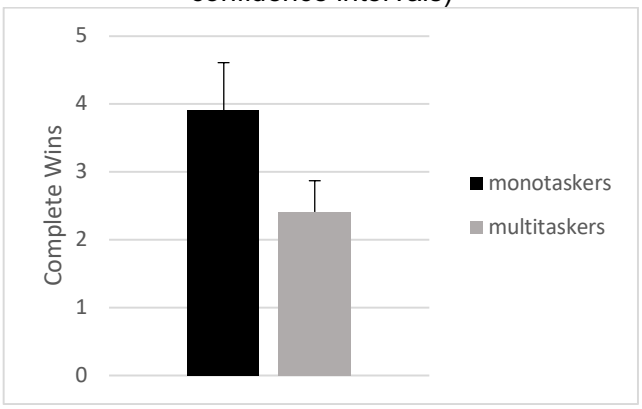
Figure 3: Comparison of participants with more Between Switches vs. more During Switches



Test of Hypothesis 2

To determine whether participants who multitask on mobile devices have lower performance on the primary task than those who do not multitask, we compared the performance on the Math Squares puzzle for multitaskers (102 participants who had at least one switch) and monotaskers (78 participants who had zero switches). The measurements used to gauge performance on the Math Squares puzzle (the primary task) was Complete Wins. The range of Complete Wins was zero to twelve, and the overall mean of Complete Wins was 3.067. As shown in Figure 4, there was a significant difference in the performance for monotaskers (M=3.92) over multitaskers (M=2.41), t(178)=3.79, p=0.0002. These results suggest that switches in general may negatively impact performance of a primary task.

Figure 4: Comparison of Complete Wins for monotaskers and multitaskers (error bars = 95% confidence intervals)



Furthermore, results of a Pearson correlation indicate that there is a significant and negative association between Total Switches and Complete Wins (ρ=-0.22, p=0.003). These results suggest that there is a negative relationship between people switching away from the primary task and their performance. Therefore, H2 was supported.

In addition to analyzing the effect of Total Switches on performance of the primary task, we also examined the amount of time spent on the Match-It game. A correlation shows a negative relationship between the average time spent playing the Match-It game and Complete Wins

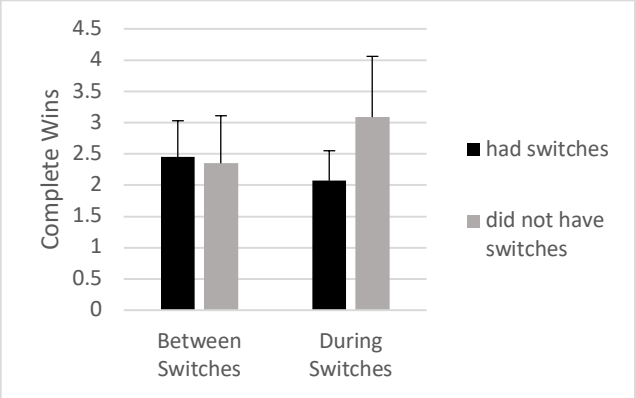
(ρ=-0.17, p=0.019). Even though the timer on the primary task was stopped and all participants spent the same ten minutes working on the primary task, the more time away from the task the lower the users performance. This suggests that the number of switches is not the only factor affecting performance on the primary task. The amount of time spent away from the primary task before returning may also impact the results.

Test of Hypothesis 3

To analyze whether task switches during a subtask negatively affect performance on the primary task more than task switches between subtasks, we examined the data for multitaskers (N=102) and explored the performance effects of During Switches and Between Switches.

For all multitaskers, a t-test showed that participants who had During Switches had significantly fewer Complete Wins than participants who had no During Switches, t(100)=2.13, p=0.036. However, performance for participants who had Between Switches was not significantly different from participants who did not have Between Switches, t(100)=-0.20, p=0.843, see Figure 5. Therefore, H3 was supported.

Figure 5: Performance differences between participants who had and did not have During Switches and participants who had and did not have Between Switches (error bars = 95% confidence intervals)



For multitaskers, we also computed a correlation comparing Complete Wins with During Switches and Between Switches. There is a significant negative relationship between Complete Wins and During Switches (ρ =-0.22, p=0.027), but no significant relationship between Complete Wins and Between Switches (ρ=0.06, p=0.545). These results suggest that switches during a subtask negatively affect performance on a primary task, while switches in between subtasks do not have a significant negative effect.

We also examined the difference in performance among those who had only Between Switches, only During Switches, both During and Between Switches, and no switches at all (Table 1). An ANOVA shows that there is no significant difference between those with no switches and those with only Between Switches (F(1, 110)=1.88, p=0.1728), but there is a significant difference between those with no switches and those with During Switches (F(1, 113)=7.80, p=0.0061). Furthermore, while there is no significant difference between those with only During Switches and those with both During Switches and Between Switches (F(1, 66)=1.63, p=0.2068), there is a significant difference between those with Between Switches and both During and Between

(F(1, 63)=5.77, p=0.0192). This suggests that the harmful effect of task switching is worse when those switches are During Switches, rather than Between Switches.

Table 1: Complete Wins and Switches

Complete Wins	**N**	**Switches**
3.92	78	No Switches
3.09	34	Only Between Switches
2.35	37	Only During Switches
1.74	31	Both During and Between Switches

DISCUSSION

In this experiment, there were no significant differences between the number of people who had more During Switches and the number of people who had more Between Switches. This seems to contradict previous studies that have determined that people prefer to task switch at breakpoints (Payne et al., 2007) and that when given a choice about when to respond to an interruption, people prefer to wait for a break between subtasks (Salvucci & Bogunovich, 2010). Similarly, Katidioti et al. (2014) found that participants preferred to switch at a moment of lower workload even in situations where they were able to switch completely at their own discretion. Our results also seem to contradict previous studies in the interruption literature that people prefer to task switch in response to an interruption when the interruption comes at a breakpoint (Adamczyk & Bailey, 2004; Iqbal & Bailey, 2005; 2008; Bogunovich & Salvucci, 2011; Borst, Taatgen, & Rijn, 2015).

There are a few possible reasons for this discrepancy. There may be factors that we are not accounting for such as the difficulty of the primary task. People may switch more/less depending on the difficulty level of the task. It is also possible that had we examined between switches not after completion of a puzzle but between-row or between-column switches vs. during-row and during-column switches we may have had different results. Finally, the low number of switches in our experiment may have led to the different results. Since participants were allowed to switch to the Match-It game as many or as few times as desired, some preferred to switch only once or not at all. Out of 180 participants whose data were analyzed, only 102 (56.67%) had any switches at all, and 32 (17.8%) had only one switch during the ten minutes. Leiva et al. (2012) found that people do not switch apps on their smartphones very often. It is possible that if participants were required to switch a fixed number of times (with the timing still at their discretion), that a clearer pattern would emerge.

Similar to previous studies (Hembrooke & Gay, 2003; Adler & Benbunan-Fich, 2012), we have found negative results when multitasking with technology. Specifically, our research demonstrates that these negative effects are also found when people multitask with smartphones. There was a strong negative relationship between primary task performance and any amount of switching.

In addition to the number of switches, we also found that time away from the primary task lowered performance. When participants in our experiment switched to the Match-It game the timer on the Math Squares puzzle was stopped, so all participants spent the same ten minutes

on the primary task. Despite this, there was a significant negative relationship between time away from the primary task and number of Complete Wins. The more participants were away from the primary task, the lower their performance. This supports previous research by Hembrooke and Gay (2003) who found that time away from the primary task had more of a negative impact on performance than the content of the interruption.

The data in this research also supports Hypothesis 3 that switching in the middle of a subtask on mobile devices is more detrimental to performance on a primary task than switches in between subtasks. This suggests that the negative effects on performance can result from the amount of time it takes to remember information about the primary task after the end of an interruption. This supports previous research that found a time lag after interruptions from the primary task (Iqbal & Bailey, 2005). When the task switch occurs at a breakpoint there is no need to remember information and the primary task can be resumed immediately. In this research, participants who switched during the Math Squares puzzle would have to remember their thought process and strategy when returning to the task which negatively affected their performance.

While there were no significant differences between those who monotasked and those who switched in between subtasks, performance was significantly lower for those who switched during the subtask than those with no switches. This implies that some switching may not be detrimental if it is between subtasks and not during the task.

Implications

Previous research has shown that there are negative consequences to multitasking with technology in general (Hembrooke & Gay, 2003; Adler & Benbunan-Fich, 2012). Since smartphones in particular are used in a way that facilitates multitasking that can become habit forming (Oulasvirta et al., 2005; Böhmer et al., 2011; Oulasvirta et al., 2012), it is important to understand the effects of multitasking with smartphones specifically. Previous research has shown that performance on smartphones can be lower than on desktops, yet people still prefer smartphones (Adepu & Adler, 2016). This research has demonstrated that similar to computer-based multitasking, multitasking with smartphones negatively affects performance on a primary task. In addition, the more time away from the primary task, the lower users' performance. Furthermore, this research suggests that there are smarter ways to multitask which can lessen these negative effects. While previous literature discusses breakpoints in terms of external interruptions, we found that task switches during breakpoints can minimize the negative effects of multitasking. People who task switch can wait for a natural breakpoint in their primary task to switch to a secondary task. This will allow them to continue their multitasking behavior while minimizing negative effects on performance of their primary task.

Limitations and Future Research

Although Mechanical Turk provides many benefits to researchers, there are some limitations as well. Because participants completed the experiments on their own, it is possible that they experienced other distractions in their environment other than the Match-It game. It is also possible that participants left the experiment for part of the ten minute time limit. However, these limitations may be balanced out by the benefits of Mechanical Turk, which allowed us to recruit a larger and more diverse group of participants than we could have recruited on a college campus.

Another limitation in our research was the low number of participants who chose to switch to the secondary task. It is possible that we would have gotten better results had there been more of an incentive to switch to the secondary task. Requiring participants to multitask a fixed number of times while still allowing them to switch at a desired time, might give a clearer picture of when people are more likely to multitask. Data from participants who only switched a couple of times may not provide enough information to determine when they may have switched when constantly multitasking.

Future research may also look at the amount of time spent away from the primary task in between subtasks and during a subtask. In this experiment, only the average amount of time per Match-It game was recorded, and a negative relationship between Average Time per Match-It game and performance on the Math Squares puzzle was found. It would be interesting to see if total time spent on the Match-It game in the middle of a puzzle had a worse effect than total time in between puzzles.

CONCLUSION

People multitask constantly in multiple environments such as the workplace and school. Multitasking with technology is very common, and is especially pervasive when people are using mobile devices. Prior research has established the negative effects of multitasking when using technology in general. This research focuses on smartphone-based multitasking and found negative consequences of multitasking on smartphones. Furthermore, the more time participants spent away from the primary task, the lower their performance. While this study did not find any difference between the number of people who multitasked in between subtasks and during a subtask, the difference in performance between these two groups was significant. Switches during a subtask had a significant negative effect on performance, while switches in between subtasks did not have a significant effect. This suggests that the negative effects of discretionary task interleaving can be lessened by the timing of the switch. Waiting to switch to a different task at a natural breakpoint can reduce the negative consequences of multitasking on mobile devices.

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DECISION SCIENCES INSTITUTE
Smart Phone use - The effect of Economics and Culture

(Full Paper Submission)

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ABSTRACT

The use of Smart phones for economically motivated activities, is examined against Hofstede dimensions of culture using 4 macro-economic indicators and the proportion of smartphone use for activities related to the cultural dimensions. Results suggest that this technological extension to human hands, is mirrored somewhat in the collective socio-economic soul of a country.

KEYWORDS: Smartphone, Apps, Satisfaction, Culture, Economics , Hofstede

INTRODUCTION

Smartphones have been steadily increasing in resolution and are at the point where they rival 60” TV screens in a 5” space. Bandwidth available has also increased exponentially and easily rivals home-internet, with dozens of Mb per second, even over cellular connections., making the loading of rich, complex knowledge sources, very commonplace. Smartphones represent a convergence of information & communication technology, facilitating many modes of communication and knowledge transfer. The extent of computing power which has now gone into Smartphones phones prompted vice president of Nokia, William Plummer to remark that "There used to be a computer industry, and there used to be a consumer electronics industry, but it's all the same thing now" (CIO, 2008). They now come with a plethora of apps which are expected to be almost seamlessly fast even over the internet (Djerv & Malla, 2012).

In this paper, we examine how national culture and economics influences smart phone use for a range of economic activities facilitated by ICT. We examine the relationship between New Business Density percent, and the Ratio of Searched_jobs/Finance_activities in the presence of Uncertainty Avoidance. Also, how GINI drives Ratio of Searched_Travel_holidays/Used_shopping_coupons in the presence of Power Distance. We also look at how Manufacturing percentage of GDP is related to the ratio of Listened_music/Played_games in the presence of Individualism/Collectivism. Gender-Parity-of-Employers is a growing concern and we see whether it is connected to the ratio of Accessed_social_network /Sent_read_email in the presence of Masculinity/Femininity

LITERATURE REVIEW

Culture is the way groups of peoples have configured the behavior which they share and learn in order to form a cohesive whole (J. A. Lee, Garbarino, & Lerman, 2007). It differentiates them from other peoples (I. Lee, Choi, Kim, & Hong, 2007). It is the content and set of values and thought-processes which are created and passed along in order to shape fellow human beings into functioning members of society (I. Lee et al., 2007). “Culture is the collective programming of the mind which distinguishes the members of one group of people from another” (Hofstede,

1991, p. 5). National culture is the values and beliefs which people adopt early in their lives (Lim, Leung, Sia, & Lee, 2004) and drives the outcomes at a national level, as well as affecting their attitudes to and contentment with those outcomes.

Hofstede's Dimensions of Culture

In the 1960s and 70s, famous a Dutch anthropologist Geert Hofstede used IBM employees in 53 countries to determine the common components of culture (Hofstede, 1980, 1991). His studies led him to differentiate cultures into four dimensions initially, and ultimately six. These dimensions of culture while attracting criticism are the landmarks with regard to viewing the collective behavior of nations and have been broadly applied in studies of culture. They include Uncertainty Avoidance, Individualism versus Collectivism, Masculinity versus Femininity and Power Distance. Temporality and Indulgence later rounded out the six and added value in differentiating between, for example, Western Cultures which tend to have a right-now mentality versus much older cultures which take a long-view of results.

Masculinity vs. Femininity

Not surprisingly, a study done by a patriarchal figure in the 60s would necessarily differentiate personalities by gender and top it off by linking the dimension to achievement and success. And so, Masculinity vs Femininity is unfortunately, as sexist as it sounds. Naturally, the feminine side would be described as being relationship focused. While the purpose of this study is not to critique Hofstede's work, certainly a modernized, progressive discussion human development needs to make clear the distinction between gender-traits and gender-abilities. Most modern re-readings make the distinction more in terms of the different approaches to doing things and not whether an individual has higher standards or works less than others (Lemish & Cohen, 2008; Palen, Salzman, & Youngs, 2000; Totten, Lipscomb, Cook, & Lesch, 2005).

Uncertainty Avoidance

Hofstede described socially driven levels of anxiety, fear of failure and unwillingness to take chances as Uncertainty Avoidance. A preponderance of innovation is not the strength of an Uncertainty Avoidant culture since they avoid the possibilities that come with adventure, in favor of the evils they know. Uncertainty avoidance is not the same as fear that comes from a threat someone knows about and understands (I. Lee et al., 2007; Marcus & Gould, 2000). Uncertainty Avoidant cultures fear uncertain situations and will focus on the possible losses that may ensue.

Individualism vs. Collectivism

People in an individualistic society tend to go it alone, preferring loosely coupled relationships which serve their individual interest. Property is seen as more personal than communal (Jhangiani & Smith-Jackson, 2007; J. A. Lee et al., 2007). Each person is responsible for themselves or those of their inner circle only (Marcus & Gould, 2000). In situations involving conflict between the wider community and personal goals, in an individualistic society, the personal goal will usually take precedence (Srite & Karahanna, 2006).

Power Distance

Power distance represents the extent to which people accept differences in power levels within a society (Marcus & Gould, 2000). Large power distance societies are marked by a sense that everyone has a 'rightful' place in society. Old age and status are respected tremendously and status is put on display to demonstrate power (de Mooij, 2000)

Smartphones and Productivity

In addition to being the state-of-the-art in communications technology, Smartphones are challenging PCs for dominance in daily computer use. Smartphones have the major advantage over office computing devices in that they can be used literally anywhere—if internet service is available (Van Biljon & Kotzé, 2007). Due to massive availability of user installable applications on Android from Google Play and iOS from the Apple Store. The amounts and kind of tasks that can be accomplished using a smartphone has increased. All these features available on a smartphone means that the gap between computer and smartphone usability is being reduced constantly by the advances in smartphone capabilities and especially the leaps and bounds being made in increasing their technical capabilities. So, the technical drivers of usage should become less important and give way to more deeply held human qualities and stable qualities such as national culture.

Mobile hotspots included as part of many cellular mobile plans, is now an every-day reality. Purchasing car parts, Booking Vacations, applying for jobs, reserving movie tickets and playing games is now unremarkable, High-end smart phones have screen resolutions, processors, memory, and storage that rival laptop computers. Smartphones can be taken anywhere and wherever there is network access, which tends to be everywhere on the beaten path. It allows you to perform internet-based activities throughout the day, not only while sitting at a desk or at home. However, comparing information is more difficult on a smartphone even though the newer smartphones allow users to use 2 apps side by side. to directly compare information about two products, services or activities. Incompatible data formats can also a problem since not all file formats are available, especially in an editable mode on a smartphone. This can make saving and retrieving information more difficult.

Naturally their ubiquity as tools of knowledge acquisition, development, accomplishment, connectivity, commerce and progress, all come at a price. Psychiatrists such as Lin and Chang, have investigated and established the existence of 'smartphone addiction, and in the process, created the Smartphone Addiction Scale (SPAI), using the Chen Internet Addiction Scale (CIAS) (Lin et al., 2014) as their point of departure. PTSD severity and impulsivity in smartphone use, linked to addictive behaviors have also been validated using the PTSD Checklist for DSM-5 (PCL-5) and Kwon et al. (2013)'s Smartphone Addiction Scale- Short Version (SAS-SV) (Contractor, Weiss, Tull, & Elhai, 2017). Smartphones also act as a tether, keeping employees working outside normal hours. This according to (Cole & Cole, 2016) reduces their ability to recover from the stress of work.

HYPOTHESES

Use of Smartphones for Uncertainty Avoidant activities reflected in Entrepreneurship

New businesses require investment which implies financial planning to maximize currently held resources to acquire the capital to start a business. Starting one, while promising the possibility of great reward, does simultaneously carry a lot of risk (Yang, 2004). This is countered by a focus on gaining employment from an existing employer. Uncertainty avoidance will determine the extent to which prospective entrepreneurs will embrace the risk of opening their own business versus continuing to be employed by existing businesses (I. Lee et al., 2007; Marcus & Gould, 2000). Customers now have instant access to their bank balances and get notifications of purchases, minutes ago on their smartphones, thanks to apps available from every major financial institution. Job search apps for companies like Indeed, Monster and Glass-Door, have become a staple for on-the-go job application, so critical in today's competitive job market where being one of the first resumes available to an employer is vital to getting an interview.

Hypothesis 1: New-Business-Density is related to ratio of smartphone use for Searched_jobs/Finance_activities moderated by Uncertainty Avoidance.

Use of Smartphones for Power Distant activities reflected by GINI

Income inequality is reflected in the flamboyant lifestyles of the rich, mirrored in the scraping for existence by the poor. Travel holidays are one of the reflections of discretionary income and the freedom of time and movement, the ability to "drop everything and go". They also reflect a level of exposure to the finer things in life and the emphasis on higher order self-development, as witnessed by social media postings in which the traveler emphasizes how many cities they have visited. This is important in Power Distant society where it becomes imperative to show you are one of the "haves" (de Mooij, 2000). On the flip side, shopping coupons while also used by some rich people, are mostly a reflection of someone's s need to economize and stretch their dollars, instead of flaunting success. Both activities are done on Smartphones, which allow ubiquitous levels of activity in either, allowing Smartphones to be used at every point of sale, and vacation plans to be constantly refined.

Hypothesis 2: GINI is related to Smartphone use for ratio of smartphone use for Searched_Travel_holidays /Used_shopping_coupons in the presence of Power Distance.

Use of Smartphones for Individualistic activities reflected by Manufacturing

Manufacturing as rethought by Adam Smith, and constantly reimagined by entrepreneurs, involves the solitary activities in which the individual carries out tasks which have been very neatly subdivided by individual skill required and specific contribution to the value generation process (Yeniyurt & Townsend, 2003). Agricultural societies, especially subsistence-based economies, as reflected in the family approach where children are an integral part of the process and sometimes removed from school

to focus on the planting and reaping of crops to boost the family income, is a very participative activity. This is necessary as it is highly (cheap) labor intensive, as activities such as weeding are difficulty to automate. In many societies it even pulls in the wider community which is on no-questions-asked standby to help reap a crop when the weather, especially flooding, poses a threat to a farmer's ability to bring a crop to market (Jhangiani & Smith-Jackson, 2007). This is reflected in the individuality/collectivist construct which drives the focus on the group versus the individual (J. A. Lee et al., 2007). Smartphone use should mirror this contrasting approach to economic activity.

Hypothesis 3: Manufacturing percentage of GDP is related to the ratio of Smartphone use for Listened_music/Played_games in the presence of Individualism/Collectivism.

Use of Smartphones for Feminine activities reflected by Gender equality of Female businesses

While Hofstede needs a rethink to indicate that contributions of men and women are equal in value, even if diverse--bringing the richness and various strengths to the mix, ensuring that the process and product benefit from the best of our different approaches and styles. Gender parity does not mean that we all look or act like the same person, but that the contributions of each gender play an equally valuable role in business and society. Social media allows the more feminine quality of relationship building to shine through over the cut-and-dry approach to basic information seeking and dissemination which is allowed by email (Lemish & Cohen, 2008; Palen et al., 2000; Totten et al., 2005). The Femininity/Masculinity aspect of national culture will determine the extent to which the two different approaches are combined and balanced, reflected in the use of smartphones for either activity.

Hypothesis 4: Gender-Parity-Employers is related to the ratio of Smartphone use of Accessed_social_network/Sent_read_email in the presence of Masculinity/Femininity.

Data

Dependent Variables

Socio-Economic indicators were acquired from World Bank, OECD, OurWorldinData.org, PewGlobal.org, Gallup Polls and UNDP.

Independent Variables

Data for smartphone use was taken from Google's Our Mobile Planet for years 2011 and 2012 which were averaged. The dataset covers 40 countries which correspond to the top 40 countries with significant, comprehensive use of smartphones. This dataset remains unique, and has never been replicated to any significant level. Each country data point represents between 500 and 1000 respondents. In some cases, the survey questions such as how often the respondent uses social networking on their smartphone allowed several responses. In this case, valid responses were: "Daily", "Weekly", "Monthly", "Less than Monthly" and "Never". To derive a country-level score, the results were converted to a log-based Likert-scale weighted average.

For example, the country score for this variable was calculated as (7 x Daily + 5 x Weekly + 3 x Monthly + 1 x Less-than-Monthly + 0 x Never) / Total-Responses

Hofstede culture data was derived from https://www.hofstede-insights.com/product/compare-countries/ and represents culture data as at 2001 which has not changed significantly in the intervening years.

RESULTS

Hypotheses were tested using linear regression in R. All models included a Hofstede dimensions of Power-Distance, Uncertainty-Avoidance, Individualism_Collectivism and Masculinity_Femininity. They also included: GDP_PerCapita, Population_perc65over, GP_PostSecondary, Happiness_2010, Used_Application and Browsed_Internet as control variables.

Model-1: New-Business-density & Uncertainty-Avoidance …

Independent Variables	Beta	t	p-value	
Used_Application	0.392836	1.593	0.1456	
Browsed_Internet	-0.57705	-2.423	0.03841	*
GDP_PerCapita	-0.00045	-2.108	0.06429	.
Population_perc65over	2.804999	3.731	0.00469	**
GP_PostSecondary	0.27022	2.402	0.03978	*
Happiness_2010	-5.99239	-2.629	0.0274	*
SPRatioColumn1_UA	81.34006	2.478	0.03512	*
Uncertainty_Avoidance	0.392966	1.83	0.10045	
SPRatioColumn1_UA:Uncertainty_Avoidance	-1.20995	-2.744	0.0227	*
f-statistic = 3.397				
R^2 = 0.7726				
adj R^2 = 0.5451				
p = 0.0414				
** p < 0.05, ** p < 0.01, *** p < 0.001*				

Hypothesis-1 suggested that countries with a higher level of Entrepreneurship as reflected in the rate of New-Business-density, would make greater use of Smartphones in job searches compared to use for Finance_activities. And also, that this effect would be increased by the Uncertainty Avoidance of the country. Overall model-1 was significant ($f = 3.397$, $p = 0.0414$) and so Hypothesis-1 was supported, since the ratio of Smartphone use in job searches to Finance_activities was significant the ratio of job-searches to Finance_activities was significant ($\beta = 81.3400554$, $t=2.478$, $p=0.03512$). However, Uncertainty Avoidance was not significant ($\beta = 0.392966$, $t=1.83$, $p=0.10045$) but the interaction variable between them was significant ($\beta = -1.2099495$, $t=-2.744$, $p=0.0227$).

Model-2: GINI & Power-Distance …

Independent Variables	Beta	t	p-value	
Used_Application	-0.03135	-0.163	0.873186	
Browsed_Internet	0.1556	0.776	0.451564	
GDP_PerCapita	0.000253	1.779	0.098584	.
Population_perc65over	-1.818	-4.61	0.000489	***
GP_PostSecondary	0.03573	0.381	0.709492	
Happiness_2010	-8.528	-3.653	0.002923	**
SPRatioColumn1_PD	-9.074	-1.476	0.163748	
Power_Distance	-0.5312	-2.296	0.038941	*
SPRatioColumn1_PD:Power_Distance	0.1961	1.874	0.083612	.
f-statistic = 8.04				
R^2 = 0.8477				
adj R^2 = 0.7423				
p = 0.0004956				
** p < 0.05, ** p < 0.01, *** p < 0.001*				

Hypothesis-2 suggested that countries with a higher level of Income-Inequality as reflected in their GINI, would make greater use of Smartphones for Searching_Travel_holidays compared to use for shopping_coupons. And also, that this effect would be increased by the Power Distance of the country. Overall model-2 was significant (f =8.04, p =0.0004956) but Hypothesis-2 had limited supported, since the ratio of Smartphone use for Searched_Travel_holidays compared to Used_shopping_coupons was not significant (β= -9.07E+00, t=-1.476, p=0.163748), even though Power Distance was significant (β= -5.31E-01, t=-2.296, p=0.038941) and the interaction variable between them was significant, but only at the 0.1 level (β= 1.96E-01, t=1.874, p=0.083612).

Model-3: Manufacturing & Indvidualism_Collectivism …

Independent Variables	Beta	t	p-value	
Used_Application	0.01235	0.036	0.97203	
Browsed_Internet	-0.1181	-0.349	0.73291	
GDP_PerCapita	-0.00061	-3.198	0.00767	**
Population_perc65over	0.4531	0.884	0.39432	
GP_PostSecondary	-0.03451	-0.239	0.81523	
Happiness_2010	5.703	1.741	0.1073	
SPRatioColumn1_IC	-41.83	-0.788	0.44582	
Individualism_Collectivism	-0.6759	-0.718	0.48638	
SPRatioColumn1_IC:Individualism_Collectivism	0.5074	0.557	0.588	
f-statistic = 1.951				
R^2 = 0.5941				
adj R^2 = 0.2896				
p = 0.1392				
** p < 0.05, ** p < 0.01, *** p < 0.001*				

Hypothesis-3 suggested that countries with a stronger manufacturing focus as reflected in the Manufacturing-percentage-GDP, would make greater use of Smartphones for Listening_music compared to use for Playing_games. And also, that this effect would be increased by the Individualism of the country. Overall model-3 was not significant ($f = 1.951$, $p = 0.1392$) and so Hypothesis-3 was not supported, since the ratio of for Listening_music to Playing_games was not significant ($\beta = -4.18E+01$, $t = -0.788$, $p = 0.44582$). Neither was Individualism significant ($\beta = -6.76E-01$, $t = -0.718$, $p = 0.48638$) nor was the interaction variable between them ($\beta = 5.07E-01$, $t = 0.557$, $p = 0.588$).

Model-4: Female-Businesses & Masculinity_Femininity …

Independent Variables	Beta	t	p-value	
Used_Application	-0.7931	-1.501	0.18391	
Browsed_Internet	0.7813	1.442	0.1995	
GDP_PerCapita	0.003024	4.588	0.00374	**
Population_perc65over	-4.763	-3.431	0.01395	*
GP_PostSecondary	-0.1202	-0.2	0.84772	
Happiness_2010	-13.21	-1.717	0.13686	
SPRatioColumn1_MF	-233.8	-2.901	0.0273	*
Masculinity_Femininity	-6.458	-3.47	0.0133	*
SPRatioColumn1_MF:Masculinity_Femininity	5.297	3.349	0.01544	*

f-statistic = 8.139
R^2 = 0.9243
adj R^2 = 0.8107
p = 0.009492
** p < 0.05, ** p < 0.01, *** p < 0.001*

Hypothesis-4 suggested that countries with a higher level of Gender-Parity-in-Employers as reflected in the Employers_percFemale, would make greater use of Smartphones for Accessing-social-network compared to use for Sending_reading_email. And, that this effect would be increased by Femininity (the negative of masculinity in the model) of the country. Overall model-4 was significant ($f = 8.14$, $p = 0.009492$) and so Hypothesis-4 was supported, since the ratio of Smartphone use in job searches compared to Finance_activities was significant ($\beta = -2.34E+02$, $t = -2.901$, $p = 0.0273$), Femininity (-ve masculinity) was significant ($\beta = -6.46E+00$, $t = -3.47$, $p = 0.0133$). However, the interaction variable between them was significant, but correlated with masculinity, not femininity ($\beta = 5.30E+00$, $t = 3.349$, $p = 0.01544$).

DISCUSSION

Entrepreneurs look for dramatic change to life financial strength rather than incremental improvements (CITE). Hypothesis-1 supports the notion that this Entrepreneurial spirit is captured in the differences between different country's use of smartphones. With countries that are more entrepreneurial favoring job-searches on smartphones over doing finances with said smartphone. Even though Uncertainty Avoidance itself was not significant in model-1, the significance of the interaction with the smartphone-use ratio was significant. However, the interaction is negative, indicating that Uncertainty Avoidance flips the relationship to favoring doing finances over searching for jobs. This is not all that surprising since Uncertainty Avoidance can play out in the maximization of the current job instead of wanting to explore new avenues.

In Power Distant countries, people with wealth will do their best to flaunt it in order to demonstrate that they have more status than people who are trying desperately to make ends meet. Unsurprisingly, Power Distance was significant with GINI—but very unexpectedly, the relationship was negative. The use of smartphones for luxury spending on vacations versus the survival driven use for shopping coupons, was not significant. There are several possible explanations, the first being that vacations are not so much a way to flaunt one's status and draw envy. This is hardly likely since nobody has a shortage of Facebook friends posting pictures of their vacation to show how well-traveled and exposed they are, in the process becoming the day's like-leader. The other possibility is that Smartphones are not considered a great way to search for vacations, which would not be surprising since the small screens would not be best for choosing your next vacation that is going to draw the most envy on Instagram. The interaction term was only significant to the 0.1 level. The more likely explanation here being that power distance reduces use for shopping coupons (the denominator in the ratio), because no self-respecting elite would be caught trying to save $2.

According to Hofstede, in Masculine countries, men are the bread-winners and by extension, the employers of bread-winners. Women on the other hand are supposed to be nurturers who maintain relationships. It was hypothesized that in more feminine countries, there should be less Gender-Inequality as far as economic power is concerned. Model-4 supports the idea that Femininity (the opposite of masculinity) is related to higher percentages of Female business owners through the negative relationship between Masculinity and percentage of Female-business ownership. However, the negative relationship between % of female-led businesses and the use of social media over emails was not expected. But it is possible that the notion that countries that are more feminine would favor social media is possibly as sexist as the very existence of a construct which says that productivity is a masculine construct, implying very politely that women should stay at home. It could be that with more feminine countries, women are too busy running those business using email, to waste time on social media. The interaction variable between these two was positive, suggesting that masculine countries where there is a tendency towards social-media instead of emails actually have higher percentages of female owned business. The implication of this is that the use of social media is a tempering of the masculine side which allows for the rise in female owned businesses.

CONCLUSIONS

The results of this study are important for several reasons. They confirm that there is a significant pattern in the way countries make use of smartphones for socio-economic activities, based on culture, which is moderated by the economic structure of the country. Also, that these smartphone uses do conform to some intuitive norms – such as social-networking (relationship maintenance) being a feminine activity.

Additionally, it was confirmed that Hofstede culture is related to socio-economic activity, for example Power Distance being related to Income Inequality, but interestingly, not in the way initially hypothesized. This would seem to suggest Power Distance is not important to people with unchallengeable economic power. It is possible the do not feel the need to flaunt their power to make themselves heard and be taken seriously, allowing them to focus on getting the best out of the people surrounding them. Financially powerful people may feel a lesser need to flaunt their power because they are more secure in their power and more focused on gaining more power by surrounding themselves with colleagues who create instead of drones who toe the line. This is reflected in the rise of Silicon Valley Billionaires showing up for work in jeans and t-shirt, in contrast to traditional managers just a few levels above, who donned pin-stripe suits to display their difference in status. These disparate ways in which power is shown is certainly consistent with the idea that by melding with staff, you get the best creativity out of them, versus drawing clear and distinct lines between them in order to establish command and control.

The other contribution of this study is the surprises found in the interactions and a few of the cultural effects. Some of the unexpected relationships suggest that technology doesn't necessarily follow cultural signals faithfully, and by its nature may flip culture on its head sometimes. We need to rethink some of the ways culture plays out in the economics and technology use of a country. Technology can be a game-changer which brings out the true nature of people when they feel freer to express themselves using tools such as mobile devices which extend their reach and give them a bigger platform, limited only by the importance of what they have to contribute.

The results of this paper will help people who design and market Smartphone apps to figure out the role that smartphones actually play among groups of countries and among groups within these countries. It is important to understand the wording, features and interface that apps should use – driven by culture - which will best appeal to prospective users in order to maximize usefulness and appeal. This will affect the layout and prominent features of apps, example, for banking compared to job search apps – across cultures. By understanding how the users of these apps vary by country, will help to optimize the way the apps are presented, the complexity of features and simplicity of use, the wording and positioning of advertising for these apps, and so on. Added to macro-economic indicators, the cultural indicators of a country will guide the design of effective apps which can translate to higher overall satisfaction with social media apps, e-mail apps, travel-search apps, shopping apps and so on.

By customizing the apps to fit the cultures and work-styles of the citizens of a country, they will ensure the smoothest and most enjoyable experiences for the users, ensuring that users derive the maximum satisfaction from using their smartphones and driving engagement, sales and customer loyalty to the institutions represented by these apps.

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DECISION SCIENCES INSTITUTE
Social Media Functionality in Higher Education: A case study involving IT/IS Students

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ABSTRACT

This paper discusses the functionality of social media in Higher Education (HE). The aim of the research reported in this paper was to identify the main factors and problem areas in the use of social media in HE. Our study included a survey involving students of Information Technology and Information Systems in Greece. The Honeycomb model and the theory of external and internal motivation were applied for this study.

The results showed that understanding content sharing is the most important issue in the planning of learning/teaching activities based on social media. We also found that conversations are less significant in HE context. Based on the analysis guidelines for planning social-media-based learning activities are proposed. Indications of further work complete the paper.

KEYWORDS: Social media, ICT/IS education, functionality, and honeycomb

INTRODUCTION

Communication, collaboration and content sharing are the foundation of social media. The term social media is interchangeable with the terms Web 2.0 and social software (Dabbagh & Reo, 2011). In recent years technology enhanced learning has become a fundamental part of Higher Education (HE) (Siakas et al., 2011). Rapid advances in Information and Communication Technologies (ICTs) have initiated fast and easy access to new electronic learning environments. In particular, Social Media Platforms (SMPs) have become an integral part of modern society. In the last 5 years they have been established both in academic and public use. They have completely changed the way we communicate, share and co-create information. Social networking is accomplished through a bottom-up approach and crowd-sourcing (Siakas et al., 2014). Engagement in SMPs, when used in education, usually means that students become active participants to a higher degree. This is partly due to the fact that learning becomes fun and is akin to leisure activities that these young people participate in, as opposed to remaining as spectators. The objective of motivating students to actively participate in their learning process is increased since students engage in all forms of social discourse by multi-way communication and action.

The aim of this study is revealing to show what aspects of SMPs can provide support for HE. In this way we can find two kinds of benefits for the future development regarding use of SMPs:

- in what way can an instructor use SMPs in teaching activities, and

- what are current deficiencies of SMPs.

We also clarify the use of SMPs in the light of motivation. Our analysis covers both external and internal motivation.

In the next sections, we present the background of this study including the honeycomb model and the motivation model. This is followed by research questions and methodology, results of the study and the discussion.

ASPECTS OF SOCIAL MEDIA USE

Kaplan and Haenlein (2010) have defined social media as a set of Internet-based services which are based on Web 2.0 ideology and technologies. These applications enable user-oriented content creation and sharing.

The honeycomb of social media is a useful tool for defining the role of a social media application in a certain context (Kietzmann et al., 2011). The honeycomb includes the following elements:

- presence;

- sharing;

- relationships;

- conversations;

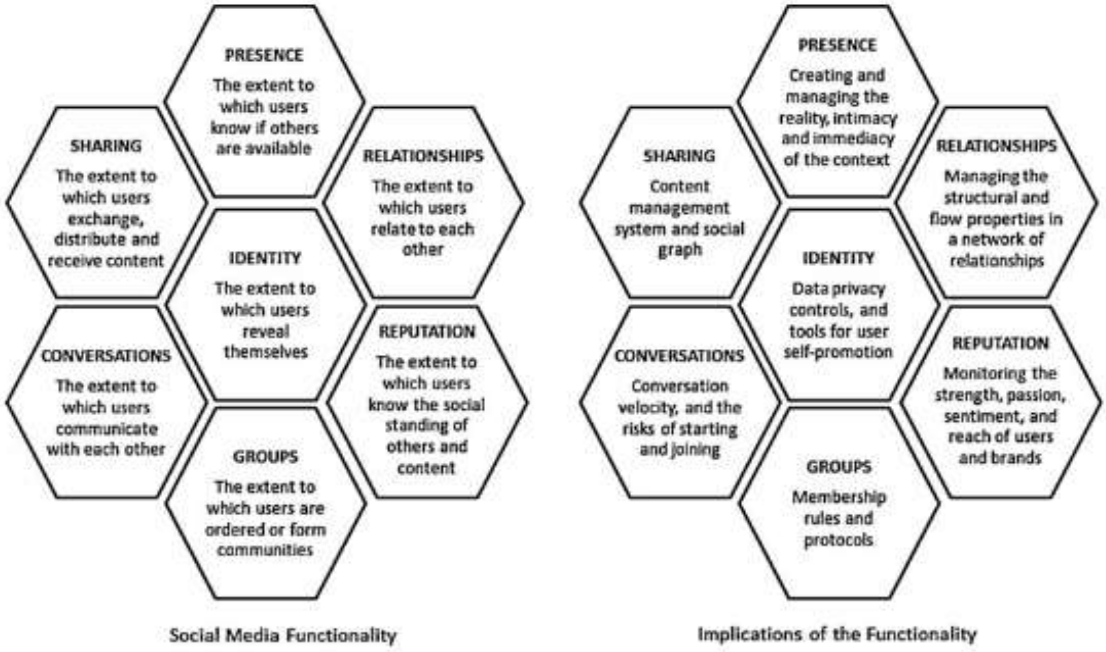
- reputation;

- groups;

- identity as the core item.

Figure 1 (see next page) demonstrates how the honeycomb can be used in analyzing social media use. First in this figure the honeycomb has been applied for the functionality of social media and then for the implications of social media.

Figure 1: Honeycomb for analyzing social media (Kietzmann et al., 2011)



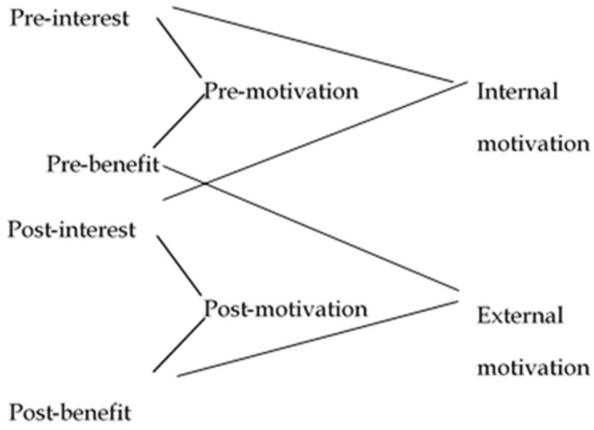
ENGAGEMENT AND MOTIVATION

Evaluating motivation is important from the perspective of our research context, because many problems in regard to learning the basics of informatics occur. Romano and Balthazard (1993) have summarized the problems. These include limited individualized attention, “cyberphobia”, in other words a fear of computers, a lack of interest in the subject matter, limited or no access to interactive learning software, and information overload leading to failure to make associations. These issues are relevant in the current era of web 2.0 and social media.

According to Schunk (1990), “motivation refers to the process whereby goal-directed behavior is instigated and sustained”. Most commonly in learning from text, motivation is understood both internally and externally (Biggs, 1984; Biggs, 1985; Entwistle & Ramsden, 1983; Linnakylä, 1988). Internal (intrinsic) motivation reflects a student's own interest in regard to espousing new knowledge. It is associated with a human's high-level need such as self-actualization. External (extrinsic) motivation reflects the need to reach goals set by others. This is connected to a human's low-level needs such as security and survival.

Motivation regarding learning from text can be evaluated as shown in figure 2 (see next page).

Figure 2: Motivation of learning from text (Linnakylä, 1989)



Pre-motivation is the sum of pre-interest and pre-benefit. Post-motivation is the sum of post-interest and post-benefit. Internal motivation is the sum of pre-interest and post-interest. External motivation is the sum of pre-benefit and post-benefit (Linnakylä, 1989).

OUR STUDY

In our study and this paper we explored what is important to the use of social media in education based on students' views. The aim was to find out what instructors should look at especially when creating social media based learning activities for their students. In this it is important to know what promotes the use of social media and what impairs.

Derived from the honeycomb model and the motivation model the major variables were:

- presence;

- sharing;

- relationships;

- conversations;

- reputation;

- groups;

- identity as the core item;

- internal motivation;

- external motivation.

Forty students from Alexander Technological Education Institute in Thessaloniki (Greece), 11 females and 29 males, whose mean age was 26 years (range 18-46 years), participated in our online Survey on Webropol platform. The respondents rated each item of five most significant social media tools on a scale of 1 to 5 where (1= not significant and 5=significant). The tools were Facebook, Twitter, LinkedIn, Pinterest, and Instagram from the list provided by Pew Research (Greenwood et al., 2016).

Each social media feature of each tool variable was merged into a one sum variable representing one feature of social media. The mean values of each sum variable were compared in order to analyze how well different honeycomb features of social media support learning. Statistical analysis was made by using SPSS.

ANALYSIS OF DATA

Table 1 shows the frequencies of the responses concerning the honeycomb variables of the study.

Table 1: Honeycomb frequencies (means)						
Presence	Sharing	Relationships	Conversations	Reputation	Groups	Identity as the core item
2.89	3.37	2.58	2.28	2.75	2.55	2.68

Table 2 shows the frequencies of the responses concerning the motivation variables of the study.

Table 2: Motivation frequencies (means)	
Internal motivation	External motivation
3.09	2.95

The Kolmogorov test showed that the data based on the responses of the students concerning the variables in our study did not agree with the normal distribution. Thus, the Mann-Whitney was appropriate for statistical analysis of the data when comparing the means of variables.

Concerning the honeycomb use model of social media we found significant differences (as all p values were less than .05) between the main variables as shown in Table 3 (see next page).

Table 3: Mann-Whitney results showing significant between the variables studied				
Variable 1	Variable 2	p value	Positive observation	Negative observation
Presence	Sharing	p=.014	Sharing is important	Presence is less important
Presence	Relationship	p<.001	Presence is important	Relationship is less important
Presence	Conversations	p=.002	Presence is important	Conversations are less important
Sharing	Relationship	p<.001	Sharing is important	Relationship is less important
Sharing	Conversations	p<.001	Sharing is important	Conversations are less important
Sharing	Reputation	p=.003	Sharing is important	Reputation is less important
Sharing	Groups	p=.001	Sharing is important	Groups are less important
Sharing	Identity as the core item	p=.004	Sharing is important	Identity as the core item is less important
Conversations	Reputation	p=.012	Reputation is important	Conversation is less important
Conversations	Identity as the core item	p=.042	Identity as the core item is important	Conversations is less important

The results show that sharing of content is the most important factor in the use of social media in HE, followed by internal and external motivation. The users of our sample did not prefer conversation on social media and instead they used other ways of communicating.

In addition, we evaluated motivation. We did not found significant difference in the Mann-Whitney test between internal and external motivation (p=0.396).

DISCUSSION

Different cultural contexts bring about differences in assumptions about learning and the expectations that participants have regarding learning and teaching, the teaching model and the relationships between educator and learner, the way the technology itself is experienced, the pedagogical aspect, the design of online courses and the way in which individuals and groups communicate and respond to their environment. New trends in teaching and learning, including social media learning environments, require a shift from instructor/educator-centered to learner-centered learning. A paradigm shift embracing active learning and knowledge sharing is needed. Participative learning is not only imperative but also made possible. The pedagogical trend today focuses more on learning than on teaching and calls for flexibility in teaching and assessment methods. To this respect, the nature of new technologies (ICTs) helps considerably (Siakas & Economides, 2012).

According to our results, social media shows its power regarding content sharing. Educators should look at this when applying social media in education. Our results also show that conversation is less important in the use of social media in education. This result may be caused by the fact that our data for this study has been collected in Greece. Because of this we will analyze the results from a cultural viewpoint referring to four main work-related cultural values described by Hofstede (2001) and the corresponding scores for Greece shown in table 4. Originally the scores were to be a continuum between 0 and 100, but when some countries were added after the formula had been developed scores greater that 100 became possible.

Table 4: Hofstede's cultural dimensions and their scores for Greece

Dimension	Description	Hofstede's Scores
Power Distance	The extent to which a society accepts the fact that power is distributed unequally among individuals	60
Uncertainty Avoidance	The extent to which a society feels threatened and tries to avoid ambiguous situations by rules	112
Masculinity vs. Femininity	The relationship between masculine assertiveness vs. feminine concern for social well being	57
Individualism vs. Collectivism	The relationship between the individual independence and the collective interdependence of a group	35

Below we discuss each dimension separately. This provides deeper view concerning what we have found in this study.

Power Distance: Greece scores 60 on the Power Distance dimension, which means that Greece is a country characterized as high Power Distance. The educational system in high Power Distance countries is teacher centered; anticipate teacher-student inequality with little questioning of authority (Hofstede, 1986; Spencer-Oatey, 1997). Students depend on teachers, who are considered to be gurus transferring personal wisdom. The quality of learning depends on the excellence of the teacher. The teachers, who are not questioned nor contradicted, initiate communication and the students speak up only when invited to do so. High Power Distance countries use less technology than low Power Distance countries, they have higher expectations on benefits of technology and in general they maintain a less critical attitude towards technology (Hofstede, 2001). Students in high Power Distance countries often feel role ambiguity and expect to be told what to do (Siakas & Mitalas, 2004).

Uncertainty Avoidance: Greece has the highest Uncertainty Avoidance score (112) of all the countries Hofstede used for his study (2001). The level of Uncertainty Avoidance determines the requirements of structures in the teaching and learning process. Students from high Uncertainty Avoidance cultures prefer structured teaching methods, tasks with clear outcomes, precise objectives, detailed assignments and no risks. They like to follow instructions and to have a strict timetable. They are motivated by security, fear of failure and they expect to be rewarded for accuracy. Self-efficacy is usually rated low (Hofstede, 2001). Students from high Uncertainty Avoidance societies also expect their teachers to be experts knowing the right answers (Hofstede, 2001; Hoppe, 1990). Teachers, who use cryptic academic language, are respected.

Masculinity vs. Femininity: Greece scores 57 on the Masculinity Femininity dimension, which means that Greece can be considered to be a Masculine society (Hofstede, 2001). In Masculine societies teachers' academic reputation and students' academic performance and excellence are dominant factors. Curriculum choices are guided by perceived career opportunities. Students try to make themselves visible in the class and compete openly with each other. The best student is considered to be the norm. Good students are awarded. Performance is usually overrated by the students themselves and the self (ego) boosted (Siakas & Mitalas, 2004). Students try to make themselves visible in the social media by posting and sharing knowledge and information. On the other side they also compete openly with each other and for that reason they may hide and obscure information and knowledge in order to be unique and get higher grades

Individualism vs. Collectivism: Greece scores 35 on the Individualism Collectivism dimension, which means that Greece is a collectivistic county (Hofstede, 2001). Purpose of education in the collectivist society is learning how to do in opposite to learning how to learn. Students' individual initiatives are discouraged. Students associate according to pre-existing in-group ties (in-group vs. out-group distinction). Teachers also deal with students as a group and students expect preferential treatment by teachers from their in-group. Students do not speak up in class or large groups and maintenance of 'face'[1] is important. Harmony should be maintained in the class and conflicts should be avoided (Siakas & Mitalas, 2004). Due to the collective characteristics of the Greek culture we believe that conversation is needed more in conventional ways such as talking face-to-face. If the social media is used by and in-group the sharing will be natural, otherwise it may need some time to build up the feeling of 'we' in the social media group.

Concluding we try to understand the power of each dimension on the opinions of the students. The Uncertainty Avoidance Dimension seems to be the most dominating dimension in the Greek culture due to the high score (112). It is likely that 'sharing' of material is considered the most important use of social media in HE due to the fact that social media provide a familiar forum with clear rules. We also need to take into consideration the free nature of social media. Due to the persisting financial crises (Dudin et al., 2016), students are looking for ways of finding material for free. Nowadays even the university libraries find it difficult to finance new resources. Another fact is that many students have to work simultaneously with their studies for financial reasons. This has led to the fact that many students due to lack of time practice surface learning instead of deep learning. Deep learning requires a willingness to thoroughly engage a topic or situation through a learning approach that is deep, opposed to surface learning that aims to get a degree, through a learning approach that is shallow and superficial. The need for students to develop critical thinking skills is indisputable, and the technological advantages of the information age have made information instantly available and readily accessible. Students know how to sift through large volumes of data in increasingly knowledge rich environments. Finding the "correct" or "best" information can, however, be problematic due to time needed, information clutter or insufficient sifting, sorting, or evaluation (Meeks et al., 2013). If the presence of the educator is obvious (needed in High Power Distance cultures) and enough time is given to the group using Social Media in HE in Greece for effective team building (in-group feeling needed in collectivistic cultures) the results are likely to be better. The

[1]Face is lost when the individual, either through his action or that of people closely related to him, fails to meet essential requirements placed upon him by virtue of the social position he occupies.

role of the educator is particularly important in Greece due to high power distance (top-down hierarchy) and uncertainty avoidance (structure needed) values.

Implications of Social Media functionality regarding sharing will be demonstrated below by an example of how an educator can initiate and motivate students to share educational content on social by media for improved learning and increased student satisfaction. In three of the modules at the department of Informatics of Alexander Technological Education Institute an experiment was introduced for investigating the outcomes of a different pedagogical approach. The students could voluntary choose to perform eight group-work assignment instead of final written exams. The groups that consisted of two-three students were asked, with clear rules and detailed instructions about the process, to investigate different subjects within the module curriculum. The students shared learning material and sources on social media, such as Google+, Dropbox and Facebook. The university annual internal assessments and interviews with students have shown that the students are very satisfied with the experiment of content and knowledge sharing. Also the average grades of the students that participated in the experiment were higher than the grades of those students that did not participate in the experiment. The students in the experiment considered that they get a deeper and wider insight in the subject under consideration. '*When reading for exams you read and try to figure out what exam questions there may be in the exams in order to pass the exam – by investigating in depth a certain subject and by sharing content you discover different viewpoints and as a natural outcome the subject become interesting*'. The experiment regarding functionality of social media in HE and sharing in particular proved that the students who participated in the experiment were more satisfied with the learning approach, they developed a higher level of critical thinking, they improved collaboration, sharing and presentation skills, hence, learning as an outcome was increased.

CONCLUSIONS AND FURTHER WORK

This paper discussed the adoption and use of social media in Higher Education (HE). The aim of the study reported was to identify the main factors and problem areas in the use of social media in HE, in particular functionality of Social Media in HE was analysed. Our study included a survey involving students of IT/IS in Greece. The Honeycomb model and the theory of external and internal motivation were identified to be suitable underlying theories for the study. The results showed that understanding content sharing is the most important issue in the planning of learning/teaching activities based on social media.

In the next phase of our research we are going to compare this data collected from Greece to data collected from Finland. In this way we can find the practices and recommendations for different cultures regarding the use of social media in education.

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Social Media Use and Digital Competence: An Empirical Study of First-Generation College Students and Their Peers

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ABSTRACT

This research focuses on the use of social media (SM) by first-generation college students and their peers, and compares how the SM use affects the digital competence of these two groups. To do so, we collected survey data from a sample of 106 students in a 4-year public university in the United States. The data analysis showed that overall, an increase in the SM use time had a positive effect on digital competence. However, findings are different between first-generation college students and their peers in that their digital competence is affected differently by SM access frequency and duration time.

KEYWORDS: Social Media, Digital competence, Digital literacy, First-generation students, Regression

INTRODUCTION

The stagnant upward mobility and postsecondary educational success of first-generation students have been a prevalent issue in the United States, especially during a time of booming economic growth and innovations in the science, technology, engineering and mathematics (STEM) field. First-generation students are undergraduates whose parents' highest level of education is a high school diploma or less (Nunez & Cuccaro-Alamin, 1998). This population of college students face economic, social, and cultural challenges in their college education. As first-generation students are from challenging economic backgrounds and are the first in their family to attend a postsecondary educational institution to attain a bachelor's degree, they are more likely to drop out of college compared to their better-equipped peers. For example, the 2008 Center for Education Statistics' Beginning Postsecondary Study revealed that "[l]ow-income, first-generation students were nearly four times more likely - 26 to 7 percent - to leave higher education after the first year than students who had neither of these risk factors" (Engle & Tinto, 2008, p. 2). The large difference in dropout rates conveys the disparity between first-generation students and their peers and brings to attention the need to put more focus into the research on strategies to support first-generation students' persistence and success in their college educational journeys.

With the numerous challenges that first-generation students face, several possible solutions have been proposed to promote educational success for these students, including the use of an early rigorous curriculum, providing financial aid for college, and encouraging engagement on the college campus (Eagle & Tinto, 2008). In recent years, with the increasing reliance on smart phones and computers for communication and collaboration, researchers are turning their attention toward social media as a factor in influencing a first-generation student's education success. For example, researchers from Royall & Company found that underrepresented student groups are more likely to rely on social media channels in their college search, with 27 percent of first-generation students selecting a college through online sites such as Facebook, Snapchat, and Instagram compared to only 17 percent of non-first-generation students (Kelly, 2017). In addition, researchers from Prairie View A&M University (Rahman, Ramakrishnan, & Ngamassi, 2017) have studied the impact of social media use on college students' learning and found evidence to show the positive impact of using social media on student learning outcomes.

We refer to the collection of information and communication technology for social media platforms as social technology, which is defined as "any technology that facilitates social interactions and is enabled by a communications capability, such as the Internet or a mobile device" (Gartner, 2017; p. 1). Similarly, we refer to the skills and knowledge that correspond with using the social media technology as digital competence.

Since social media is playing an increasing role in the educational success of first-generation students, there is an opportunity for colleges to improve their social media resources and investments. However, not much is known about how the use of social technology affects the digital competence of first-generation students.

To fill in the gap, in this study, we attempt to address the following two research questions: (1) What are the determinants of digital competence of first-generation college students? (2) What is the relationship between first-generation students' use of social media and their digital competence?

To answer the research questions, we collected survey data from a sample of 106 students in a 4-year public university in the United States. To develop the hypotheses, we drew upon digital literacy research (e.g., Dabbagh & Kitsantas, 2011; Ng, 2012) and studies of first-generation students (e.g., Engle & Tinto, 2008; Nunez & Cuccaro-Alamin, 1998). Our quantitative data analysis showed that overall an increase in the social media use in terms of duration time had a positive effect on the digital competence of the college students. However, findings are different between first-generation and their peers: the duration time on social media had a positive effect on the digital competence of first-generation students, but the frequency of social media access had a positive effect on their peers, those who are not first-generation students. In addition, household income and age were significant factors in the first-generation student data sample, but gender was significant in the non-first-generation students' data sample.

This paper is organized as follows. In the next section, we develop our hypotheses. Following that, we present the research methodology and our preliminary findings. We conclude the paper with discussion and implications.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Digital literacy is broadly defined as individual ability to embrace information and communication technologies (ICT), in particular the use of mobile phones and social media technology (Ng,

2012). Possessing a certain level of digital literacy is essential for success in the college education. The study of undergraduates at a university in Australia suggested that in general, college students are able to use a wide range of computer information technologies, including desktop computers, laptops and mobile technologies for texting, capturing information, researching on the Internet, and downloading music and video files, but it is important for higher education institutions to provide them with opportunities to use the technologies for meaningful purposes (Ng, 2012).

In this paper, we focus on individual ability to use social media technologies and platforms and tools, and define a person's ability to efficiently utilize social media technology for certain tasks such as gathering information or collaborating on projects as digital competence. Social media, one major component of digital technology, is important to students "as a channel for communication, collaboration, and creative expression" (Dabbagh & Kitsantas, 2011, p.3). Through the use of social media, students will become more familiar with navigating through online sites and posts. Furthermore, as a tool for the interconnectedness and expression of a multitude of different people, social media will provide students with exposure on how to use digital technology to access educational opportunities and keep up with important current events. Therefore, we hypothesize that:

Hypothesis 1: Use of Social Media has a positive effect on users' digital competence.

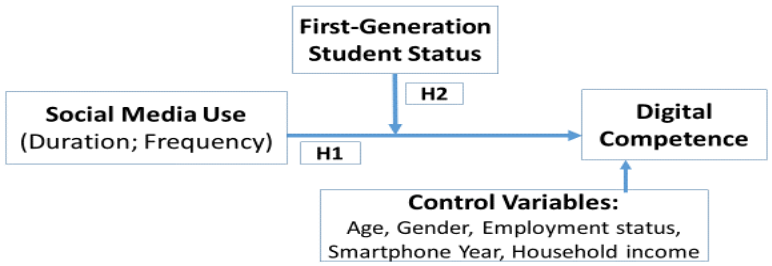
Social media is a great tool for students when searching for educational opportunities and being connected with others. Furthermore, it is beneficial in improving a student's familiarity with the uses of digital technology such as online collaborative projects and presentations. However, social media use can have a larger influence on a first-generation student's digital competence compared to those who are not first-generation students. This is because students that are not first-generation students may already have access to other resources for educational purposes such as their parents, tutors, or peers.

In contrast, first-generation students often encounter more barriers in their college education than their peers: they lack financial support from their family and have multiple obligations beyond their college responsibilities. Nunez & Cuccaro-Alamin (1998) outlined some of the barriers students face when completing their degrees: "poor academic preparation, family responsibilities, and full-time work, for instance, can pose severe challenges to a student's ability to integrate into postsecondary institutional life" (p.2). Although these factors are influential in determining a student's success in college, other factors that may often be overlooked are a student's experiences prior to postsecondary education, such as extracurricular activities and social experiences (Engle & Tinto, 2008). By missing out on such experiences, these students eventually lacked the necessary preparation and social exposure that would usually foster success in college. Since they often lack these resources, they often rely on self-regulated learning, the learning enabled by a student's ability to independently and proactively engage in self-motivating behavioral processes and aimed at attaining goals (Zimmerman, 2000). Such self-regulated learning relies greatly on social media use and digital competence. Thus, we hypothesize that:

Hypothesis 2: The relationship between social media use and digital competence is moderated by the status of first-generation students; the effect is bigger when users are first-generation students than those who are not.

Both hypothesis 1 and 2 are depicted in the research model in Figure 1 below.

Figure 1: Research Model



METHODS

Research Site and Data Collection

The research site is a four-year public, urban university located in the west region of the United States. As an ethnically and economically diverse university, the campus recently reports that 61% of its student population identify themselves as the first in their families to go to college. The survey was conducted online in November 2017 by freshmen who were expected to complete the survey in 10 minutes. The survey asked the students to identify themselves as "first-generation college students" or not. In addition, respondents to the survey were ensured that no names or personal identity information would be collected to protect their confidentiality. The survey included questions about their social media usage behavior, such as time spent on social media, frequency of using social media, and the list of social media accounts they have.

Table 1: Demographic Characteristics of Participants

		Non-FirstGen (n=18)	FirstGen (n=88)	Grand Total (n=106)
	Total	**17.0%**	**83.2%**	**100.00%**
Gender	Female	12.26%	62.26%	74.53%
	Male	4.72%	18.87%	23.58%
	Gender Non-Conforming	0.00%	1.89%	1.89%
Ethnicity	American Indian or Alaskan Native	0.0%	0.9%	0.9%
	Asian or Pacific Islander	3.8%	1.9%	5.7%
	Black or African American	3.8%	6.6%	10.4%
	Hispanic or Latino	4.7%	72.6%	77.4%
	White / Caucasian	4.7%	0.9%	5.7%
Employment Status	Employed full-time	0.9%	1.9%	2.8%
	Employed part-time	5.7%	19.8%	25.5%
	Not employed	10.4%	61.3%	71.7%
Household Income	1_Less than $25,000	5.7%	39.6%	45.3%
	2_$25,000 - $49,999	2.8%	34.0%	36.8%
	3_$50,000 - $74,999	5.7%	4.7%	10.4%
	4_$75,000 - $99,999	0.0%	1.9%	1.9%
	5_$100,000 or more	2.8%	2.8%	5.7%

The table below summarizes the demographic characteristics of the survey participants. A total data sample of 106 participants is analyzed and reported in this article. The majority of the 106 students surveyed, 83 percent, are first-generation students. 62.26 percent of all students are female and first-generation students. 72.6 percent of those students are Hispanic or Latino and first-generation students. 61.3 percent of those students are unemployed and first-generation students. 39.6 percent of those students have a family income of less than $25,000 and are first-generation students. 34 percent of those students have a family income between $25,000 and $49,999 and are first-generation students. All the percentages are based on the grand total of 106 respondents.

Model

The two items for digital competence are adopted from Ng (2012); the items were measured by using the 5-likert scale. These two questions are "*I can learn new social media technologies easily"* and *"I have the technical skills I need to use social media technologies for learning and to create artifacts (e.g., videos, digital stories, wikis, and blogs)"*. For each dimension, we code "strongly agree" as 5, "agree" as 4, "neutral" as 3, and "disagree" as well as "strongly disagree" as 2 and 1. As a result, the total rating for each measure ranges from 1 to 5. We took the average of the two items to measure an individual's overall digital competence.

We then measure social media use by access Frequency (*Frequency*) and use duration time (*Duration*). Our main model is Equation (1), which is estimated using the ordinary least squares (OLS) model for all students or for only the first-generation students. In the model, the control variables are Age, Gender, Employment Status, Years of having a Smartphone, and Household income.

$$\text{Digital Competence} = ß_0 + ß_1\, Frequency + ß_2\, Duration + ß_3\, Age + ß_4\, Gender + ß_5\, Employment + ß_6\, SmartPhoneYr + ß_7\, Household\_Income + \varepsilon \quad (1)$$

RESULTS

Descriptive Statistics

Distribution of Social Media Accounts by Participants

83.02% of all students own an Instagram. 68.87 percent of all students own an Instagram and are first-generation students. 82.1 percent of all students own a YouTube. 67.9 percent of all students own a YouTube and are first-generation students. 45.3% of all students own a Facebook. 35.8 percent of those students own a Facebook and are first-generation students, and 47.2 percent of those students don't own a Facebook and are first-generation students. In total, 87.7 percent of all students own a Snapchat. 73.6 percent of all students own a Snapchat and are first-generation students.

42.5 percent of all students own a Twitter. 32.1 percent of all students own a Twitter and are first-generation students. Only 16.0 percent of all students own a Pinterest. 11.3 percent of all students own a Pinterest and are first-generation students. Finally, 3.8 percent of all students own a LinkedIn. 2.8 percent of all students own a LinkedIn and are first-generation students. The distribution of social media account ownership is summarized in the table below.

Table 2: Distribution of Social Media Accounts by Participants (n=106)				
Social Media Account	Ownership?	Non-FirstGen	FirstGen	Grand Total
(1) Snapchat	YES	14.2%	73.6%	87.7%
	NO	2.8%	9.4%	12.3%
(2) Instagram	YES	14.1%	68.9%	83.0%
	NO	2.8%	14.2%	17.0%
(3) YouTube	YES	14.2%	67.9%	82.1%
	NO	2.8%	15.1%	17.9%
(4) Facebook	YES	9.4%	35.8%	45.3%
	NO	7.5%	47.2%	54.7%
(5) Twitter	YES	10.4%	32.1%	42.5%
	NO	6.6%	50.9%	57.5%
(6) Pinterest	YES	4.7%	11.3%	16.0%
	NO	12.3%	71.7%	84%
(7) LinkedIn	YES	0.9%	2.8%	3.8%
	NO	16.0%	80.2%	96.2%
Grand Total		17.0%	83%	100%

Percentages in this table and in tables 3&4 are based on the grand total of 106 respondents.

Among all these social media accounts, the three most popular types of social media are Snapchat, Instagram and YouTube with 87.7 percent, 83 percent and 82.1 percent respectively. The two least popular types of social media are Pinterest and LinkedIn with 16.0 percent and 2.8 percent respectively.

Social Media Use Patterns among Participants

Among all the first-year college students, the majority used social media every 2-3 hours (33.0 percent), followed by every 1 hour (23.6 percent). For the first-generation students, the pattern is similar with the majority using social media every 2-3 hours (27.4 percent), followed by an equal percent of first-generation students using social media every 1 hour and every 4-6 hours (17.0 percent). The distribution of social media access pattern is summarized in the table below.

Table 3: Patterns of Social Media Use by Participants (n=106)			
	Non-FirstGen	FirstGen	Grand Total
By Social Media Access Frequency			
Frequency1_Every 30 minutes	0.9%	15.1%	16.0%
Frequency2_Every 1 hour	6.6%	17.0%	23.6%
Frequency3_Every 2-3 hours	5.7%	27.4%	33.0%
Frequency4_Every 4-6 hours	3.8%	17.0%	20.8%
Frequency5_Every 7 hours +	0.0%	6.6%	6.6%
By Social Media Use Duration			
Duration1_Less than 1 hour	3.8%	17.0%	20.8%
Duration2_1-2 hours	5.7%	20.8%	26.4%
Duration3_3-4 hours	4.7%	21.7%	26.4%
Duration4_5 hours or more	2.8%	23.6%	26.4%
Grand Total	17.0%	83%	100%

As shown in the table above, the different amount of time students spend on social media is equally proportioned between 1-2 hours, 3-4 hours, and 5 hours or more (26.4 percent) and a

smaller percent of students using social media for less than 1 hour (20.8 percent). The pattern for first-generation students is slightly different with the largest percent using social media for 5 hours or more (23.6 percent).

Self-Assessment of Social Media Skills and Usage

Both first-generation students and non-first-generation students have about the same evaluations on how easily they can learn social media technologies. However, more non-first-generation students strongly believe that they have the technical skills to use social media technologies for learning than first-generation students with 27.8 percent and 21.6 percent respectively. These patterns in participants' self-evaluation are shown in the table below.

Table 4: Participants' Self-Assessment of Social Media Competence (n=106)			
	Non-FirstGen	FirstGen	Grand Total
Response to the statement: "I can learn new social media technologies easily.			
Agree	50.0%	42.0%	43.4%
Agree strongly	22.2%	27.3%	26.4%
Disagree strongly	0.0%	1.1%	0.9%
Neutral	27.8%	29.5%	29.2%
Grand Total	100%	100%	100%
Response to the statement; "I have the technical skills I need to use social media technologies for learning and to create artifacts (e.g., videos, digital stories, wikis, blogs)."			
Agree	27.8%	29.5%	29.2%
Agree strongly	27.8%	21.6%	22.6%
Disagree	0.0%	8.0%	6.6%
Neutral	44.4%	40.9%	41.5%
Grand Total	100%	100%	100%

Spearman Correlation

We have examined the spearman correlations for the variables used in our analysis. The highest correlation we observed is 0.21 between employment status and age, which does not raise any multicollinearity concerns for our regression model.

Main Results

Our main results are given in Table 5, Table 6 and Table 7. Table 5 is based on the first competence measure. Table 6 uses the second competence measure while the average of the two measures is considered in Table 7. Each table presents three sets of results: full sample, first-generation, and non-first-generation.

Table 5 demonstrates that when we focus on the full sample (again, based on the first competence measure), age is negatively associated with digital competence (-0.25, $p < 0.05$) and the duration time of using social media is positively related to digital competence (0.21, $p < 0.01$). When we look at the findings of the first-generation students, the results are similar to those in the full sample. However, when we switch our focus to the non-first-generation student group, gender (male compared to female, coefficient is 1.25, $p < 0.05$) and social media usage frequency (-0.44, $p < 0.10$) become the only two significant factors. However, given the small sample size of this group, this result needs to be interpreted with caution.

Table 5: Main Results based on the First Competence Measure			
	Full Sample	First-Gen	Non-First-Gen
Intercept	7.89*** (2.29)	9.05*** (2.81)	1.90 (4.72)
Gender_Male	-0.05 (0.18)	0.00 (0.2)	1.25** (0.41)
Age	-0.25** (0.13)	-0.34** (0.16)	0.12 (0.27)
Employed	0.13 (0.17)	0.10 (0.20)	0.29 (0.38)
SmartPhoneYear	0.05 (0.05)	0.08 (0.05)	0.08 (0.14)
Household_Income	0.05 (0.07)	0.11 (0.09)	-0.06 (0.15)
Social Media Frequency	-0.09 (0.07)	-0.04 (0.07)	-0.44* (0.20)
Social Media Duration	0.21*** (0.07)	0.21*** (0.07)	0.14 (0.21)
N	106	88	18
Adj R^2	0.11	0.11	0.45

Standard errors are in parenthesis, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We next turn our attention to the second measure and the aggregate measure of digital competence. The results are presented in Table 6 and Table 7 respectively.

Table 6: Main Results based on the Second Competence Measure			
	Full Sample	First-Gen	Non-First-Gen
Intercept	4.85 * (2.65)	7.54 ** (3.27)	2.58 (4.47)
Gender_Male	0.32 (0.21)	0.20 (0.24)	0.74* (0.39)
Age	-0.11 (0.15)	-0.27 (0.18)	0.13 (0.25)
Employed	-0.03 (0.20)	-0.01 (0.23)	0.29 (0.36)
SmartPhoneYear	0.06 (0.06)	0.04 (0.06)	-0.14 (0.14)
Household_Income	0.11 (0.08)	0.21* (0.11)	0.02 (0.14)
Social Media Frequency	-0.06 (0.08)	0.02 (0.09)	-0.42 * (0.19)
Social Media Duration	0.17** (0.08)	0.16 * (0.09)	0.19 (0.2)
N	106	88	18
Adj R^2	0.05	0.05	0.21

Standard errors are in parenthesis, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

First, our main results regarding the positive association between social media duration time and digital competence hold in both the second measure and the aggregate measure under the full sample and the first-generation group. In addition, the negative association between social media usage frequency and digital competence for the non-first-generation group also holds in both Table 6 and Table 7. We discuss the implications of these findings in the next section.

Table 7: Main Results based on the Aggregate Competence Measure			
	Full Sample	First-Gen	Non-First-Gen
Intercept	6.37 *** (2.21)	8.30*** (2.73)	2.58 (4.47)
Gender_Male	0.13 (0.17)	0.1 (0.2)	0.74 * (0.39)
Age	-0.18 (0.12)	-0.31 ** (0.15)	0.13 (0.25)
Employed	0.05 (0.17)	0.05 (0.19)	0.29 (0.36)
SmartPhoneYear	0.05 (0.05)	0.06 (0.05)	-0.14 (0.14)
Household_Income	0.08 (0.07)	0.16 * (0.09)	0.02 (0.14)
Social Media Frequency	-0.07 (0.07)	-0.01 (0.07)	-0.42 * (0.19)
Social Media Duration	0.19 *** (0.07)	0.18 ** (0.07)	0.19 (0.2)
N	106	88	18
Adj R^2	0.09	0.11	0.21

Standard errors are in parenthesis, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Overall, the main results from the regression analysis supported the first hypothesis on the positive role of social media use on digital competence, based on the duration time of social media use, as shown in the results of the full sample in Tables 5-7. This positive relationship holds in the sample of first-generation students (column 2, Tables 5-7), but not in the non-first-generation student sample (column 3, Tables 5-7). These results provide evidence to show that first-generation students benefit more from social media use in improving their digital competence, thus supporting the second hypothesis.

DISCUSSION

This research sought to investigate the behaviours and competence levels of social media use in first-generation college students and their peers, mostly at the age of 18 in their freshman year at college. The research findings indicate that social media use is pervasive among college students, regardless of their first-generation student status. More than eighty percent of the survey participants own the three most popular social media accounts: Snapchat, Instagram, and YouTube. About 4 out of 10 survey participants (39.6%) reported accessing social media every one hour or every 30 minutes, and half of the participants (52.8%) reported spending three or more hours daily on social media.

Participants in our survey provided us some examples on how they utilize social media platforms to search for educational resources online and to communicate with their classmates to share course-related information. These types of social media enabled activities were found beneficial to the college students in our study, as they explained:

> *Using social media is helpful to my study, because you can find videos and peoples experiences in certain areas that you're study. For example my disability class focuses a lot on films and social media.*

> *I will say social media helps because if the person is stuck on something, they can talk to one of their classmate or look up on YouTube on how to solve the problem they are stuck on.*

These responses by the students suggest that it's important for college students to develop skills in using social media. However, our study shows that only half of the participants (51.8%) in our data sample were confident about their competence in using social media technologies for educational purposes such as creating videos, digital stories, wikis, or blogs. On the other hand, 41.5 percent of the participants took a neutral stand on their competence in using digital technology (See Table 4). Participants in our study are first-year college students with ages between 17 and 21, with an average age of 18.1. They are all born after 1995; they are from the Generation Z, the segment of the population born between 1995 and 2010. Growing up in a world of smartphones and free Wi-Fi, young adults of this generation are assumed to be equally Internet-savvy and proficient in information and communication technology, especially those social networking applications such as Facebook, YouTube, Twitter, Instagram, and LinkedIn (Priestley, 2015). Our study shows that not all of the Generation Z college students are equally competent at using social media technologies for academic work. However, the regression analysis in our study has provided sufficient evidence to show the more time spent on social media, the more the digital technology competence of young adults' would improve.

Another important finding is that the social media access frequency is negatively associated with digital competence, and this negative effect is significant for the non-first-generation students (e.g., -0.42 at $p<0.1$ in Table 5, column 3). This may be partially explained by the distraction caused by frequent access to social media for entertainment purposes instead of educational purposes. Such uses of social media for entertainment purposes are reflected in the instances below:

> *I believe there may reach a point where social media interactions would become distracting. For example, if a student has many friends and all want to talk.*

> *I think that they are a good use to communicate with friends or professors, but there are times where social media could be distracting*

As social media use becomes pervasive among young adults, Generation Z, it is important for them to not only develop their competence with digital technology, but also to use that competence for meaningful activities that support their educational growth. The findings of this study suggest that it is time for higher education institutions to consider incorporating social media tools and platforms in the academic program design (e.g., course delivery channel, instructor feedback mechanism) to take advantage of the students' digital competence and to benefit from the technological affordances for communication and collaboration. For college students, they should focus on their purposeful use of social media to capitalize on an important educational resource.

Our finding may be limited by the organizational characteristics of the research site, the economically-diverse urban public university with majority of students are undergraduate students of first generations. Thus, the findings of this study should be applied to other types of higher education institutions with caution.

CONCLUDING REMARKS

Developing competence with social media technologies is important for the college students, especially first-generation college students who lack educational resources at home or in their own community. One Forbes article noted, “As a digital generation, Generation Z expects digital learning tools such as these to be deeply integrated into their education. For them, technology has always been a fully integrated experience into every part of their lives” (Kozinsky, 2017). One promising direction for future research is to conduct a longitudinal study to examine the role of social technology competence on the college persistence of first-generation students. Dennis and colleagues (2005) have suggested that support from peers, such as sharing notes, studying in groups, sharing learning strategies, made the biggest impact upon first-generation college students’ success in college. With such a widespread use of social media in today's society, social media platforms may provide a convenient tool for first-generation students to access and mobilize resources made available by their peers or teachers.

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DECISION SCIENCES INSTITUTE
Social Media Utilization in U.S Counties: A Spatial and Multivariate Analysis

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ABSTRACT

This paper analyzes the spatial distribution and socio-economic determinants of social media utilization in 3,109 counties of the United States in 2012. A theory of determinants is presented that is modified from the Spatially Aware Technology Utilization Model (SATUM). Socio-economic factors including demography, economy, education, innovation, and social capital are posited to influence social media utilization dependent variables. Spatial analysis is conducted including exploratory analysis of geographic distribution and confirmatory screening for spatial randomness. The determinants are identified through OLS regression analysis. Findings for the nation indicate that the major determinants are demographic factors, service occupations, ethnicities, and urban location. Further subsample analysis is conducted for the U.S. metropolitan, micropolitan, and rural subsamples. The subsamples differ most evidently in effects of ethnicities and construction occupations, and there are inverse effects of social capital at the micropolitan and rural levels. Exploratory spatial analysis generally indicates similar geographic patterns of use of social media nationally. We find that Twitter users are more heavily concentrated in southern California and have strong presence in the lower Mississippi region, while Facebook users are highly concentrated in Colorado, Utah and adjacent Rocky Mountain States. Social media usage is lowest in the Great Plains, lower Midwest, and South with the exceptions of Florida and the major southern cities such as Atlanta. The overall extent of spatial agglomeration is very high and is examined in detail for the nation and subsamples. The paper concludes by discussing the policy implications of the analysis at the county as well as the national levels.

KEYWORDS: Social media, spatial analysis, United States, counties, regression, spatial autocorrelation, and policy

INTRODUCTION

Access to ubiquitous and high speed internet is fundamentally impacting modern societies worldwide and impacting ways in which individuals, households, and businesses utilize the internet. In the United States, the digital divide is evolving (McHenry et al, 2017). The digital divide has been defined as “the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard both to their opportunities to access information and communication technologies and to their use of the Internet for a wide

variety of activities (OECD, 2011). The U.S. Department of Commerce National Telecommunications and Information Administration now publishes data not only on internet access but also on internet usage. In the U.S., internet adopters use the internet for myriad purposes – for e-communication (emailing, text messaging, social networking), e-commerce (making purchases online, paying bills online, and others), e-education and e-entertainment (watching podcasts, videos, listening to music), accessing health information online (retrieving health insurance records, interacting with physicians online), to more sophisticated forms of usage such as teleworking and interacting with household devices. Concurrently, attention in the extensive digital divide literature is gradually shifting from understanding and examining aspects of adoption of information and communications technologies (ICTs) to analyzing disparities in use (Sarkar, Pick, and Parrish, 2017) – referred to in the literature as the third-level (usage-, practices-, and application-oriented) digital divide.

In this paper, we examine the antecedents of social media utilization in the counties of the United States. Among person aged 15 years or older, 74.4% of Americans (153.7 million) used the internet for online social networking in November 2017 compared to 70.6% (137.3 million) in July 2015 (NTIA, 2018). This growth in the use of online social networking spanned demographic attributes such as age, gender, race and ethnicity, educational attainment, as well as economic variables such as employment status and family income. The growth in online social networking in the U.S. also spanned population density in urban versus rural areas. While the rate of growth varied (for example, 3.4% increase in online social networking in urban metropolitan areas versus 6.5% in rural areas between July 2015 and November 2017), it is clear that social networking among Americans using popular social media platforms is on the rise.

Given this increasing popularity in utilization of the internet for social networking in the U.S. spanning demographic and socioeconomic attributes of users, as well as their location, this paper examines demographic, socio-economic, governmental, and societal openness influences on social media adoption and utilization in 3,109 counties of the United States. Among social media platforms, we focus on Facebook, Twitter, and LinkedIn. The geographic unit of analysis of this study is U.S. counties. Apart from being the oldest form of government in the United States dating back to the 1600s, county governments administer their own economy, education, justice and public safety, health care, social services, transportation, and other services that directly impact the county residents. In addition, counties are often responsible for implementing a broad array of federal, state, and local programs including digital literacy initiatives. In the digital divide literature focusing on technology adoption and diffusion in the United States, the county has hardly been studied before. In fact, disparities in adoption and diffusion, but not utilization of ICTs in U.S. counties has been systematically addressed in only one prior study (Sarkar, Pick, and Rosales, 2016). Additionally, antecedents of social media usage in the U.S. has not been studied in prior literature.

Overall, our research questions are the following:
(1) What factors impact social media use in U.S. counties?
(2) How does social media use vary geographically across U.S. counties?
(3) What county-level policies regarding social media use stem from the findings of this research?

As internet use for social networking increases as part of broader tapestry of growing use of the internet in the U.S., the potential of social media to bridge demographic, social, economic, and locational disparities in some cases and to exacerbate differences in others remains a topic of

keen interest to researchers, practitioners, and policymakers in many fields. Situated in this context, the development and subsequent validation of a conceptual framework of social media utilization in U.S. counties is the central contribution of this paper. No prior study has examined associations of demographic, socio-economic, governmental influences, along with social capital and societal openness on social media adoption and utilization. Derivation of county-level policies to bridge gaps in internet usage for social networking is another related contribution. A novelty of this work is its spatial analysis of social media utilization patterns in U.S. counties, stemming from locational disparities in usage between urban versus rural users. This paper also represents a directional shift in the digital divide scholarly discourse due to its focus on utilization divide rather than adoption and diffusion divide of the internet in the U.S. This is another novelty of this work.

The remainder of this paper is organized into sections on Literature Review of broader county-level studies focused on the digital divide in the U.S., conceptual model of social media use, regression findings, spatial patterns of social media use, policy implications, limitations, and conclusions.

LITERATURE REVIEW OF SOCIAL MEDIA ADOPTION AND UTILIZATION

Academic work on examining various aspects of social media adoption, diffusion, utilization, and impacts is advancing rapidly. Given the proliferation of social media platforms such as Facebook, YouTube, WhatsApp, Instagram, Twitter, LinkedIn, Weibo, Snapchat to name a few, this is hardly surprising. In the digital divide context though, analysis of adoption, diffusion, and utilization of the internet for social networking and underlying disparities of social media use is largely novel.

Participation in social networking has been examined thorough a variety of lenses. Over the past few years, surveys and studies conducted by the Pew Research Center have shed considerable light on social media adoption and utilization patterns among Americans. A recent study (Pew, 2018) has shown that Facebook continues to remain as the dominant social networking platform in the U.S., followed by YouTube, which has many social elements, but is not recognized as a typical social networking platform. Frequency of use, reciprocity of use, issues related to content-trust and disparities stemming from demographic and socioeconomic differences have been cataloged. Incidentally, the role of gender, age, race/ethnicity, educational attainment, and related demographic attributes and socioeconomic variables such as income and employment, participation in the service sector workforce, and others have been the subject of numerous digital divide studies (Pick and Sarkar, 2015).

Diffusion of user-generated content in social media (Qiu, Tang, and Whinston, 2015) and peer influences on participation in social networking have also been the subject of recent studies (Lee, Qiu, and Whinston, 2016; Pearce and Rice, 2017). Such studies shed light on the important role that social capital has been argued to play in providing both material and skills access to those laggards who either do not have access to ICTs such as the internet or do not possess the skills to participate in online activities (Chen, 2013). In terms of examining peer influence and network formation, the study by Lee et al (2016) is notable since it found evidence of homophily in strategic network formation in a location-based social networking context. Pearce and Rice (2017) considered the tension between the digital divide nature and the capital-enhancing nature of social networking sites. Using a nationally representative sample of Armenian adults, this study found evidence of a digital divide between users and non-users of social networking, a modest divide between users of two primary social networking sites used

by Armenians – Facebook and an indigenous Armenian social networking platform, and a slight divide between engagement in capital-enhancing activities on the two primary social networking sites. Both studies (Lee et al., 2016; Pearce and Rice, 2017), recent Pew reports (Pew, 2018), as well as prior digital divide literature (discussed in Pick and Sarkar, 2015) are relevant and instructive and inform the inclusion of correlates of social media usage in the conceptual model of social media usage discussed in the next section.

County- or provincial-level studies of the digital divides in the United States are relatively rare, often due to the lack of reliable ICT adoption, diffusion, and usage data at such geographic unit of analysis. In a prior study examining correlates of ICT adoption in U.S. states, Pick, Sarkar, and Johnson (2015) found that social capital, education, societal openness, urbanization, and ethnicities are significantly associated with ICT utilization. Facebook and Twitter users per capita – two key dependent variables in the study were however found to be not associated with urbanization but positively associated with per capita immigrant population – indicating likely contagion spurred by social contact within respective immigrant communities. Pick and Azari (2005) analyzed socioeconomic influences on technological levels for 164 counties in the United States. While social media adoption or use was not among the study's ICT dependent variables, it revealed that important correlates of technology sectors are professional/scientific/technical services workforce, other services workforce, household income, federal grant funds, college education, and ethnicity. A handful of prior studies have examined citizen engagement via e-government portals of U.S. counties (Huang, 2006, 2007; Manoharan, 2012). Broadband and high-speed internet digital divides in U.S. counties have been the subject of reports of the U.S. federal government (The White House, 2015). Internet diffusion in U.S. counties has been examined through a socioeconomic and geographic lens by Khatiwada and Pigg (2015) using a large sample of 3,000 U.S. counties; yet this study does not include social media adoption or use variables. Overall, the digital divide of internet use for social networking at the provincial level is absent in prior literature. This is the first systematic attempt to examine the influences of demographic, socio-economic, social capital, employment, and innovation on social media utilization in U.S. counties. The study is further enriched by geographic analysis of spatial patterns of social media usage; this provides vital clues about discrepancies in social media usage between demographically and socio-economically diverse metropolitan, micropolitan, and rural U.S. counties.

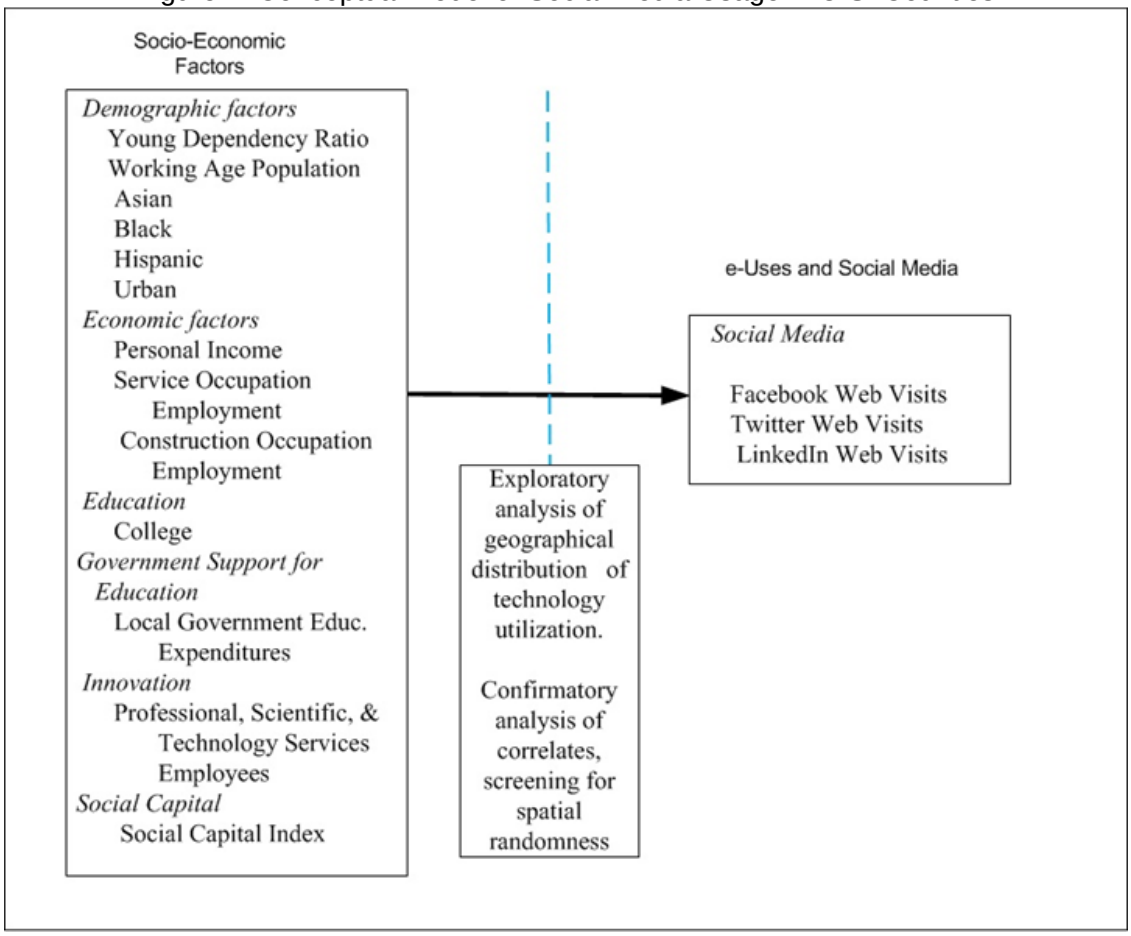
CONCEPTUAL MODEL OF SOCIAL MEDIA USE

The paper's conceptual model is drawn from the Spatially Aware Technology Utilization Model (SATUM), which is appropriate for research on composite influences of various social, economic, and political determinants on ICTs, which can include social media variables. SATUM is based on a large literature of studies, mostly of nations, but also of states, provinces, prefectures, and EU economic units (Nishida, Pick, and Sarkar, 2015; Pick, Sarkar, and Johnson, 2015; Pick and Sarkar, 2015; Vicente and Lopez, 2011). SATUM also has spatial relationships as components, so a research study can assess the extent of spatial bias in multivariate statistical analysis and can perform spatial cluster analysis and other spatial techniques (Farkas et al., 2017). The present study's SATUM-based model is depicted in Figure 1.

Demographic influences: Prior studies have documented an urban-rural differential for ICT utilization. NTIA provided evidence of such a differential for households using broadband in the home; rural households were found to trail their urban counterparts by 10 percent in 2010 (NTIA, 2011). It has been reasoned that more populous, wealthy urban regions in metropolitan

areas with higher levels of educational attainment and higher median home values are more likely to have greater demand for broadband services. We posit that percent of urban population is associated social media utilization in US counties. Evidence of significant disparities in broadband usage at home by different racial/ethnic groups has also been documented; in 2010, Whites and Asians led Black and Hispanic households in broadband use by at least 18 percent (NTIA, 2011). Due to the disparity in internet access due to race and ethnicity we propose that race and ethnicity are associated with technology utilization in US counties; for Asians the association is posited as positive, and for Blacks and Hispanics the association is posited as negative.

Figure 1. Conceptual Model of Social Media Usage in U.S. Counties



Economic influences: Economic factors such as income, integration in the global economy, international trade openness, R&D, degree of economic openness, and GDP have been widely cited to influence ICT diffusion and utilization. Unemployed Americans, aged 16 years or older lag their employed counterparts in broadband usage by more than 10 percent in 2010 (NTIA, 2011). Income-based adoption disparity among individuals in the US for broadband has been documented: in households with annual income of $75,000 or more, 97 percent of individuals used the Internet, compared to 72 percent in households with $30,000 or less income (Perrin and Duggan, 2015). Hence, we posit that personal income per capita is associated with social media use in US counties. Construction costs, specifically installation and maintenance costs were found to be associated with the probability of cell tower location for a spatial econometric

study of cell phone coverage in sub-Saharan Africa. We argue that in the US, the construction sector will impact the physical and infrastructural aspects of ICT development. Therefore, we posit that services sector employment, and construction sector employment are associated with technology utilization in US counties.

Education influences: There is widespread evidence of the influence of education on ICT access and utilization. While adults with at least a Bachelor's degree are very likely to use broadband internet at home (almost 85 percent in 2010), the level of utilization drops rapidly to slightly more than 50 percent for individuals with a high school diploma (NTIA, 2011). In 2013, 93 percent of college graduates used the Internet, versus 50 percent for less than high school education (Perrin and Duggan, 2015). Other education correlates such as level of educational attainment, enrollments in tertiary education, and expenditures per student have been found to be significantly associated with internet use, broadband access, and personal computer use. Accordingly, we posit that college graduation is associated social media use. Government spending on education has been found to be associated with PCs, ICT expenditure, and ICT infrastructure quality (Author, 2008). Therefore, we also posit that local government education expense is associated with social media use.

Innovation influences: Innovation has impacted ICT utilization in some prior research. It can lead to more appealing and productive technology devices and services that increase usage. For instance, as social media capabilities and ease of use have improved through innovation, more users have tended to adopt it. In one study of the uses of several types of technologies for a worldwide sample of nations, innovation measured by scientific articles per capita was the most important independent variable (Author, 2008). Its importance has also been shown for in Asian nations (Quibria et al. 2003). Professional, scientific, and technical services workforce has been found to be significantly associated with receipts and payroll in three technology sectors (Author, 2005). The rationale was such a services sector is comprised of scientists, engineers, medical and health professionals, university researchers, lawyers and attorneys, who are naturally inclined towards innovative technology and are likely to be consumers of ICTs for research and development purposes. Accordingly, we propose that professional, technical, and scientific services employees per capita, as a proxy for innovation, is associated with social media use.

Social capital influences: Social capital is the scope of ties and linkages in a population through physical and communication means and well as by organizations that foster human collaboration or by bonding between people who possess resources (Putnam, 2001; Rupasingha, Goetz, and Freshwater, 2006). It was a key factor in a study of the digital divide for a survey sample of individuals in the US (Chen, 2003), as well as in a two-stage nationwide study of the decisions by persons to go online, subject to peer influences (Agarwal, Animesh, and Prasad, 2009). Thus, we propose that social capital is related to usage of social media.

The dependent variables are three social media usage attributes of number of Facebook, Twitter, and LinkedIn website visits over a 30-day period. Facebook and Twitter subscription have been included in previous digital divide studies (Pick, Sarkar, and Nishida, 2014; Pick Sarkar, and Johnson, 2015).

STUDY DESIGN, METHODOLOGY, AND DATA

Data

Data on various dependent and independent variables for this study were collected from multiple sources. Data on independent variables such as population, ethnicity, employment, income, governmental support for education, and sales revenue generated by publishers were obtained from various Census sources such as the US Decennial Census 2010, surveys conducted by the US Census Bureau such as the American Community Survey (ACS) of 2012, Local Education Agency (School District) Finance Survey of the National Center for Education Statistics of 2009, and US Economic Census of 2007. Data on US county-level social capital come from Pennsylvania State University's Northeast Regional Center for Rural Development (Rupasingha and Goetz, 2008). While data for several independent variables are obtained for the period 2010-12, social capital data are from the year 2009 which is the latest year for which such data are available. For dependent variables, data on the three social media dependent variables, usage of Facebook, Twitter, and LinkedIn, were extracted from Esri's Business Analyst software (Esri, 2014). Esri computes estimates of these dependent variables by combining 2013 geodemographic segmentation data with Doublebase® 2012 data from GfK MRI. Doublebase® 2012 data consist of an integration of information from four consumer surveys. The relevant data collection and estimation methodology statement for dependent variable data extracted from Esri's Business Analyst can be found at Esri (2015).
Usage of such data for US digital divide studies is unprecedented in the literature. Since all dependent variables, except for three, were from the three-year period 2010-12, time simultaneity has been assured for them. The fact that data for three of the independent variables lags by 3-5 years is justified as follows. Professional, scientific, and technical services employees are from the Economic Census of 2007, which was the latest date at which the variables were available. The 2009 variables of local government educational expenditures and social capital derive from specialized sources that do not have recent release dates. We feel the one-year lag for the period 2010-2012 is acceptable for these two variables, since they are not known to change rapidly year-to-year. All variables were converted to per capita whenever possible; variable definitions, sources, and descriptive statistics (N = 3,109 counties) of the dependent and independent variables are in Table 1.

Methodology

The methodology comprised techniques of descriptive statistics, correlation analysis, mapping of variables using a geographic information systems (GIS), testing spatial autocorrelation for the social media dependent variables, and ordinary least squares regression (OLS). For descriptive statistics, mean and standard deviations were computed for dependent and independent variables, in order to gauge the averages and extent of variation for all U.S. counties (Field, 2009). Correlation analysis was applied in order to screen the independent variables for multi-collinearity (Field, 2009, Hair et al., 2010).

Geographic Information Systems (GIS) can be utilized as an exploratory method to spatially describe and understand patterns of distribution of variables (Longley et al., 2011). In this investigation, GIS mapping is done to observe outlying values for the variables, with focus on the social media dependent variables. Given our sample of 3,109 counties, map displays reveal key trends, without overloading the display.

Table 1. Definitions and Descriptive Statistics of Dependent and Independent Variables

Abbreviation	*Name of Dependent Variable*	*Source*	*Year of Data*	*Definition*	Min	Max	Mean	SD
FACEBOOKR	Visited website in last 30 days: facebook.com	BA	2010-2012	Facebook per capita	0.20	0.69	0.40	0.06
LINKEDINR	Visited website in last 30 days: LinkedIn.com	BA	2010-2012	LinkedIn per capita	0.01	0.19	0.03	0.02
TWITTERR	Visited website in last 30 days: twitter.com	BA	2010-2012	Twitter per capita	0.02	0.14	0.04	0.02
Variable	*Name of Independent Variable*	*Source*	*Year of Data*	*Definition*				
YOUNGDEPR	Young Dependency Ratio	CENDEC10_DP01	2010	**POP0-19/POP20-64**	0.17	0.88	0.45	0.07
COLLEGER	College Graduates or Higher, Age 18+	CENACS10_DP02	2008-2012	Population Estimate of College Graduates or Higher, Age 18+	0.03	0.54	0.13	0.06
PINCPC12	Personal Income Per Capita	BEA_CA1-3	2012	Personal Income Per Capita	17264.00	116843.00	36523.76	9182.78
WKAGEPOP	Working Age Pop (Pop. 20-64)/Total Population	CENDEC10_DP01	NA	**POP20-64/TOTPOP**	0.46	0.74	0.58	0.03
SERVICER	Service Occupations	CENACS10_DP03	2008-2012	Persons 16+ in Service Occupations, per capita	0.03	0.21	0.10	0.02
CONSTRUCTR	Construction Industry, Employed Persons 16+	CENACS10_DP03	2008-2012	Construction Industry, Employed Persons 16+, per capita	0.00	0.16	0.04	0.01
ASIANR	Asian Population	CENDEC10_DP01	2010	Asian Population per capita	0.00	0.36	0.01	0.02
BLACKR	Black Population	CENDEC10_DP01	2010	Black Population per capita	0.00	0.86	0.10	0.15
HISPANICR	Hispanic/Latino Population	CENDEC10_DP01	2010	Hispanic/Latino Population per capita	0.00	0.96	0.08	0.13
URBAN	Urban Population	CENDEC10_DP01	2010	Urban Population per capita	0.00	100.00	41.48	31.44
LGOVEDEXPR	Local Govt Education Expenditures	NCES_F33	2009	Total Expenditures (see variable definition document for more information)	69.57	36664.34	1985.97	1144.67
PSTSVCEMPR	Professional, Scientific, and Tech Services Employees	CENECON07	2007	Number of Professional, Scientific, and Technical Services Employees	0.00	0.18	0.01	0.01
FACTORAVE	Transformed Social Capital	Rupasingha and Goetz, 2008	2009	US County Social Capital	0.00	0.47	0.17	0.04
	SOURCES	Abbrev	Detailed Reference					
	US Census Bureau, DEC 2010, Table DP-01	CENDEC10_DP01	US Census Bureau, Decennial Census 2010, Summary File 1					
	US Census Bureau, ACS 2012, Table DP-02	CENACS12_DP02	US Census Bureau, American Community Survey 2012, 5-year estimates, Table DP-02					
	US Census Bureau, ACS 2012, Table DP-03	CENACS12_DP03	US Census Bureau, American Community Survey 2012, 5-year estimates, Table DP-03					
	US Census Bureau, ACS 2012, Table DP-04	CENACS12_DP04	US Census Bureau, American Community Survey 2012, 5-year estimates, Table DP-04					
	US Census Bureau, ACS 2012, Table DP-05	CENACS12_DP05	US Census Bureau, American Community Survey 2012, 5-year estimates, Table DP-05					
	Federal Communications Commission, Form 477	FCC_477	Federal Communications Commission, Form 477, Local Telephone Competition and Broadband Deployment					
	Bureau of Economic Analysis, CA1-3	BEA_CA1-3	US Dept of Commerce, Bureau of Economic Analysis, CA1-3, Personal Income, Per Capita Income					
	Bureau of Economic Analysis, CA04	BEA_CA04	US Dept of Commerce, Bureau of Economic Analysis, CA04, Personal Income Summary					
	US Census Bureau, Economic Census 2007	CENECON07	US Census Bureau, Economic Census 2007					
	US Department of Commerce, NTIA, State Broadband Initiative, Analyze Table	NTIA_SBI_Analyze	US Dept of Commerce, National Telecommunications and Information Administration, State Broadband Initiative (CSV format December 31, 2012).					
	National Center for Education Statistics, F-33	NCES_F33	US Census Bureau, Governments Division, Local Education Agency (School District) Finance Survey (F-33), National Center for Education Statistics, Common Core of Data					
	esri Business Analyst Data	BA	esri Business Analyst Data, GfK MRI DoubleBase Survey 2012					
	Rupasingha and Goetz, 2008	---	Pennsylvania State University's Northeast Regional Center for Rural Development					

A key question is this study is whether social media usage in US counties shows statistically significant patterns of agglomeration of high and low values, or is social media usage in US counties spatially randomly distributed. We diagnose spatial autocorrelation – a common problem plaguing many technology diffusion datasets using Moran's I test statistic. The Moran's I test is inferential; the null hypothesis is that the values of a variable are randomly distributed spatially. Its interpretation is done by the p value for statistical significance (if p is not significant,

the variable is randomly distributed spatially). Further, if the Z score is positive, the values of a variable are more geographically agglomerated (high values located near high ones and low values near low ones). If it is negative, the spatial pattern resembles a “checkerboard” pattern, in which high values are surrounded by low ones and vice versa (Moran, 1950; Openshaw, 1984).

Following the mapping analysis, ordinary least squares (OLS) regressions were performed for each social media usage dependent variable, in stepwise order, allowing in only those of the independent variables with significance levels of equal or less than 0.05. As an additional test of multi-collinearity, the variance inflation factor (VIF) was computed for each independent variable. We utilized the common cut-off of 5 or greater for VIF to be of concern (Myers, 1990) and no multicollinearity problems were detected. Three diagnostic tests were administered to ensure that regression assumptions were met. Joint Wald Statistic is a test of the joint significance of several coefficients of individual independent variables (Wald, 1943). The Koenker (BP) Statistic Test is a test for heteroscedasticity, i.e. the variance of the residuals is not constant (Lyon and Tsai, 1996). The Jarque-Bera Statistic is a goodness-of-fit test of whether sample data, in this case regression residuals, have skewness and kurtosis that correspond to a normal distribution (Jarque and Bera, 1980). Additionally, regression residuals were tested for the presence of spatial bias using Moran’s I test statistic. Model relationships which result in spatially random errors are regarded as valid. If errors in the model fit are spatially autocorrelated, it implies that the geographic forces are exogenous to the conceptual model. In case Moran’s I testing indicates that regression residuals are not spatially randomly distributed, regressions results have to be treated with caution.

REGRESSION FINDINGS

The regression findings for the entire country indicate that the most important determinants for the three social media variables are college graduation, young dependency ratio, proportion working age population, and percent urban. As seen in Table 2, the most important determinant is college education. This is in concert with other studies of U.S. counties (Author, 2005), household surveys of the U.S. (Chen, 2013), sample of U.S. states (Author, 2015), and international samples of nations (Baliamoune-Lutz, 2003; Yates et al., 2011). The mechanism may be that college educated people tend to be more conversant with social media through greater exposure to ICTs and the web during their years of education. That LinkedIn has the strongest education effect may be due to the enhanced presence of college educated users of LinkedIn compared to Facebook and Twitter.

Demographic influences on ICT and social media have been reported in studies of Japan (Author, 2014) and the U.S. (Author, 2015). In the present study, both young dependency ratio and urban are positive; while for Japan, farm population is associated with reduced ICT usage including Facebook and Twitter, which implies that percent urban would increase them. On the other hand, young dependency ratio reduced some ICT variables and Twitter. This somewhat surprising finding is ascribed to young families being located in Japan mostly in rural areas, which would tend to have lower ICT and social media use.

Working age population has a strong positive correlation for all three social media indicators. This finding differs from the unimportance of proportion employed civilian workforce in a regression study of the U.S. states (Author, 2015). Service occupation is significantly associated with Facebook and Twitter use, although less strongly that for overall workforce. The findings on service occupations correspond to the importance of professional and service

occupations for payroll and receipts in most technology sectors for U.S. counties in 1997-2000 (Author, 2005) and to the significant relationship of employment in services to technology level for 164 European Union sub-national regions in 27 European nations (Vicente and Lopez, 2011).

Table 2. OLS Regression Findings for Socio-Economic Determinants of Social Media Variables, 2010-2012, Country and Metropolitan Samples

	(Lower 48) Country			Metropolitan		
Independent Variable	FACEBOOK	TWITTER	LINKEDIN	FACEBOOK	TWITTER	LINKEDIN
Young Dependency Ratio	0.352***	0.357***	0.195***	0.493***	0.331***	0.225***
College Graduates or Higher, Age 18+	0.443***	0.353***	0.591***	0.627***	0.575***	0.761***
Personal Income Per Capita						
Working Age Pop (Pop. 20-64)/Total Population	0.350***	0.348***	0.267***	0.481***	0.414***	0.232***
Persons 16+ in Service Occupations	0.087***	0.092***		0.168***		
Persons 16+ in Construction Occupations					-0.209***	
Asian		0.135***	0.169***			0.173***
Black	-0.261***	0.181***		-0.178***	0.169***	
Hispanic	-0.249***			-0.154***	0.176***	
Urban	0.365***	0.272***	0.183***	N/A	N/A	N/A
Local Govt Education Expenditures						
Professional, Scientific, and Tech Services Employees						
Social Capital						
# of vars entered	7	7	5	6	6	4
Adjusted R-squared	0.760***	0.741***	0.820***	0.742***	0.755***	0.885***
Sample Size	3109	3109	3109	1161	1161	1161
OLS Regression Tests						
Joint Wald Statistic	7592.998***	6197.461***	7132.232***	1938.830***	2916.017***	5654.608***
Koenker (BP)	268.437***	228.120***	362.019***	33.406***	28.579***	90.485***
Jarque-Bera	616.561***	15713.923***	18055.782***	260.933***	1860.032***	121.843***
Spatial autocorrelation of dependent variable						
Moran's I	0.421***	0.363***	0.674***	0.434***	0.709***	1.168***
Spatial autocorrelation of regression residuals						
Moran's I	0.433***	0.030	0.107	0.286***	0.163**	0.252***
	* Signif. at 0.05, ** signif. at 0.01, *** signif at 0.001.					

For the U.S. county sample, urban location is related to usage for all three social media variables, although its strength of association is highest for Facebook, followed by Twitter and LinkedIn. This may be the result of Facebook, versus Twitter and LinkedIn, having more areas of low use in rural regions including Appalachia, the lower South, and the southeast border area of Texas. The finding contrasts with lack of urban correlation for Facebook and Twitter for the U.S. states in 2010 (Author, 2015). However, it is similar to the finding for Japanese prefectures of an inverse relationship of proportion farm population with Facebook and Twitter users per capita in 2009-2010 (Author, 2015). The lack of effect for U.S. states might be due to the larger unit of analysis, i.e. state versus county, not being fine-grained enough to register the

differences in and around the numerous American metropolitan areas. However, the finding corresponds to a survey study for the U.S. in 2010, in which 78 percent of urban adults used the Internet, versus 70 percent for rural dwellers (Perrin and Duggan, 2015, page 9).

The findings for influences of ethnicities varied among the three social media variables. For Facebook there is inverse association with Blacks and Hispanics, while for Twitter there is association with Asian and Blacks, and for LinkedIn association is present with Asian. We reason that Asian has generally opposite effect from Blacks and Hispanics, with Twitter being an exception for Blacks. This is based on other studies with similar findings (Perrin and Duggan, 2015; Author, 2015). For American adults in 2010, percent that used the Internet varied from 90 percent for Asians to 71 percent for Hispanics and 68 percent for Blacks (Perrin and Duggan, 2015, page 7). For U.S. states in 2009-2010, findings for contemporary technologies indicate positive association of Asians to a variety of ICT variables, while Hispanics associations are inverse. This included a positive Asian association and inverse Hispanic association with Facebook users, although no effects were evident for Twitter users (Author, 2015).

The results for the metropolitan, micropolitan, and rural subsamples largely correspond to those for the nation as a whole (Tables 2 and 3). Accordingly, only major differences from country-wide findings are noted here for the subsamples.

Metropolitan subsample: The main difference from the national results is an inverse relationship of construction occupations with Twitter Use. This finding was not noted at the state level in 2009-2010 for Twitter or Facebook (Author, 2015). A possible indirect explanation is that areas having a high proportion of construction workers tend to be less educated and of lower income, which are known to decrease social media use. The direct effect related to the impacts of construction occupations is unexplained.

Micropolitan subsample: For the micropolitan subsample, there is a stronger association for the service occupations on all three social media variables than for the country or metropolitan samples, although correspondence to rural sample results. It may be that in the smaller cities and towns of micropolitan or rural America, there are proportionately more service workers, so with more presence, their influence on social media is greater. Another explanation is that social media may be a more important form of services communication between service workers and spread-out or even isolated service customers.

Social capital unexpectedly reduces Twitter and LinkedIn use. This is contrary to prior reported positive effects, at the U.S. state level, of social capital on desktop, internet, and positive effect broadband use and of the social-capital proxy variable of immigrant population on Facebook and Twitter (Author, 2015). We reason the influences for LinkedIn and Twitter are attributed to a substitution effect, in which those counties having strong social capital have lower average need for citizens to access LinkedIn, since those with a strong physical social network, usually mostly local or regional in extent, have less need for the worldwide professional networking of LinkedIn or social networking of Twitter. Facebook may be more valuable to users than Twitter or LinkedIn on a local basis, since it can contribute more to supplementing (rather than substituting for) existing physical networking. The positive effect of professional/scientific/technical workforce, limited to only LinkedIn, is due to LinkedIn's market emphasis on business and professional people. The inverse effect on Facebook of local government education expenditures is unexplained.

Rural subsample: This subsample's inverse association of social capital with LinkedIn corresponds to the explanation just given for micropolitan. Likewise, there is the positive effect

of professional/scientific/technical workforce on social media corresponds to the nation. The inverse effect on LinkedIn of local government education expenditures is unexplained.

Table 3. OLS Regression Findings for Socio-Economic Determinants of Social Media Variables, 2010-2012, Micropolitan and Rural Samples

	Micropolitan			Rural		
Independent Variable	FACEBOOK	TWITTER	LINKEDIN	FACEBOOK	TWITTER	LINKEDIN
Young Dependency Ratio	0.545***	0.584***	0.338***	0.318***	0.619***	0.180***
College Graduates or Higher, Age 18+	0.385***	0.516***	0.725***	0.355***	0.187***	0.355***
Personal Income Per Capita						
Working Age Pop (Pop. 20-64)/Total Population	0.457***	0.539***	0.435***	0.202***	0.414***	0.222***
Persons 16+ in Service Occupations	0.175***	0.198***	0.160***	0.121***	0.161***	0.261***
Persons 16+ in Construction Occupations		-0.177***	-0.108***			0.089***
Asian	0.217***	0.130***		0.234***	0.125***	0.172***
Black	-0.291***	0.251***		-0.397***	0.258***	
Hispanic	-0.343***			-0.244***		
Urban	N/A	N/A	N/A	N/A	N/A	N/A
Local Govt Education Expenditures	-0.125***					-0.118***
Professional, Scientific, and Tech Services Employees			0.058**			0.086***
Social Capital		-0.087**	-0.111***			-0.152***
# of vars entered	8	8	7	7	6	9
Adjusted R-squared	0.694***	0.697***	0.771***	0.505***	0.361***	0.372***
Sample Size	637	637	637	1311	1311	1311
OLS Regression Tests						
Joint Wald Statistic	894.903***	779.111***	424.397***	1004.646***	213.198***	149.722***
Koenker (BP)	72.313***	112.968***	127.845***	244.571***	190.195***	256.122***
Jarque-Bera	116.315***	420.707***	1504.491***	89.059***	18472.807***	70571.308***
Spatial autocorrelation of dependent variable						
Moran's I	0.352	-0.178	-0.022	0.335***	-0.160*	0.105
Spatial autocorrelation of regression residuals						
Moran's I	0.853	0.128	0.770	0.077	-0.269***	-0.020
	* Signif. at 0.05, ** signif. at 0.01, *** signif at 0.001.					

Before concluding this section, it is important to observe that all coefficients in the regressions (results in Tables 2 and 3) are statistically significant at the .001 level. This is due to the large overall sample (n = 3,109 counties) as well as sub-sample sizes of metropolitan (n = 1,161), micropolitan (n = 637) and rural (n = 1,311) counties. It is therefore essential to examine the magnitude of the standardized coefficients to determine which independent correlates have higher associations with social media usage. Further, given the large sample size fallacy, it is important to focus on effect size (Lantz, 2013; Sullivan and Feinn, 2012). According to Sullivan and Feinn (2012), the adjusted r-squared is an acceptable effect size index for studies that examine associations between variables. Adjusted r-squared values range between approximately 0.50 and 0.90 in this study with a couple of exceptions: for Twitter and LinkedIn in the rural subsample. Such effect size is characterized as large (Sullivan and Feinn, 2012) indicating that large sample size fallacy (Lantz, 2013) has been addressed.

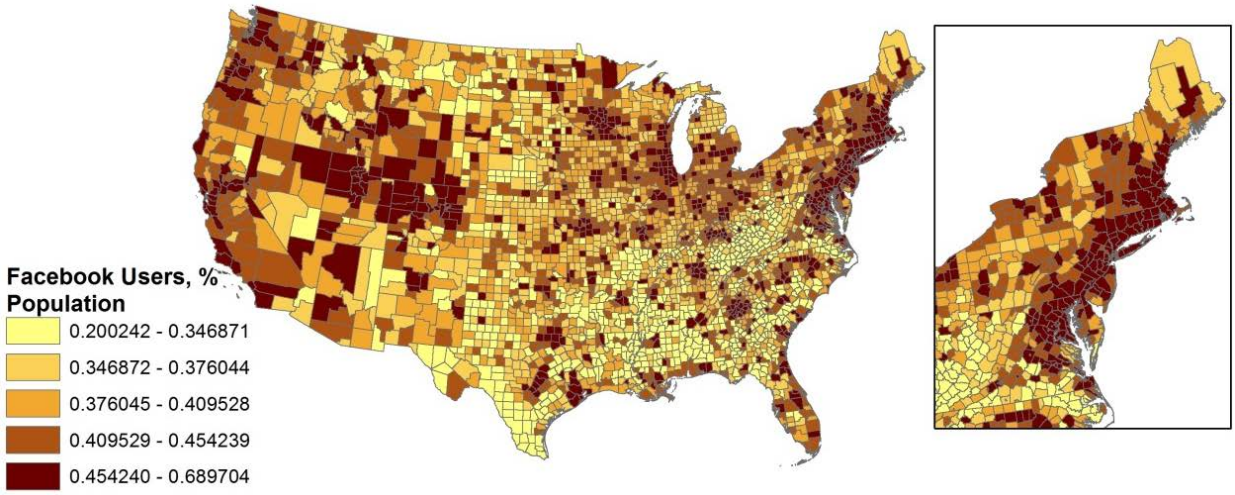
SPATIAL PATTERNS OF SOCIAL MEDIA USE

In this section, the descriptive maps for the three social media variables are examined and interpreted, as well as the spatial autocorrelation findings. Since the maps show 3,109 counties, it is beyond the scope of this paper to examine their many hundreds of descriptive features, relationships, and differences, and accordingly this paper points only to the most prominent features nationally.

For Facebook (Figure 2), the findings show considerable range of percentage Facebook use, ranging from low use (20-35 percent) to high use (45 to 69 percent). Low levels are most evident in the southwest Texas border area, rural parts of the Great Plains stretching north-south from the Dakotas to Texas, the mid to lower-central South and in Appalachia and rural, inland parts of the Carolinas and Georgia. High areas of use are seen in the Boston to Washington megalopolis (see cutout on Figure 2), Atlanta, Chicago-Milwaukee, Minneapolis, Denver and Salt Lake City metropolitan areas, Seattle and Portland metro areas, San Francisco-San Jose, and parts of Southern California (i.e. San Luis Obispo, Santa Barbara, Orange, and San Diego Counties), but excluding Los Angeles County. This finer geographic detail was missing in a prior study's state map of Facebook users (Author, Figure 2), which for instance did not show the prominent features evident at the county level for Boston-Washington megalopolis, southwest Texas or Appalachia. Overall, these findings reflect the positive influence of location in large and creative metropolitan areas and reducing effect of poor and remote rural counties. The high Facebook levels in Denver, southern Wyoming, Salt Lake City, and surrounding Rocky Mountain areas have not been previously reported.

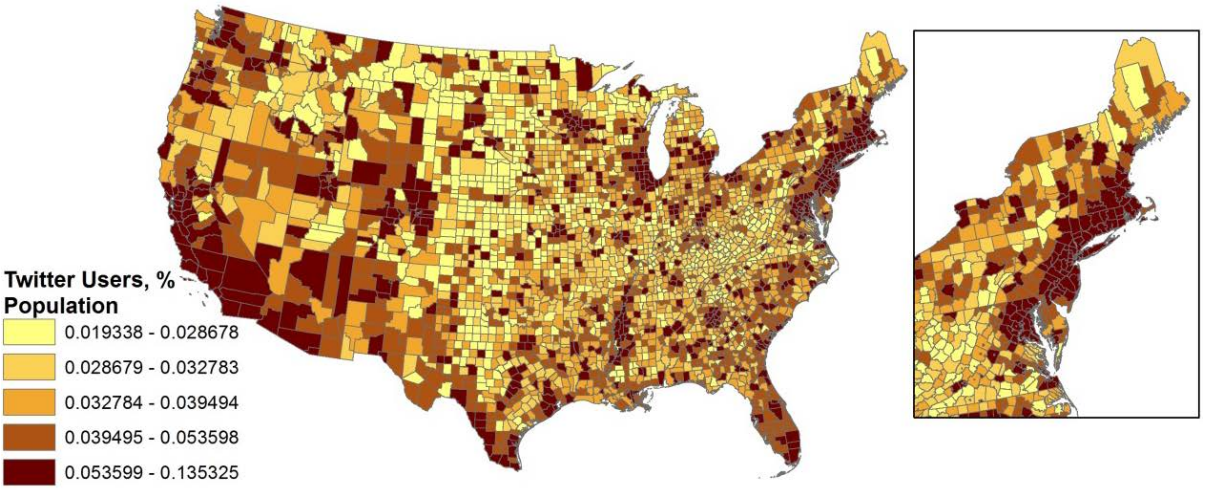
The concept of megalopolis originated through Jean Gottman's study of the massive combined metropolitan areas of the Northeast coastal region stretching from Boston to Washington (Gottman, 1961). In 2000, the Northeast megalopolis was estimated to have 49.6 million population or a sixth of the U.S. population (Short, 2007). The high Facebook adoption by a half to two thirds of the population in this vast, dense megalopolitan region magnifies the social media impact, since the tens of millions of users are physically within several hours drive time of each other. This region also reflects the key positive determinants of Facebook use that were already discussed including college education, urban, working age population, and presence of significant Asian population in its large cities.

Figure 2. Spatial Distribution of Facebook Users (% Pop), U.S. Counties, 2012



The spatial distribution of Twitter users (Figure 3) corresponds generally to the pattern to Facebook, with however the following differences: (1) the levels of Twitter use on the southwest border of Texas are much reduced compared to Facebook use, (2) usage in Southern California is substantially higher and includes all the counties in metropolitan Los Angeles and San Diego, (3) Denver and surrounding Rocky Mountain region is high in usage, but not as extremely high as Facebook, and (4) Appalachia and the mid-central South are moderate rather than very low for Facebook.

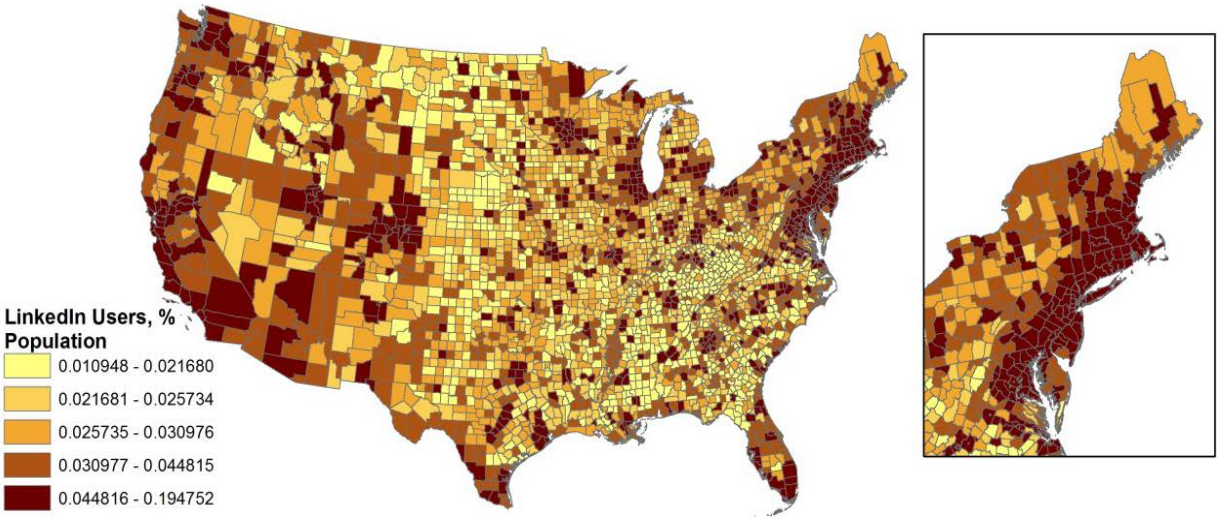
Figure 3. Spatial Distribution of Twitter Users (% Pop), U.S. Counties, 2012



The high Twitter use in the entertainment industry cluster of southern California might stem from Twitter's greater entertainment aspect than for Facebook or LinkedIn, while Twitter's relatively higher use in the lower-central South and Appalachia might be due to Twitter's simplicity and low storage needs, which are more suitable to the less affluent and educated population in those areas. LinkedIn's spatial distribution (Figure 4) resembles Twitter's, but has a north-south band of low use that extends from North Dakota to the Texas Panhandle and is unexplained.

Spatial autocorrelation analysis of the dependent variables (see Tables 2 and 3) reveals that results for Moran's I are highly significant for the country, metropolitan samples, inconsistent for the rural samples and not significant for the micropolitan sample. This reflects that the social media use is highly agglomerated in its metropolitan portion, which also influences the agglomeration level of the country as a whole, while micropolitan counties are less influential on their neighbors, resulting in lack of agglomeration of counties. For rural areas, agglomeration is significant for Facebook, for unknown reasons, while Twitter has significant inverse Moran's I value, implying that there is a trend towards lack of spatial autocorrelation, while there is a random spatial distribution for LinkedIn.

Figure 4. Spatial Distribution of LinkedIn Users (% Pop), U.S. Counties, 2012



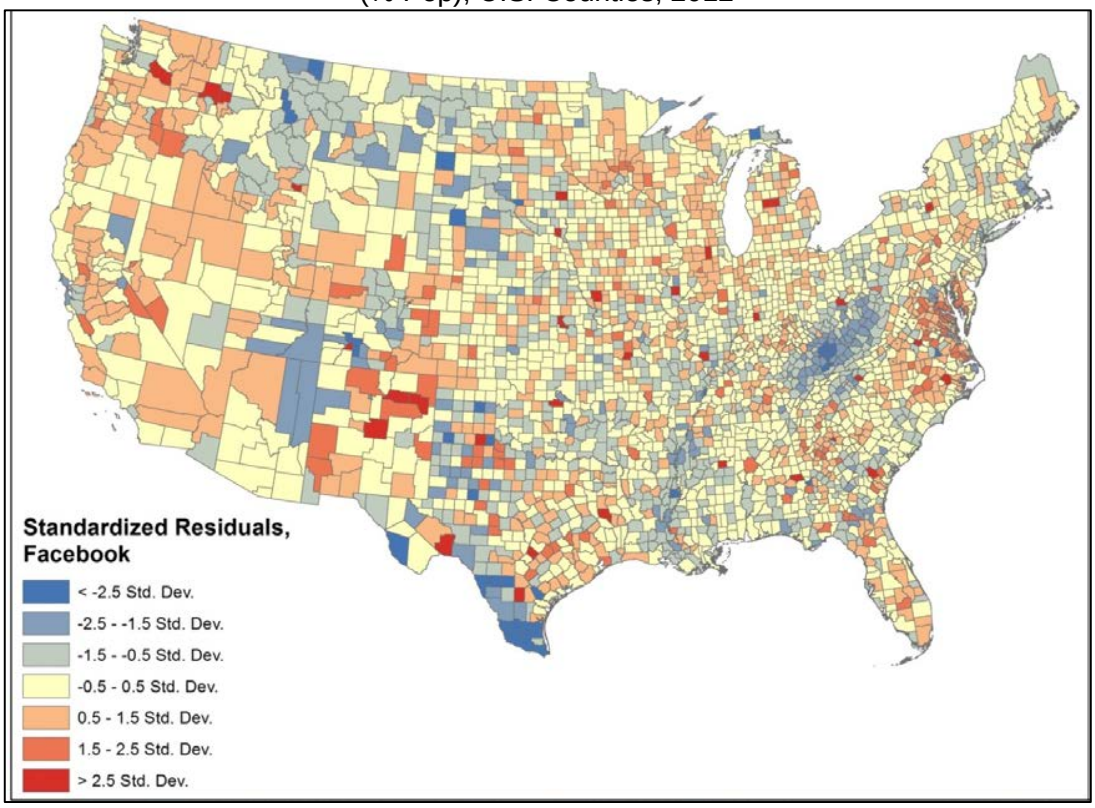
Spatial analysis went further and computed the extent of randomness of spatial autocorrelation, as measured by Moran's I, for the residuals of the OLS regressions. The results indicate a low spatial autocorrelation, compared to the high spatial autocorrelations values of the original variable, for the country and metropolitan samples, while the residual spatial autocorrelation level for the Micropolitan and Rural samples is random, except for an inverse Moran's I value for Twitter. Hence, in general, the OLS regressions have either reduced substantially or eliminated the spatial autocorrelation present in the original dependent variable, which means that the model and its independent variables are able to account quite fully for the very high autocorrelation for the observed dependent variables. Nevertheless some agglomeration remains, in particular for Facebook for the country sample and for all three social media variables in the metropolitan subsample, so those findings must be viewed cautiously. Figure 5 is a map of the standardized residuals for Facebook at the country level, and it is evident that the Facebook spatial autocorrelation persists in the residuals and is similar in pattern to the spatial autocorrelation pattern the Facebook raw variable (i.e. compare Figure 5 to Figure 2).

DISCUSSION OF RESULTS

This study has confirmed some well-known determinants from the digital divide literature. In particular among model variables, very prominent ones confirmed to have influence on social media, are age structure (Author, 2015), college graduation (Baliamoune-Lutz, 2003; Author, 2005; Author, 2008; Vicente and Lopez, 2011; Yates, Gulati, and Weiss, 2011; Chen, 2013), urban location (Arai and Naganuma, 2010; Fong, 2009, Chen, 2013), and ethnicity (Author,

2005; Perrin and Duggan, 2015; Florida, 2012). Among these are a pair of variables, urban location, and college graduation, which have commonly been closely correlated (Chen, 2013). Although missing from this research due to multi-collinearity, per capita income is often also correlated with this pair, so that it should be considered for inclusion in future research, perhaps to replace one or two in the triad.

Figure 5. Distribution of OLS Regression Residuals (Standard Deviations) for Facebook Users (% Pop), U.S. Counties, 2012



Although professional, scientific, technical service occupation had a strong influence on ICT in a prior U.S. county study (Author, 2005), it was unimportant in the findings, except for LinkedIn for the micropolitan and rural subsamples. The difference is ascribed to a shift in the dependent variables, which, for the earlier study, were revenues and business receipts and payroll for the IS-Data Processing industry, broadcasting-telecommunication industry, and motion picture-sound industry. While for those complex sectors, the scientific/professional workforce would clearly have an impact, that impact is much less likely for the present countywide consumers of social media, who tend to be younger, educated individuals, but not necessarily technically inclined. Accordingly, for social media use, county policymakers need not concentrate on workforce development, by they but it should do to boost productivity in complex, digital industries.

Social capital is an unexpectedly weak determinant country-wide. For the subsamples, its effect was slight and only present as an inverse determinants in the micropolitan and rural samples for Twitter and LinkedIn. We ascribe the inverse findings to the substitution effect for physical social capital that was discussed earlier. Construction workforce had a slight and mostly opposite,

inverse effect. This is unexplained and points to further research to try to determine the mechanism. The Spatially Aware Technology Utilization Model (SATUM) is applicable to this investigation. Nearly all the independent variables have at least some empirical association with the social media. The only exception is personal income, which was eliminated in the present study due to multi-collinearity. The present SATUM model has the potential to be applied to small geographic samples of counties, with sample sizes as small as 50. For example, two areas identified descriptively to have high usage of social media, western coastal counties stretching from Washington State to southern California and the Northeast megalopolis, might be studied as subsamples to determine their determinants for social media. Likewise, the social media determinants in the Great Plains and middle South counties could be analyzed by regression to determine their determinants for low social media usage.

For large samples, with varied environments, geographically weighted regression constitutes an alternative way to aggregate results over distinctive geographies. However, for the full set of U.S. counties, it is problematical due to the irregularity of the county polygons across the nation, although it could be applied in sub-national regions such as Midwest with more consistently shaped boundary shapes.

Spatial autocorrelation in the present investigation is very useful in assessing extent of agglomeration for raw variables and for regression residuals. For such a large sample, it has the advantage to summarize systematically the extent of agglomeration, which the eyeball would miss.

Given the very large sample sizes, more complex models could be constructed with Structural Equation Modeling (SEM), path analysis, or econometrics. For SEM, the set of independent variables could be enlarged by selecting additional ones from the U.S. Population and Economic Censuses, American Community Survey using 5-year range of data, or other robust county samples. Although a theoretical model has already been tested by SEM for a worldwide sample of nations (Author, 2011), a more complex factor model could be formulated for U.S. counties, and relevant theory could be applied from that study. However, it is likely other relationships would need to be induced. A challenge would be to take geography into account, in applying SEM.

POLICY IMPLICATIONS AND LIMITATIONS

County governments can set ICT policies, as can metropolitan governments which are defined as area based on one or more county (U.S. Census, 2015). These governments can influence ICT policy, by providing their own public Internet services, fostering or supporting ICT training for citizenry, encouraging the hiring of local ICT graduates (Kvasny and Keil, 2006), encouraging and helping with incentives for service industries make greater use of IT including by small businesses. Regarding IT training, the governments need citizens to go beyond just completing courses or certificates, but to leverage the training for the “next step,” which might be further education or a closely-related job (Kvasny and Keil, 2006).
It is more difficult to develop polices based in demographic determinants of social media, since the population processes are not under the control of the county government. Nonetheless, the counties could focus their training options on demographic categories associated with more ICT usage, such as young, urban, affluent people. However, at the same time, social equity would push county policymakers in the opposite direction, to favor training for technologically underprivileged age groups in rural areas.

Although our study suggests that county policies not emphasize formation of social capital, an earlier study at the state level indicated strong impact from social capital, and it pointed to the need for state policymakers to emphasize it (Pick, Sarkar, and Johnson, 2015).

Limitations

One limitation is that the dependent variables were collected in large-scale industry surveys, which are subject to a survey sampling error. However, when a newer survey becomes available, longitudinal comparisons can be made for error checking. This also points to the limitation that the study is cross-sectional, so cannot recognize the magnitude changes of variables and varying influences over time. However, this limitation can be overcome by a future study that includes the present data for 2010-2012, along with data for a later period.

A limitation already mentioned is that the regression analysis does not model complex and/or bi-directional relationships. This can be addressed by using SEM, path analysis, or other techniques for analyzing complex models. A challenge for such studies will be to formulate a more complex theoretical model than SATUM, which could be derived from limited prior complex models, induction, and reasoning. Another methodology that could be applied to parts of the nation with fairly consistently shaped and sized polygons is geographically-weighted regression (GWR). This is a not a present limitation because the entire nation has polygons which are frequently irregularly sized and shaped, so GWR could not be applied. The study is limited by use of data that are from 2010-2012. More recent data on the dependent variables is available; however, many of the dependent variables are not updated, so it might be several years before a data set with good time simultaneity will be available. Finally a limitation is that case studies of counties are not available that could illustrate the SATUM theory and support or contradict the present empirical findings. If this need is met by developing case studies, interview questions would need to be designed to add higher levels of understanding of geographical aspects of county technology use.

CONCLUSIONS

This research has developed a conceptual model in which socio-economic variables influence social media use, with accompanying spatial analysis. The model is tested empirically by OLS regression, revealing that the key correlates of social media use are age structure, college education, young dependency ratio, working age population, and percent urban. The sample of U.S. counties is divided into subsamples of metropolitan, micropolitan, and rural counties, and analysis of those OLS findings allow comparisons to be made with the country-wide sample. The spatial analysis consists of descriptive mapping and spatial autocorrelation analysis both of the dependent variables and of regression residuals. This latter analysis reveals the U.S. to be highly agglomerated in social media for counties. At the extreme of high valued agglomerated counties is the Northeast megalopolis and coastal southern California stretching up to San Francisco and eventually to Seattle. There also is an area of high social media use that centers on the Rocky Mountain region from Denver to Salt Lake City. Area of low social media use include the Great Plains, Appalachia, and the mid lower South. Policy implications of the research are applied to formulation of county policies. Examples would be to encourage education, innovation, and training for service workers including for small businesses. This research points to further projects that could illuminate the county social media patterns, the forces that are related to social media use, and the geographic texture of usage in America.

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Agile Software Development and Organizational Citizenship: A Behavioral Lens on the "Good Coder"

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ABSTRACT

Agile methods have emerged to promote software developer productivity, yet IS projects continue to face challenges. Meanwhile, IS research has provided limited evidence of the correlation between specific Agile development practices and higher levels of developer performance. This model development proposal will address these gaps in two ways: First, it will propose that specific Agile practices contribute to higher levels of job engagement. Secondly, it will propose favorable levels of job engagement influence stronger levels of both in-role and organizational citizenship behaviors.

KEYWORDS: Software Development, Agile, Organizational Citizenship Behavior, Job Engagement, Mediation

INTRODUCTION

Software projects are complex and costly (Guinan et al 1998; Li et al. 2010; Ply et al. 2012; Wiener et al. 2016; Hsu et al. 2016; Purvis et al. 2016; Ozer and Vogel 2015; Cecez-Kecmanovic et al. 2014; Conboy 2009; Harris et al. 2009; Xu and Ramesh 2008; Xu and Ramesh 2007; Chilton et al. 2005; Boh et al. 2007). The use of distributed software development teams has led to coordination challenges, team conflicts, and mixed approaches in performance management (Ramesh et al. 2012). IS development activities are strategic in nature (Ang and Slaughter 2001) and elicit high levels of business risk (Nidumolu 1996; Lee and Xia 2010). Administrative activities such as estimating, requirements elicitation, project planning, and system testing still depend on the input, output, and throughput of software developers.

A project's delivery time, cost, and quality pivot significantly on developer productivity. This is because the specialized knowledge of individual developers influences a project's execution success (He et al. 2007). According to Boh et al. (2007), the largest component of a firm's software costs is development labor. These costs are high because development work is complex, lacks repetitiveness, and is difficult to automate. Developers are consistently challenged to meet deadlines and maintain high standards of quality and productivity. This pressure may become a source of stress for individual contributors (Srivastava et al. 2015), especially those who are not fully engaged in the work that they do. In turn, the perceived strain of the work environment can attenuate performance, or lead to burnout (Nahrgang et al. 2011). Fluid requirements and shifting technologies invoke unplanned reprioritizations, re-tooling, and development re-assignments.

Methodologies such as Agile, Scrum, and eXtreme Programming structure project work in ways so that developers can flourish in an uncertain environment. Rather than executing project phases linearly, these lean and minimalist methodologies are said to place developers in a better position to succeed through (1) smaller iterative work cycles and (2) strong emphasis on

knowledge sharing, team collaboration, and (3) frequent interactions. These processes are believed to benefit not only immediate delivery cycles, but also job satisfaction (Tripp et al. 2016) and the broader organization (Ply et al. 2012).

Software developers spend considerable time and effort dealing with abstract information (Perlow and Weeks 2002). Their skillsets must adapt to emerging technologies, development platforms, and languages. Developers must also be versatile and willing to share knowledge with one another (Hoda et al. 2012; Ozer and Vogel 2015; Strode 2016; Chapman et al 2017; Kudaravalli et al. 2017). Cross-functional (varying domain expertise) teams of developers become more essential in complex project environments (Fong Boh et al. 2007; Harter and Slaughter 2003; Deephouse et al. 1995). Agile-centric activities such as collaborative development, daily standup meetings, and iterative planning are believed to encourage these collaborative behaviors. Work plans are structured incrementally, and executed in short cycles (1-2 week iterations). Expectations for high performance, productivity, and throughput from individual contributors are expected in these contexts. Furthermore, software developers will be expected to perform outside of their traditional job duties as methodologies evolve and change (Chih-Ching et al. 2013, Shin et al. 2014). High expectations and demanding workloads can be optimally managed when people (a) feel engaged in the work that they are doing, and (b) that the work that they're doing is important (Maslach et al. 2001). With the optimal conditions and resources, employees can remain engaged, even when under high demands or workloads (Bakker and Shaufeli 2008).

Developers command significant investment; academic training, organizational training, wages, benefits, administrative costs, hardware, and tools are needed to realize material outcomes from development staff (Rasch and Tosi 1992; Surakka 2007). To perform their job function in organizations, developers must be knowledgeable about technologies, the business domain, user needs, and the tools required to build applications (Mehta and Bharadwaj 2015; Vidgen and Xiaofeng 2009). Due to this multifarious expertise, the residual benefits from each developer's knowledge can be a powerful source of operational advantage. The challenge for IS organizations is to provide an environment where this knowledge can be harnessed to benefit (a) immediate work contexts and (b) the broader organization without (c) attenuating expected job performance. For that to happen, developers must feel engaged enough with their jobs so they are proactive and affiliative in dynamic environments – in other words, to reflect what is commonly known in organizational research as the behavior of "good soldiers" (Organ 1988). According to Sonnentag (2003), "Proactive behavior is crucial in modern organizations characterized by fast changes and reduced supervision. To show flexibility, to meet customer demands, and to compete in the global economy, organizations need employees who go beyond narrow task requirements (p. 519)." If a developer's engagement is limited only towards the immediate needs his/her assignments, a developer is less likely to make contributions to the work his/her colleagues are doing, and the organization at large. Conversely, if developers are going above and beyond, projects and the broader organization only stand to benefit.

Organizational citizenship is a theoretical basis to further investigate factors influencing these "good soldier" (or in this case, "good coder") behaviors. Even though Organizational Citizenship Behavior (OCB) research is well-established, prolific, and has addressed a variety of job contexts, there is little empirical evidence concerning antecedents and consequences of these behaviors specifically among IS development personnel (Chou et al. 2013; Yoon 2008). Furthermore, research concerning development methodologies and their associated outcomes have been largely non-empirical and anecdotal (Mangalaraj et al. 2014; Li et al. 2010; Ply et al. 2012; Faraj and Sproull 2000). To address these gaps, this model development paper will address the following two research questions: (1) Are software development practices

positioning developers to feel more engaged in their work? (2) If so, does this engagement promote better in-role performance and higher levels of organizational citizenship?

LITERATURE REVIEW

Software development involves the utilization of knowledge to design software features and correct flaws or errors (Ozer and Vogel, 2015). In this study, the translation of user or system specifications into software represents the characterization of developer's main job role. Software development is intellectually challenging and socially ingrained. Developers must code productively and collaborate effectively with others (Kudaravalli et al. 2017). According to Maruping et al. (2009), software development is challenging because it is a complex activity requiring overlapping skills, high levels of coordination, and effective project management. A diverse knowledge base allows developers to react quickly in dynamic environments, provide good solutions, and estimate the impact of change effectively (Li et al 2010). Developers may encounter variegated, ambiguous, and complex information as work shifts and change. Many times, requirements are uncertain (Sheffield and Lemeteyer 2013), and developers must adjust accordingly by refactoring or changing code.

The need to respond rapidly to changing user requirements is essential to project success. According to Perlow and Weeks (2002), software developers (knowledge workers) could experience mismatches between skills and abilities and job requirements. With rapid shifts and changes to technologies, software developers must often undergo paradigm shifts in development approaches (Armstrong and Hardgrave 2007). In recent years, techniques such as Agile software development have been introduced to help software developers work more efficiently in these rapidly changing environments. Theory-motivated, empirical, and behavioral research on software development is somewhat sparse – furthermore, it almost always emphasizes teams. The findings, however, can be used to uncover what is generally expected of individual developers on a day to day basis. For those developers demonstrating "good soldier" behavior, organizations can learn how to better maximize the return on costly development staff investments. Orienting these individual contributions towards colleague success and broader organizational success can result in positive inertia and residual feedback loops into subsequent projects.

As a point of departure, identifying what software developers do in their job is critical to categorizing and distinguishing these behaviors. Thus, the objective of the following section is to gain a better understanding of what developers "do", and link those behaviors to software methodologies designed to encourage them.

Software Development Methodologies

Agile-based methodologies have emerged to encourage (1) incremental management of workloads, (2) more effective response to changes (Highsmith and Cockburn 2001), (3) the use of self-managing teams (4) joint ownership of code and (5) delegation of responsibilities to various team members (Maruping et al. 2009). The Agile Manifesto (Beck et al. 2001), an industry-recognized document outlining Agile's basic tenets, focuses on project activities which emphasize individuals, interactions, and being responsive to change. An Agile developer must be accepting of rapid shift and change with the work that is being done. On any given day, developer assignments may shift due to changes in priority or user requirements. These rapid shifts can influence a developer's perception of his / her job in very volatile ways. At times, the need for flexibility and adaptiveness may require role shifts – developers may need to become testers or even requirements analysts. The work being done is meant to feed back into the next

set of team activities, including future iterations, retrospectives, and standups. More specifically, Agile is oriented towards ensuring each developer is reflecting on past work where needed, and focusing on the immediate needs of each delivery cycle. Tripp et al. (2016, p. 273) provide a summary of several Agile project management activities to facilitate these behaviors, which are summarized as follows:

(1) **Stand up meetings** - frequent (usually daily) where each developer shares prior progress, planned progress for the day and obstacles.

(2) **Iterative delivery** - the process of planning and delivering software in iterative, small chunks, rather than in their entire over a single, prolonged cycle.

(3) **Retrospectives** - meetings held at the end of each iteration to identify successes and improvement opportunities from the previous cycle.

(4) **Burndown** - visual representation of the work that has been completed and the work remaining in the current release.

These Agile management activities are intended to "vertically load" the responsibilities of each developer, combining design, development, testing, and other tasks into a single developer's responsibilities. In addition to these project management activities, there are specific technical approaches employed by teams, including continuous integration, test-driven development, and paired programming.

Dawande et al. (2008) provides an overview of eXtreme Programming (XP), which is considered a foundational "Agile" methodology. Prior to Agile methods, traditional waterfall projects would incur significant disruption when unforeseen changes were need during project execution. XP encourages the practice of paired programming, where two developers work concurrently on software at the same time. Developers participating in paired programming must be willing to share knowledge and co-locate with their partner at the same workstation. In pairing, effort is required by developers in multiple dimensions including (1) the coding/testing effort itself (2) forming the pair and (3) sharing knowledge. Advanced developers, if paired with novices, may require even more effort in terms of knowledge sharing, mentoring, or helping. Developers who have never worked with one another will also require more effort to get the pair formed and build rapport. Depending on a project's objectives, pairing (which is thought to reduce effort) may or may not be preferable over solo programming (which is thought to reduce development time). According to Dawande (2008)," pair programming may be better suited for novel projects where completion time is less of a concern, but there is a strong need for every team member to understand the nuances of the development (p. 90)." Therefore, methods such as paired programming, while designed to account for rapid/unforeseen shifts in requirements, still come at a cost.

According to Nelson and Armstrong (2009), methodological changes have led to a paradigm shifts in what is expected of developers. Over time, organization are becoming less reliant on lower level coding expertise, and more reliant on abstract skills normally demonstrated by "well-trained analysts (p.273)." In other words, developers are expected to think at higher, more abstract, and more complex levels than they have been in the past. Therefore, the nature of programming as a skill has undergone an evolution from simply coding designing, analyzing, and assessing reusability of modules. For those trained in a more traditional sense of programming, where lower-level coding skills are almost entirely emphasized, there has been a need to make significant transitions in work ability and style. One example of this shift is illustrated by the transition from structured programming to object oriented programming. In

their comparison of programming background and fitness with object-oriented paradigms, Nelson and Armstrong (2009) determined that paradigm shifts can take an extensive amount of time and can vary in difficulty depending on whether an individual developer's cognitive style fits with the paradigm in question. This may require organizations to invest more in training and expertise consultation when there are shifts. At the same time, for such training to be effective, individual programmers must also be open to change, interested in their work, and resistant to anchoring in prior methods or ways of thinking.

Lee and Xia (2010) investigated the antecedents and consequences of software development agility, which is the extent to which teams can effectively and efficiently respond to user requirements. More specifically, they studied the influence of how Agile team autonomy and diversity influence the ability for teams to respond to changing requirements efficiently and effectively. Agile developers may be expected to self-organize into different sub-teams when appropriate, participate in standups or retrospectives to keep work moving and to identify improvement opportunities, program in pairs, make decisions without formal or explicit authority to do so, continuously review changes with peers or users, and, most importantly, meet the objectives of each iterative cycle. In their model, Lee and Xia (2010) determined that teams with higher levels of autonomy are less likely to accommodate unplanned changes to a certain extent. This may result in less desired functionality, but can also mean the team can deliver a minimally viable product on time and within budget. Therefore, organizations should consider trade-offs when giving teams the authority to make their own decisions.

Kudaravalli et al. (2017) studied the impact of software development team configuration and team conflict on team coordination success. Their model emphasized the importance of team members collaborating with one another to build working software, especially in design phases. Design coordination, which must deal with ill-structured and abstract information, was optimized around decentralized team configurations. Coordination in technical tasks, however, evoked more coordination success when teams centralized themselves around a specific expert. Organizations which buy into complete centralization or decentralization of teams may find themselves at a cross roads when designs need to move into coding phases. Furthermore, highly interdependent teams that are decentralized need developers who can work effectively with others, remain productive even in times of team conflict or disagreement, and adjust their work style depending on the phase of a project.

Mangalaraj et al. (2014) studied in the influence of paired designing and design patterns on the quality of design outcomes. Using theoretical foundations based on distributed cognition and collaborative design, they determined that software designs articulated by high performing individuals were of similar quality to designs articulated by pairs. This illustrates collaborative work methods based on Agile team configurations may not derive reported benefits, especially when individual contributors vary in skill and ability. Furthermore, paired design teams were found to take more time than individuals. This also underscores the importance of individual level performance and its ultimate influence on overall outcomes. Even though software design and development is almost always done in team settings, organizations must not lose sight of the fact that individual level contributions matter and can greatly influence overall outcomes. Rather than emphasizing collaboration, Mangalaraj et al. (2014) determined that establishing good design patterns may have a better impact on delivery of high quality solutions.

Nidumolu and Sumbramani (2003) investigated the influence of standardized or decentralized control mechanisms within project teams. Developers are often faced with an uncertain environment or unforeseen changes in requirements. Organizations must decide whether to centralize or decentralize controls and outcome measures for project teams. Controls can be

oriented towards behaviors (methods) or results (outcomes). Their study determined that in uncertain environments, standardized outcome controls and decentralized behavior controls (granting decision authority to teams) can have favorable influences on performance. When organizations rely on vertical coordination to reach critical decisions, development teams may lose momentum or inertia while awaiting those decisions. And, because methods such as Agile are based on autonomous teams, organizations must be able to rely on development team members to work effectively with one another and avoid conflict when critical decision points are reached.

Maruping et al (2009) also investigated the impact of controls on software development performance. More specifically, they sought to understand how control mechanisms and requirements uncertainty interacted with the use of Agile practices. Control mechanisms are especially salient in Agile teams. According to Maruping et al. (2009), "agile methodologies suggest that team members be largely responsible for managing their own processes, making decisions about how project goals will be attained, and delegating task responsibilities to various team members (p. 381)." This further illustrates a serious challenge for organizations – on one hand, the efficiency of development teams relies on self-led, self-motivated individuals and teams. On the other hand, development labor represents the greatest degree of software costs. Maruping et al. (2009) determines that project leaders must be judicious in how they relinquish this autonomy to teams. They found that autonomy is optimized when it is given to entire teams, not just individuals. Furthermore, specific performance objectives must be given, otherwise gains from autonomy will not be optimized. Overall, Agile can favorably influence project outcomes the most when requirements are uncertain and teams are granted autonomy in conjunction with the right mix of outcome controls.

Vidgen and Wang (2009) conducted a case study to compare software development team agility between two teams: the first team utilized XP (eXtreme Programming), and the other team utilized a traditional waterfall approach. The XP team incrementally delivered software in one-week cycles. Each user story (requirement) began with a planning exercise, followed by coding, testing, and integration steps. For those on the XP team, developers were held to strict expectations in terms of delivery in these cycles. Developers were timed as they coded, studied, and took breaks. Even though the rate of change on the team was high, the study illustrated the rigorous, stringent, "assembly-line" nature of programming in an XP environment. The XP team also experienced occasional difficulty dealing with pace, as well as slow-downs when communication between developers and users became extraneous. Developers were expected to share feedback with one another and leverage the work being done so it fed back positively into the next iteration. Furthermore, the XP environment was structured in such a way so that each individual contributor needed to be responsible and willing to share knowledge with one another.

Xu and Ramesh (2007) investigated the degree to which software firms adhered or tailored their implementation of standardized processes. Organizational contingency theory states that firms may decide to "tailor" software development processes to unique technologies and business domains. Some of the factors a firm may take into consideration when determining whether to adopt a tailored approach depends on several factors, many of those impacting the developers. For example, a team of inexperienced developers may work more advantageously in an iterative environment which emphasizes peer reviews and feedback. Projects experiencing budgetary or time constraints may decide not to utilize daily/frequent standup or planning meetings, to free up a developer's time to conduct design and development activities. Projects dealing with a significant amount of ill-structured requirements or a complex business domain may decide to emphasize more documentation than what would normally be required in an

"Agile" environment. Therefore, a project's specific needs and context may expect different things from developers over the course of time.

Tiwana and McLean (2005) investigated the influence of expertise integration on overall team creativity. Creativity can be essential to successful outcomes because development involves the "generation and evaluation of new ideas, designs, solutions, and artifacts (p. 18)." Exploring multiple solutions can give teams a better chance of finding one that minimizes costs and supports the minimally viable products advocated by Agile approaches. Expertise from varying domains is required to arrive at a variety of solution options. This underscores the importance of individual contributors feeling connected enough with their teammates to explicate various knowledge backgrounds and to propose different ideas. In Tiwana and McLean's (2005) model, expertise integration results in a set of mutually understood and negotiated sets of beliefs. The team must have favorable levels of relational capital (ie trust, reciprocity) and absorptive capacity (recognizing potential of one another's expertise) to successfully integrate one another's expertise. Overall, these findings suggest that developers on teams with varying types of domain knowledge cannot work well with one another unless there is some degree of social connectivity; developers must be able to coordinate and work effectively with others.

He et al. (2007) built on this idea as they studied the emergence of team cognition on software projects. Software developers cannot rely strictly on their coding knowledge to be effective on teams. Developers must also rely on meta-knowledge concerning team composition, especially in areas where the developer needs assistance or lacks the necessary knowledge to complete tasks. For instance, developers may have specific specialties to complement one another in a project team. One developer may have expertise in user interface development, while another may specialize in database processing. And, even though these areas of expertise are distinct, developers on the team overall must share an understanding of the "procedures, sequences, and actions (p. 265)" required to complete the work. Organizations must emphasize the necessity of good team formation – when team members have a solid background of what each member knows, the efficiency of eliciting information from one another increases. The way teams communicate with one another may also influence the emergence of expertise location awareness and shared understanding. For example, teams which utilized face to face contact over emails developed stronger levels of team cognition. In summary, a developer must be able to learn about what their colleagues know, and have interactive engagements with them to maximize their contribution to the team.

Rasch and Tosi (1992) adapted expectancy theory, goal-setting theory, and individual characteristics to study antecedents of individual software development performance. Expectancy theory (Vroom) considers performance as a function of ability, effort, and role ambiguity. Goal-setting theory (Locke and Lantham) considers goal specificity as an important part in reducing role ambiguity, and increasing goal difficulty can result in higher levels of effort. Individual characteristics such as self-esteem, need for achievement, and locus of control can also impact individual effort and performance. Rasch and Tosi (1992) found that individual effort was positively influenced by goal specificity and goal difficulty. Intellectual ability had the strongest direct influence on developer performance. This highlights two important issues for organizations. First, in terms of software development team member selection and configuration, firms must find ways to assess developer ability, which may be difficult considering the complexity of the work. Secondly, the way project goals are articulated and described to teams can have a strong influence on individual effort.

Deephouse et al. (1996) conducted an exploratory study to understand software development process influence on project performance. Processes such as design reviews, cross-functional

teams, and prototyping were assessed to determine overall impact. Planning was found to positively influence on meeting targets and project quality, while cross-functional teams were found to positively influence quality. Process training, environmental stability, user contact, design reviews, and prototyping did not have a significant influence on project outcomes. Although these findings came from a limited sample and were exploratory in nature, it is an example of an empirical study finding little impact of software development processes on performance.

Chilton et al. (2005) studied software developer job/ability fitness (Kristof) using adaption-innovation theory (Kirton). Adaption-innovation theory is centered on the idea that individuals have a cognitive style which can range on a continuum between highly adaptive to highly innovative. Adaptors prefer structure, rules, and few solutions. Innovators prefer many solutions, little structure, and are oriented towards the "big picture" (p. 197). When a person's cognitive style doesn't fit well with his/her job environment, additional energy is spent to cope, which can adversely impact performance. This theory was validated by Chilton et al. (2005), who found that software developers experiencing lack of fit with their job demands experienced more strain. This strain ultimately led to a negative influence on performance. Performance was appraised by managers, and measured based on three dimensions: soft skills, managerial skills, and technical skills. This illustrates the multidimensional nature of a software developer's skillset; not only must programmers be able to convert requirements into code, but they also must be diplomatic, present ideas to others, demonstrate empathy, listen carefully to others, and have leadership qualities.

Boh et al (2007) investigated the influence of learning curves on productivity at multiple levels of analysis (individual, group, and organization). The unit of analysis in the study was characterized as modification requests, or requests to add new functionality or repair a system defect. These modification requests were analyzed longitudinally to determine if experience within systems led to experiences that ultimately contributed to learning across different levels. Not surprisingly, individuals specializing in specific areas, working within the same system, became more productive as they learned about the system over time. Furthermore, experience in related systems (versus unrelated systems) appeared to transfer well across systems. Boh et al. (2007) also found, at the individual level, that developers learned from their counterparts. When developers are willing to help their colleagues, the benefits cascade beyond individuals to the group level. Interestingly, however, too much sharing and helping among a group may hinder organizational level productivity because teams may become entrenched in certain methods or approaches. Such an effect could result in a non-linear relationship, where helping one another may benefit groups and the organization at large to a certain extent, but may also result in a "too-much-of-a-good-thing" type of scenario.

Guinan et al (1998) investigated the influence of group processes on software development team performance during the requirements phase. Group processes (internally and externally oriented) can be influenced by behavioral or technical factors. They found that behavioral factors have a stronger influence on group processes than technical factors. Structured methods such as diagramming, data modeling, and joint application design (JAD) were not found to significantly impact team performance. Furthermore, behavioral factors (managerial involvement, team skill, and experience spread) were more influential on group processes than technical factors. Additionally, some of the feedback was observed from key informants: (1) Outcomes were better when teams were cohesive (2) it was a challenge to find the time to mentor new team members (3) people should be emphasized over tools (4) team members must be comfortable speaking to others they do not know and (5) it is often necessary to involve

others from outside the immediate project team. This illustrates the notion that a developer's skillset should expand beyond technical tasks.

Sarker and Sarker (2009) built on this concept and conducted an interpretive study to investigate agility in distributed software teams. As noted in Lee and Xia (2010), agility is the extent to which teams can respond effectively to rapid changes. To influence this agility, certain expectations emerged in terms of the development staff:

1) Adapt to rapid or unforeseen assignment to different teams (rotation).
2) Multiple skills/versatility (i.e. ability to perform both web and database development)
3) Use of communication technologies, source control management tools, project lifecycle tools.
4) Participation in frequent/short stand up meetings.
5) Work with individuals from different countries or in different time zones.

Based on Sarker and Sarker's (2009) findings, developers working in Agile environments are expected to have a blend of both technical and "soft" skills. Developers lacking the ability to work effectively with others, or who cannot succinctly articulate their progress during standups, may impede progress in Agile teams. Although technical skills are essential when converting system requirements into code, the languages and platforms shift and change over time.

Hardgrave et el. (2003) investigated software developer intentions to follow formal methodologies. Their model was based on the theories of technology acceptance model (TAM, Davis) and diffusion of innovation (DOI, Rogers). The antecedents to intentions included individual and organizationally related factors including perceived usefulness, complexity, social pressure, compatibility (like fitness), and perceived organizational mandate (degree to which individual felt the organization was mandating methodology use through formal policy). Not surprisingly, perceived usefulness of a methodology was a significant and positive influence on intentions to follow a methodology. The strongest influences on perceived usefulness were complexity (unfavorable influence on perceived usefulness) and compatibility; these influences were even stronger than organizational mandates. Overall, this illustrates the role individuals play in methodological adherence; the need for developers to buy into the methodological practices handed down to project teams is critical. If developers believe a methodology is requiring too much mental effort or is difficult to follow, they may not follow standards/guidelines. If developers feel that the methodology is compatible with work style, they may be more willing to adhere to standards/guidelines.

Ply et al. (2012) investigated the interaction between software process maturity, control modes (outcome vs. behavioral), and IS employee attitudes (role ambiguity, role conflict, work overload, professional efficacy, job satisfaction, and cynicism). Their study was based on the Capability Maturity Model (CMM), which was developed by the Software Engineering Institute (SEI) in the late 1980's and early 1990's. CMM is not a specific methodology like Agile per say, but rather a reference model which provides specific guidelines to organizational software processes. These processes address various areas including requirements management, performance management, service management, project management, and organizational development/readiness. The degree to which firms adhere to the prescriptions set forth in CMM is rated in levels. For instance, level 1 represents no formal processes, whereas level means processes have been fully established and are in optimization mode (see Ply et al. (2012) pp. 605-606 or a good summary of each CMM level). One of the key findings in this study was that IS professionals working in CMM level 3 organizations reported lower levels of professional efficacy and job satisfaction than their CMM level 1 counterparts. Level 5 IS professionals also

reported higher levels of cynicism than their lower level counterparts. Overall, these results seem to suggest a "dark side" as the rigor and standards of software processes increase.

Agile methods often call for cross-functional teams who can shift roles and take on different responsibilities. Developers may need to modify or change code that they did not originally create. It can be argued that this type of software change is more difficult than novel development because it requires not only an understanding of pre-written code, but also an understanding of original intent of the software in question. Therefore, developers in a maintenance or bug-fix setting require dual-task problem solving abilities. Shaft and Vessey (2006) conducted an experiment which compared difference in modification performance based on (a) familiarity of the software and (b) the type of modification (control flow modification, or ordering/sequencing of action vs. function modifications, or main goals/objectives of the software). They found that program comprehension (understanding of previously written software, syntax, programming constructs) does not always lead to higher modification performance, especially when a lack of cognitive fit exists between the developer's mental representation of the code and the type of modification required. This illustrates the importance of team configurations, requirements, documentation, and training when projects reach a maintenance/bug-fix/modification mode. Developers who are strictly versed in programming/syntax may not necessarily perform well on modification tasks. In certain contexts, they will also need a degree of familiarity with the application domain itself, which they may not have had prior to the task. Overall, their findings illustrate the nature of development work and how it spans beyond simply knowing how to write code.

Due to the nature of the work, developers are at risk of experiencing career exhaustion over the long run. Constant shifts and changes in demands from coworkers and customers can leave developers feeling burned out. Not surprisingly, Armstrong et al. (2015) found that that when IS professionals perceived higher levels of workload demands, the likelihood of feeling "career exhaustion" increased. This type of career exhaustion, which is conceptually linked to burnout, would automatically occur if the only factor taken into consideration was perceived workload. Fortunately, favorable individual level job appraisals are still possible, even when workloads are heavy. Armstrong et al. (2015) illustrated that when IS professionals felt they were treated fairly and in control of their career, they were less likely to perceive this type of exhaustion. Furthermore, methodologies encouraging self-led teams and autonomy can encourage developers to experience less career exhaustion, and potentially hedge against burnout. Whether this holds true under different software methodologies remains a question.

To be effective, software developers are required to be sociotechnical experts. Software developers must be able to fully participate in project meetings, assist with planning, provide information or help to colleagues, be aware of teammate variance in expertise, and adhere to rigorous and fast-paced methodologies. From a technical perspective, software developers must work with ill-structured information, create/review/modify code, and stay on pace with new or emerging technologies. Because the role of a developer covers so many areas, outcomes have the potential to benefit not only individual appraisals (both self and supervisors/colleagues), but also project outcomes and the organization at large. Job satisfaction, while linked to favorable individual outcomes such as performance, is volatile to change and can vary depending on several contextual factors. This may explain why satisfaction-based studies have led to mixed findings in software methodology research (Ply et al. 2012, p. 610). Therefore, satisfaction may not be rigorous or stable enough to capture the essence of complex links between developer work configurations, the developer's relationship with his/her job, and the outcomes emerging from those links. This is especially true in Agile environments, where the work may shift rapidly on a day to day basis. According to Maslach et

al. (2001), “Job satisfaction is the extent to which work is a source of need fulfillment and contentment, or a means of freeing employees from hassles or dissatisfiers; it does not encompass the person’s relationship with the work itself. Job involvement is similar to the involvement aspect of engagement with work, but does not include the energy and effectiveness dimensions. Thus, engagement provides a more complex and thorough perspective on an individual’s relationship with work (p. 416).” Engagement, in turn, can be linked to stable behaviors not only described as “in role”, but also those behaviors which may have broader organizational benefits.

Job Engagement

While job satisfaction captures an individual’s overall job attitude, job engagement captures persistent and dimensions that are highly relevant in complex and demanding jobs like software development. Job, or work engagement, is defined as a “positive, fulfilling work-related state of mind that is characterized by vigor, dedication, and absorption (Schaufeli & Bakker, 2006, p. 702; Schaufeli et al. 2002). Job engagement captures a level of dedication an employee has towards his or her job (Owens et al. 2016). Recent interest concerning job engagement in industry is motivating further research on this characteristic (Eldor and Harpaz. 2016). Job engagement is an important part of assessing employee performance, and can foster organizational effectiveness. Although engagement is considered non-volatile, research has shown some within person variation may occur day to day (Sonnentag 2003). According to James et al. (2011), employers are becoming more interested in assessing employee engagement; there are economic costs when engagement is not occurring (i.e. burnout or sub-optimal individual contributions), and having engaged employees has become an important organizational goal (pp. 176-177). An engaged employee may be able to cope with pressure and demands more effectively. Organizations who foster resources which encourage higher levels of engagement can position themselves to meet the growing business demands in a complex and dynamic economy.

There are two main views of job engagement in organizational research: (1) as the opposite of burnout view and (2) as the psychological appraisal view (Byrne et al. 2016). The former is based on Maslach et al., and the latter is based on Kahn. Studies such as Maslach and Leiter (2009) regard engagement on a continuum, where individuals expressing lower levels of burnout are said to be more engaged. Studies such as Rich et al. (2010) regard engagement as the investment of one’s complete self in their work. Kahn (1990) described personal work engagement as the immersion of one’s physical, cognitive, and emotional self into one’s job. The degree to which an individual expresses these dimensions can vary, and are favorable in “appropriate conditions (Kahn 1990, p. 700.).” Kahn (1990) also described antecedents which lead to favorable levels of job engagement: psychological safety, psychological meaningfulness, and psychological availability (Zhong et al. 1995, p. 825). Project management practices in Agile environments may encourage these conditions. For instance, a developer’s psychological safety and availability may be cultivated in standup meetings or retrospectives, where team members collectively share progress or roadblocks. Iterative planning may invoke feelings of meaningfulness, showing progress at earlier intervals throughout a project. Extant research on job engagement has shown negative correlations with burnout, although more recent studies have criticized this opposite-of-burnout view (Byrne et al. 2016). The dimensions of job engagement are traditionally characterized as follows:

1) ***Vigor*** is associated with high levels of mental resilience, especially when challenges arise. This type of mental orientation can be beneficial when code is experiencing unit testing errors,

or when there is difficulty eliciting necessary system feature requirements from non-technical customers.

2) ***Dedication***, which captures a level of pride and enthusiasm, can be of great importance when sharing status updates in team meetings, assisting requirements analysts, working extra hours, or working in collaborative pairs.

3) ***Absorption*** is being fully concentrated and engrossed in work, which can be extremely beneficial when additional effort or work hours are required to meet milestones.

Although these dimensions are conceptually distinct from job satisfaction, more work has been encouraged to empirically differentiate and distinguish job engagement from job satisfaction (Wefald and Downey 2008).

Using data from sales personnel and their subordinates, Haynie et al. (2016) hypothesized that job engagement mediated the relationship between perceptions of organizational justice (fairness) and task performance, organizational citizenship behaviors, and job satisfaction. Rich et al.'s (2010) scale was chosen to measure job engagement because other measures have been criticized because they do not capture Kahn's (1990) original dimensions. OCB's were measured using Lee and Allen's (2002) 16 item instrument. Distributive justice (fairness perceptions oriented towards outcomes) was found to be a significant predictor in this relationship, which aligns with prior theory stating that distributive justice prompts positive affect (engagement) towards work outcomes.

Using a multi-level model, Zhong et al. (2015) investigated how employee role behaviors are impacted by job engagement, high performance human resource (HR) practices, cultural factors, and perceived organizational support (POS). Examples of high-performance HR examples include: selective staffing, internal mobility, employment security, clear job descriptions, incentive rewards, and results-oriented appraisals. The authors found that POS partially mediated the relationship between high performance HR practices and employee engagement. In other words, an organization can use HR practices to cultivate the extent to which an employee believes the organization supports them. This, in turn, leads to more favorable levels of employee engagement. One interesting finding in this study, however, is that job engagement had no significant relationship on extra-role (OCB) behaviors. One explanation provided was that more engaged employees may be prioritizing in-role behaviors over extra-role behaviors. However, they also encouraged future research specifically address those relationships further.

According to Nahrgang et al. (2011), "There are many job demands and resources present in the working environment, and it is important to understand which job demands deplete mental and physical resources the most and which job resources are the most motivating (p. 72)." One of the mechanisms through which this type of motivation can be realized is through job engagement. Engagement is a measure of involvement, participation, and communication – three areas which are critical in Agile development teams.

James et al. (2011) compared the extent of job engagement and its antecedents across different age groups. The large sample (N=8433) consisted of all ages did not distinguish based on job title. Engagement was measured using a custom scale developed for company. The antecedents to engagement were conceptualized as supervisor support and recognition, schedule satisfaction, career development and promotion, and job clarity. Control variables included gender, education level, hourly vs. exempt status, full vs. part time, and marital status. Their analysis determined that older workers demonstrated higher levels of engagement than

younger workers. Furthermore, engagement was influenced more favorably by supervisor support and recognition in younger workers, while younger workers were more influenced by career development and promotion. Job clarity, which measured tool / resource availability and expectations, was a strong influence on engagement for both younger and older workers. This illustrates that engaged employees must have a clear understanding on what is expected of them, and that they have the tools necessary to do their jobs. In software development environments, facilitating conditions such as standups and iterative planning methods can continuously address these areas to ensure what is expected is articulated, requirements are clear, and that roadblocks are addressed.

Wu et al. (2016) conducted a time-lag study to address mixed findings surrounding workplace ostracism and employee engagement. Workplace ostracism is defined as the extent to which an employee feels he or she is being excluded or ignored (p. 362). Ostracized employees may feel more motivated to engage in acceptance-seeking behaviors benefiting other individuals as well as the organization. On the other hand, ostracized employees may be discouraged, and feel less motivated to engage in such behaviors. In their model, Wu et al. (2016) hypothesized that organizational identification (incorporating organization into mental self-schema) mediated the relationship between workplace ostracism and organizational citizenship behavior. Job engagement at period 2 (after 10 weeks), was found to have significant, negative correlations with workplace ostracism, and significant, positive correlations with organizational identification, organization based self-esteem, and felt obligation towards the organization. This illustrates that employees who feel more included socially with their peers are more likely to feel engaged in their work they do. Engaged employees are also more likely to engage in prosocial behaviors. Software development practices such standups, pairing, retrospectives, and iteration planning meetings can give each team member an opportunity to participate, share, and collaborate with their peers. In turn, these practices may lower the possibility that a team member feels excluded or left out.

Wang et al. (2014) investigated organizational justice, job insecurity, and job engagement's effects on job performance. Job insecurity is the uncertainty one feels towards the continuity of his/her employment. If an employee feels insecure in their job, their engagement may suffer, which can lead to lower levels of performance and higher economic costs to the organization. In a dynamic and shifting economy, employees must feel secure enough in their job so that they remain engaged and productive. Uncertainty management theory (UMT) research has shown that perceptions of fairness help individuals cope under conditions of uncertainty. Collecting data at multiple periods, Wang et al. (2014) determined that job (work) engagement mediated the relationship between job insecurity and job performance. This was especially true when insecurity interacted with lower levels of perceived organizational justice.

Shaufeli et al. (2009) used the Job Demands-Resources (JD-R) to study the influence of burnout, engagement, job resources, and job demands on absenteeism. According to the authors, "the Job Demands–Resources (JD-R) model is a heuristic and parsimonious model that specifies how job strain (burnout) and betterment (work engagement) may be produced by two specific sets of working conditions that can be found in every organizational context: job demands and job resources (p. 894)." Job demands are the aspects of the job requiring effort (could be physical/social/organizational), and job resources are the things which reduce that effort, help achieve goals, and/or encourage growth/development. Examples of job demands include work overload, emotional demands, and work-home interference. Examples of job resources include social support from supervisors/co-workers, feedback, coaching, autonomy, task variety, and training. JD-R research has shown that job resources can help employees remain dedicated to their efforts and can reduce strain and burnout. Shaufeli et al. (2009)

hypothesized that, over time (1 year), increases in job resources will predict future work (job) engagement. The authors found that when resources increase, job engagement tends to increase as well. Subsequently, higher levels of work engagement negatively influenced voluntary absenteeism. Furthermore, they found that organizations, to foster higher levels of engagement, organizations should focus on increases in resources, rather than on reduction in demands. Employees who are working under conditions of high demand can remain engaged if enough job resources are available.

Petrou et al. (2012) studied the effect of job autonomy, work pressure, and job crafting on job engagement. Job crafting is "proactive employee behavior consisting of seeking resources, seeking challenges, and reducing demands (p. 1122)." Asking a colleague for help is an example of seeking resources. Looking for a new task or taking on more responsibilities are examples of seeking challenges. Procrastination or task avoidance are examples of resource reduction. Resource reduction, in turn, can be considered an active behavior when employed as a coping strategy for job demands. Petrou et al. (2012) hypothesized, at the day level, that seeking resources and challenges positively influence job engagement, while demand reduction negatively influences job engagement. On days when employees sought challenges or reduced demands, they were more engaged. Individual crafting behaviors were found to differ day to day. When higher levels of employee work pressure and autonomy were perceived, employees sought more resources.

Sonnentag (2003) studied the effect of recovery on job engagement and proactive behaviors. Recovery during leisure time (nights and weekends) can be an important consideration for maintaining well-being and favorable levels of performance. The way individuals recover when they are away from work can have an impact on how they perform when they return to work. When employees recover properly, Sonnentag (2003) hypothesized higher levels of work engagement and higher levels of proactive behaviors. Proactive behaviors were conceptualized as volitional and self-improving, and items were worded so these behaviors could be measured as traits and as daily behaviors (personal initiative and pursuit of learning). A multi-level analysis nested daily appraisal within the person, so that the relationship between day to day variances and the overall person could be evaluated. Work engagement was found to mediate the relationship between recovery and proactive behaviors. The study also showed how day to day activities can introduce variability into work engagement and proactive behaviors. Organizations fostering daily and consistent methods which cultivate an engaging environment can protect against negative variations. In software development environments, daily standups and frequent face to face collaboration have the potential to provide these affordances.

Byrne et al. (2016) evaluated two common measures of job engagement: the Utrecht Work Engagement Scale (UWES, Shaufeli et al. 2002) and the Job Engagement Scale (JES, Rich et al. 2010). The UWES is based on the conceptualization of engagement as the opposite of burnout. It is a reverse-coded version of the Maslach Burnout Inventory (MBI). The JES is based on Kahn's conceptualization of engagement, and captures dimensions of physical, emotional (affective), and cognitive assessments. Byrne et al. (2016) determined that the UWES captures a broader, more general domain of job engagement. Job engagement, when measured with the UWES, was strongly correlated with stress (-), job performance (+), strain (-), organizational commitment (+), job commitment (+), psychological availability (+), and burnout (-). However, this may be due to UWES' redundancy and confounding effects. The JES was found to demonstrate "less overlap with associated attitudes (p. 1218)," and more distinctiveness in the nomological network of engagement.

Saks (2006) describes the concept of job engagement in the context of related constructs such as organizational citizenship behavior (OCB), job involvement, and organizational commitment. Organizational commitment refers to one's attachment to an organization. As stated by Saks (2006), "engagement is not an attitude, it is the degree to which an individual is attentive and absorbed in the performance of their roles (p. 602)." Job involvement is tied to self-image and focused only on cognitions concerning the need satisfying abilities of the job. Job engagement, on the other hand, measures cognition, emotions, and behaviors. Saks determined that job characteristics and perceived organizational support were significant predictors of job engagement. Job engagement was also found to significantly influence outcomes such as job satisfaction, organizational commitment, intention to quit, and organizational citizenship behaviors oriented towards the organization (OCBO's). Job engagement was measured with developed scales, rather than the UWES or the JES. See Hallberg and Shaufeli (2006) for a similar study which also established the distinctiveness of job engagement from job involvement and organizational commitment.

Organizational Citizenship Behaviors (OCB's)

Individual contributor performance can be assessed based on three dimensions – (1) in role behaviors (expected tasks), (2) behaviors which promote the performance of others, and (3) behaviors which promote the effectiveness of the organization. Organizational citizenship behavior (OCB) theory emphasizes the relationships between these dimensions of performance, along with their antecedents and consequences (Williams and Anderson 1991). According to Dekas et al. (2013), "OCBs are crucial in the knowledge economy, where roles are less defined and the external environment is rapidly evolving. (p. 220)." OCB's are salient to IS researchers and practitioners because they can have a favorable influence on knowledge sharing, software quality, and customer service (Dekas et al. 2013; Chih-Ching et al. 2014).

Organ (1989) conceptualized the "classic" dimensions of OCB as follows: (Yoon 2008; Chou et al. 2013, p. 106): (1) **Altruism**, or helping behaviors, (2) **Conscientiousness**, or going beyond organizational standards (3) **Courtesy**, or action to prevent problems. (4) **Sportsmanship**, or positive thinking, or acceptance of minor impositions) and (5) **Civic virtue**, or constructive and responsible involvement in organizational governance. These dimensions emerge at an individual level, but could (a) be influenced by group/organizational level antecedents and have (b) group/organizational level outcomes. As described by Schnake and Dumler (2003), "The OCB construct itself is a multi-level construct. Mixed-level antecedents predict the extent to which individuals engage in OCB; however, theoretically it is OCB in the aggregate, and not individual instances of OCB, which impact organizational effectiveness (p. 295)." Beyond organizational effectiveness (Podsakoff et al. 1997), OCB's also depend on cultural aspects (Motowidlo 2000; Perlow and Weeks 2002), and have an impact on overall productivity.

OCB's can improve organizational effectiveness, but may have negative consequences as well. If an individual contributor is spending too much time helping others, the individual's in role productivity may suffer. OCB's may lead to burnout if organizations are not judicious in terms of keeping promises (psychological contracts) and providing the right level of emotional support and gratitude (Brown and Roloff 2015). Co-workers may construe the demonstration of others' OCB's as self-serving, which could have negative impacts on job satisfaction (Tepper et al. 2004). OCB's are instrumental to performance appraisal and promotion, but individual behaviors could decrease once the promotion is gained (Hui et al. 2000). OCB's may also increase the risks of emotional exhaustion and work-family conflict, especially in with higher level task performers. (Deery et al. 2016).

The impact of OCB's should be appropriately weighed in parallel with the extent an individual is performing his/her actual expected job duties. According to Van Dyne et al. (1995), an extra-role behavior is discretionary, goes beyond delineated role expectations, and benefits the organization. For instance, a developer mentoring a new employee, when the developer is not instructed or expected to do so, would be considered an extra-role behavior (Ang and Slaughter 2001). OCB's are not enforceable – they are affiliative, promotive, may be unrewarded, and support the effective functioning of an organization (Organ 1997). At the outset, OCB's were devised to address how job satisfaction influences extra-role behaviors. Organizational research using OCB theory continued to evolve, which gave rise to construct ambiguity, confusion, and conceptual bleed-over across terms to describe helping behavior, such as extra-role behavior and contextual performance (Borman and Motowidlo 1993). Although both Motowidlo and Organ both de-emphasized the importance of labeling, Motowidlo (2000) provided some additional conceptual guidance for research: Extra-role behaviors are discretionary and intended to benefit the organization. OCB's are discretionary, but also lack formal recognition by reward systems, and in aggregate promote the effective functioning of the organization. Contextual performance is concerned with enhancements to the social and psychological context of work, as well as antecedents and consequences of task performance. As research in OCB's progressed, Organ (1997) also considered the distinction between in role and extra role behaviors as having less utility. Mackenzie et al. (1998), however, still regarded these distinctions as important (p. 88). In summary, in role and extra role behaviors lie somewhere on a continuum, and concrete distinctions between the two is difficult to recognize universally (Podsakoff et al. 2000, p. 549). As will be seen below, OCBs have also been found to influence promotion appraisals, which conflicts with "unrewarding" characterizations.

Vandyne et al. (1995) noted the ambiguity of several different constructs describing extra role behaviors in organizational research. Furthermore, it is difficult to distinguish between in role and extra role behaviors because assessments depend on who is observing the behavior, relative differences between employees, and the time frame in which individuals are being observed. Additionally, a lack of construct clarity between different types of extra-role, prosocial behavior has led to ambiguity in OCB research. Vandyne et al. (1995) subsequently characterized the uniqueness of OCB with the following arguments:

(1) OCBs are a specific type of extra role prosocial behavior with distinct characteristics.
(2) OCBs do not include prosocial organizational behaviors can be disruptive (like whistle blowing)
(3) OCBs are generally compliance-based, promotive, and affiliative.
(4) The civic virtue dimension of OCBs is constrained and fully immersed in organizational politics.
(5) OCBs may include constructive recommendations for change.
(6) Extra role behaviors like OCB should be studied specifically rather than as a generic prosocial behavior construct.

Arda et al. (2017, p. 17-18) provide a longer list of OCB dimensions operationalized in organizational research – these additional dimensions include loyalty, obedience, and participation (Bolino et al. 2002; Graham 1991). Graham's (1989) dimensions are (1) interpersonal helping (helping coworkers) (2) individual initiative (communications to others/group to help group performance (3) personal industry (performance of tasks above and beyond call of duty) and (4) loyal boosterism (promotion of organizational image to outsiders (Moorman et al. 1998). Dekas et al. (2013), through a scale development exercise at Google, revealed OCB dimensions which may be more suitable for knowledge workers (OCB-KW scale), including helping, voice, civic virtue, employee sustainability, and social participation. Williams

and Anderson (1991) adapted Organ's (1988) dimensions and developed scales for OCB-I's (OCB's directed at individuals) and OCB-O's (OCB's directed at the organization). Williams and Anderson (1991) illustrated evidence supporting these unique dimensions of performance – in role behaviors, OCBI's, and OCBO's. OCBI's (Individual) benefit individuals (helping a coworker), while OCBO's (organization) are organizationally focused (adhering to informal organizational procedures. Podsakoff et al. (1990) developed a 24-item scale for OCB's which also capture Organ's (1988) original dimensions.

OCB's may be frequent, infrequent, occur spontaneously, and may arise in unforeseen situations (Smith et al. 1983). Specific examples of OCB's include, "helping co-workers, communicating new and critical information, maintaining a conscientious attitude toward the work environment, actively participating in decision processes and discussions, and refraining from complaining about minor irritants (Yen et al. 2008, p. 395)." OCB's may go unnoticed by superiors but can still result in significant increased task performance (Arda et al. 2017) and other organizational gains, including "resource transformations, innovativeness, and adaptability (Organ 1988; Williams and Anderson 1991, p. 601)." Circumstances requiring creative, fast, and context-specific effort may require unexpected and often unrewarded solutions. According to OCB's seminal researchers (Smith, Organ, and Near 1983), these behaviors cannot be explained by the normal day-to-day motivational bases of job duties. The reason for this, according to Organ (1988), is because OCB's are said to be performed without the promise of rewards. In a study conducted by Bruque et al. (2016), OCB's were found to positively influence individual outcomes such as adaptation to change and task performance. Therefore, software development, which is driven by organizational needs for innovation, task orientation, and the ability to be flexible is a suitable context with which to apply the lens of OCB.

The determination of whether a behavior is in role vs. extra role may be subjective and partially dependent on social construction (Morrison 1994). Because perceptions of job roles and their boundaries can vary widely among individuals and organizations, the OCB construct has undergone a great deal of scrutiny and retrospection. Employees and supervisors may differ on whether they categorize a behavior as in role vs. extra role. The same behavior, over time, may be categorized differently as well.

Shin and Choi (2014) integrated person-environment fit theory (Kristof 1996) and regulatory focus theory (Higgins 1997, 1998) with OCB. In their model, OCB was operationalized using Dewitt and Dewett and Denisi's (2007) typology of "change OCB and "maintenance OCB." Maintenance OCB's, which can be individually or organizationally oriented, are concerned with the status quo and existing relationships. Change OCB's are focused on are all organizationally focused and are oriented towards work methods, policies, and procedures (Shin and Choi 2014 , p.3). Regulatory focus theory states that individuals with promotive self-regulation approach positive outcomes with eagerness, risk taking, and achievement orientation. On the other hand, individuals with preventive self-regulation approach objectives more vigilantly, conservatively, and with a tendency to avoid negative outcomes. Person-environment fit theory says that employees provide more value to the organization when their individual preferences are congruent with the characteristics of the work environment. Their model demonstrated that higher levels of congruency between leader and subordinate prevention focus lead to higher levels of subordinates' maintenance OCB's. This same congruence effect was lacking for increased levels of change OCB.

Podsakoff and Mackenzie (1997) provided an overview of OCBs and empirical evidence in research demonstrating links to organizational effectiveness. OCB's can help in "'lubricating' the social machinery of the organization, reducing friction, and/or increasing efficiency (p. 135).".

As indicated on p. 156, the following reasons describe why OCBs influence work group and/or organizational performance: (1) enhancement to coworker productivity, (2) enhancement to managerial productivity (3) freeing up resources for more productive purposes (4) reduction in the need to devote scarce resources (5) effective means of coordinating activities (6) enhance ability to attract/retain the right people (7) enhancement to stability of organizational performance and (8) enhancement to ability to adapt to environmental changes.

Mackenzie et al. (1998) evaluated the antecedents and consequences of in role and extra role behaviors, specifically in salespeople. Extra role behaviors are important to assess because they are "linked empirically with organizational performance and success (p. 95)." There is also value in distinguishing between in role and extra role behaviors for salespeople because: (1) managers take both into account in performance appraisals (2) both have implications for organizational performance (3) the two types of performance are believed to have different antecedents and consequences (IE in-role performance influences satisfaction, and satisfaction influences extra role behaviors). Extra role behaviors were measured in this study using a Podsakoff and Mackenzie (1994) instrument, which was developed based on Organ's OCB dimensions of altruism, sportsmanship, and civic virtue, and then aggregated into a composite score. In their model, role ambiguity and role conflict influence in role performance. In role performance and job satisfaction negatively influenced turnover. Extra role performance was a consequence of organizational commitment and job satisfaction. These findings helped confirm the direction of causality between performance and satisfaction. It also helped confirm that in role and extra roles are distinguishable from one another and may have unique characterizations in a nomological network.

Podsakoff et al. (2000) conducted a review of findings in prior OCB research (antecedents, consequences) and provided guidelines for future research. Antecedents to OCB dimensions in research were categorized as individual differences/ability, task characteristics, organizational characteristics, and leadership behaviors. In terms of all 5 of Organ's (1988) OCB dimensions, the following correlated favorably and significantly based on the authors' analysis: Task feedback, intrinsically satisfying tasks group cohesiveness, transformational leadership, and supportive leadership. In terms of consequences, OCB's have been linked to objective measures of organizational performance, such as index of sales, product quality, sales quotas, revenue, and customer satisfaction (p. 547). Research in OCB's is most useful when the antecedents and consequences to in and extra role behaviors can be distinguished. Otherwise, organizations would not know which mechanisms or "levers" are influencing on type of behavior over the other. As far as future research directions, Podsakoff et al. (2000) recommend the following

1) Identify unique antecedents and consequences of different forms of OCB.
2) Include multiple forms of citizenship behavior and statistically test for differences.
3) Further research the influence of task characteristics and leadership behaviors.
4) Further research the influence of OCBs on unit level performance and possible mediators between OCBs and performance.
5) Work group or organizational level performance outcome variables deriving from OCB should be investigated.
6) Articulate and test the effects of cross-cultural differences.
7) Mitigate against common method variance (single source bias) and issues concerning direction of causality (experiments or longitudinal designs).

Podsakoff et al. (2009), in a more comprehensive meta-analysis, tested hypotheses of OCB consequences (unit and individual level), along with moderators between OCBs and

performance. OCBs were found to positively influence ratings of performance and reward allocation; they were also found to negatively influence turnover intentions, actual turnover, and absenteeism. Organizational outcomes that were positively influenced by OCBs included productivity, efficiency, productivity, and customer satisfaction. When performance was self-reported, the influence of OCB's on outcomes was stronger. This illustrates a moderating effect related to research design. Organizations fostering and encouraging OCBs are more likely to realize gains in organizational performance. Furthermore, employees who were found to be rated higher in OCBs tended to be rated higher in task performance as well. The distinction between OCB-I and OCB-O was not found to be meaningful in terms of individual level differences, however, this may be due inconsistencies in post hoc categorizations.

Ang and Slaughter (2001) investigated the differences between permanent and contract software developers in the following areas: work attitudes, work behaviors (in-role/extra-role), and work performance. In-role behaviors, which are expected and rewarded, can cause significant impact when they are not fulfilled by well-paid employees like software developers. Extra-role behaviors, or those considered voluntary and beyond expected job duties, are essential to projects and organizations at a whole. The consequences of not carrying out extra or in-role behaviors may be different, but when a developer is not assisting others, filling in a colleague who was absent, or volunteering to take on some extra duties, there could be noticeable effect on project outcomes. In their study, contractors were found to demonstrate the same degree of in role behaviors as permanent employees, but expectedly less extra-role behaviors. Furthermore, there was a high degree of positive correlation between in-role and extra-role behaviors. Therefore, organizations with permanently employed inhouse developers have an opportunity to harness residual benefits beyond what is simply and explicitly expected from them on a day to day basis.

Cui (2017) investigated the influence of personality dimensions (openness to experience, conscientiousness, extraversion, agreeableness, neuroticism) on IS professional knowledge sharing behaviors. More specifically, knowledge sharing was characterized as "in role" (the extent to which sharing knowledge was expected) and "extra role" (sharing more knowledge than what would be expected in the individual's day to day activities). Extraversion lacked significant influence on any knowledge sharing behaviors. Openness to experience strongly influenced extra role knowledge sharing, while agreeableness strongly influences both in role and extra role knowledge sharing. Therefore, individuals who are hired based on (a) their willingness to remain flexible to change and (b) their ability to collaborate well with others may share knowledge above and beyond what is normally expected. This, in turn, can lead to positive effects on team cohesion and ultimately better team performance.

O'Reilly and Chatman (1986) investigated the influence of organizational commitment (compliance, identification, and internalization) on prosocial behaviors. The dependent variables in the study were in-role and extra-role behaviors. In-role behaviors were operationalized as items measuring working full shifts, completing assignments on time, and compliance with rules and regulations. Extra role behaviors were operationalized as items measuring volunteering, making suggestions, attending functions that were not required, and participating in planning / organization of social events. Based on the results of two separate studies, O'Reilly and Chatman (1986) concluded that extra role behaviors were a function of identification and internalization. In other words, employees who simply follow the rules are not likely to engage in affiliate, prosocial behavior. They stated that the "motivational basis for extra-role behaviors is likely to require more than simple compliance. A failure to develop this psychological attachment among members may require the organization to bear increased costs associated with more detailed and sophisticated control systems (p. 493)."

Rioux and Penner (2001) investigated the role of personal motives and the demonstration of OCBs. The authors argued that there was little research available which explained the motives for engaging in OCBs. Because OCB measures are sensitive to the rater (self vs. peer vs. supervisor), responses from all three sources were obtained. A scale was developed to measure citizenship motives, comprised of three dimensions: organizational concern, prosocial values (wanting to engage with and help others), and impression management (how one looks to co-workers). The authors hypothesized that prosocial motives would account for significant variance in OCBs. Prosocial motives accounted for significant variance in altruism, courtesy, and civic virtue. Organizational concern accounted for significant, favorable variance in in civic virtue. These relationships were evident regardless of the source of OCB ratings. In summary, Rioux and Penner (2001) determined that personal motives play a part in the demonstration of OCBs.

Eldor and Harpaz (2016) studied the influence of perceived learning climate on employee engagement and extra role behavior performance. Extra role behaviors were conceptualized as proactivity, knowledge sharing, creativity, and adaptivity. If employees feel that the organization supports the creation, acquisition, and transfer of knowledge, Eldor and Harpaz (2016) argued that employees will feel more engaged and ultimately demonstrate more proactive and volitional knowledge sharing and creativity. This is because research has shown that employees with favorable levels of job engagement demonstrate higher levels of arousal and activation. To understand delineate the influence of engagement from related constructs such as job satisfaction and job involvement, Eldor and Harpaz (2016) also tested the mediating influence of those constructs. They found that job engagement was the strongest mediator between perceived learning climate and extra role behaviors. This reinforces the idea that job engagement is “a different and more effective factor than more traditional explanations of job attitudes such as job satisfaction and job involvement (p. 228).” This type of engagement can be especially valuable on Agile development teams, where creative thinking, problem solving, and knowledge sharing behaviors can be critical to overall project success.

Diefendorff et al. (2002) studied the influence of job involvement, personality , work centrality, and gender on OCB’s. Job involvement is extent of one’s preoccupation, concern, and engagement with one’s job. Work centrality is the extent individual’s view work as a part of their life (importance belief). The authors found a significant interaction between job involvement and gender against two OCB dimensions: courtesy and sportsmanship. The influence of job involvement on courtesy and sportsmanship were stronger for females than males. Civic virtue was found to be the most closely related to job involvement.

Bachrach et al. (2006) studied the influence of task interdependence on group performance and OCB’s. According to the authors, “theory on self-managed work groups proposes that decision-making autonomy within a group may enhance motivation, and consequently, group performance (p. 1397).” Helping behaviors in low task interdependent groups may be construed as feedback for low performance. Furthermore, prior organizational research found contradictory results for OCB’s in groups having higher levels of task interdependence. Bachrach et al. (2006) hypothesized that task interdependence moderated the effects of helping behavior on group performance, where highly task interdependent groups would have more favorable performance, while low task interdependence groups would have more negative impacts on performance. OCB’s were operationalized as observations of group member helping. While high task interdependent groups demonstrated higher levels of helping behaviors and performance, the low task interdependent groups also demonstrated some lift in performance as well.

Allen and Rush (1998) investigated the relationship between employee performance judgments and OCBs. Employees demonstrating OCBs are may trigger "an affective response (p. 248)" in managers. This trigger leads to manager appraisals which are more favorable; the authors hypothesized that this "liking" response mediate the relationship between OCB's and overall evaluation and reward recommendations. Reward recommendations were directly and favorably influenced by OCB's, along with perceived affective commitment and causal motives. Drawing on social exchange theory, Aryee et al. (2002) determined that trust in supervisor mediated the relationship between distributive justice (i.e. perceptions of fair treatment) and both OCB-I's and OCB-O's. Bell and Manguc (2002) found that organizational identification (perceived oneness with the organization positively influenced all 5 dimensions of OCBs.

Chao-Min et al. (2015) evaluated citizenship behaviors in professional virtual communities (VC's). Virtual communities are online forums characterized by "self-organization, technology-mediated communication, weak ties among members, and the absence of formal reward systems (p. 948)." These online communities may bring together open source developers or programmers. They define virtual community citizenship behavior (VCCB) as behaviors which benefit the whole of the community. Agile software development, while more structured, have similar attributes, such as self-organization and technology-mediated communications. Chao-Min et al. (2015) operationalized individually-directed (VCCBI's) and community-directed (VCCBO's) citizenship behaviors, using Williams and Anderson's (1991) concepts. In their model, social (VC) attachment and satisfaction were hypothesized to be antecedents to VCCBI's and VCCBO's. The authors surveyed members of Programmers Club, a professional, online forum made up of IS programmers, designers, engineers, and analysts. The instrument used was pilot tested and then administered (N=196) to a Programming Club forum. Structural equation modeling revealed that satisfaction and virtual community attachment favorably influence VCCBI and VCCBO. Some of the manifest characteristics ultimately contributing to these higher levels of satisfaction and attachment included knowledge sharing efficacy, self-reflection learning, and social playfulness. This could be reflective of an Agile software development environment due to (a) the need to share knowledge among team members (b) the opportunity to contribute in planning meetings and retrospectives and (c) interact with group members and form relationships through stand-up meetings, pairing, or collaborative design.

Deng et al. (2015) conducted a mixed-method study to characterize customer-oriented OCB's of IS support staff. Customer-oriented OCB's were defined as employee discretionary behaviors in serving customer interests and needs not explicitly requested (p. 495)." In this study, the customer-oriented OCB were those demonstrated by personnel that were oriented towards a system's business users, specifically in the post-implementation phase. Customer-oriented OCB's differ from traditional OCB's because they're directed towards customers rather than colleagues on the same team. The organizational impact these OCB's have is inherent in "the dynamic knowledge transfer activities in IS post-implementation support (p. 491)." The coding scheme used a combination of previously identified customer-oriented OCB categories (education, anticipation, and justification from Rafaeli et al. (2002)) and newly developed ones (Personalization-business, personalization-technology). Using data from the organization's ticketing database and interviews, IS support/user interactions were analyzed, categorized, and evaluated across two different systems. Anticipation OCB's were found to be the most frequently employed, where IS support would provide anticipatory advice to users which may be useful to the user in the future, even though the knowledge was not specifically tied to the original ticket. The extent of which OCB's also varied as the post-implementation phase progressed.

To understand the demonstration of extra role performance, researchers should include measures of in role performance. This allows subsequent analysis to uncover characteristics that are unique to extra role behaviors. For example, Eisenberger measured in role performance using the following items adapted from Williams and Anderson (1991) : (1) Meets formal performance requirements of the job (2) fulfills responsibilities specified in job description (3) Performs tasks that are expected of him or her and (4) adequately completes assigned duties. Ang and Slaughter (2001) adapted scales from Vandyne and Lepine (1998) for in role behaviors, which include the following items: (This particular coworker) (1) fulfills the responsibilities specified in his/her job description (2) performs the tasks that are expected as part of the job (3) meets performance expectations and (4) adequately completes responsibilities. Extra-role behaviors such as OCBs are believed to go above and beyond these in role expectations. An individual demonstrating a lack of in role behaviors even in the presence of extra role behaviors would still be a concern, because that would imply that individual is not performing the basic duties for which they were hired.

THEORETICAL DEVELOPMENT/MODEL

The model being developed in this study has the potential to establish a link between software methodologies, job engagement, and individual software developer behaviors. Agile practices have emerged to improve software development productivity, versatility, and flexibility. Although practitioners continue to proliferate and employ these practices, research conclusions remain mixed in terms of whether the cost incurred by these methods truly outweigh their benefits. IS organizations, under continued pressure to meet project objectives, must also decide whether to wholly adopt modern methodologies like Agile, adopt alternative structured methods, or tailor processes specifically to address technical, environmental, or project challenges (Xu and Ramesh 2007). A clear and generalizable roadmap between processes and outcomes remains elusive. Paired programming has been linked to better performance on novel projects, but may incur other costs when novices are paired with experts (Dawande et al. 2008). Autonomous teams are thought to be more effective when responding to change, but may act obstructively when faced with unplanned changes (Lee and Xia 2010). Collaborative, iterative planning may help teams efficiently manage its backlog, but the technical work may still rely heavily on the oversight of a centralized technical expert, which can introduce bottlenecks (Kudaravalli et al.2017). Tripp et al. (2016) found favorable relationships between specific Agile practices and job satisfaction, but it remains unclear how greater satisfaction in this context amounts to higher levels of individual performance.

Agile practices are structured in a way so that team members can be versatile, cross-functional, contributive, self-reflective, and engaged. Standup meetings help team members communicate progress, roadblocks, and provide opportunities to “step up.” Burndown charts and other visualizations give team members the opportunity to identify work which may be lagging or failing to meet certain time/cost/quality objectives. Iterative delivery gives developers a chance to identify and work on critical slices of work, to deliver integrations and minimally viable products in an efficient and organized way. Retrospectives provide insights into improvement opportunities both individually and as a team. Therefore, Agile practices can be theorized to help developers feel more engaged, which in turn should influence his or her behaviors. This type of engagement captures deeper, abiding dimensions of employee perceptions (Maslach et al. 2001). Interest in engagement is gaining among employers, especially due to its economic implications – For example, engagement can influence lower levels of burnout, and higher levels of individual performance (James et al. 2011). Higher levels of job engagement have also been linked to behaviors with broader impacts at the organizational level. If the model in this study elicits significant results, it can serve as a benchmark for evaluating the efficacy of several

Agile practices. Conversely, if this model elicits insignificant results, then it can be said that Agile practices may have a negligible impact on the kinds of attitudes and behaviors managers should be encouraging. Prior research in job engagement has been linked to higher job performance (Wand et al. 2014), lower levels of absenteeism (Shaufeli et al. 2009), proactive behaviors (Sonnentag 2003), and organizational commitment (Saks 2006).

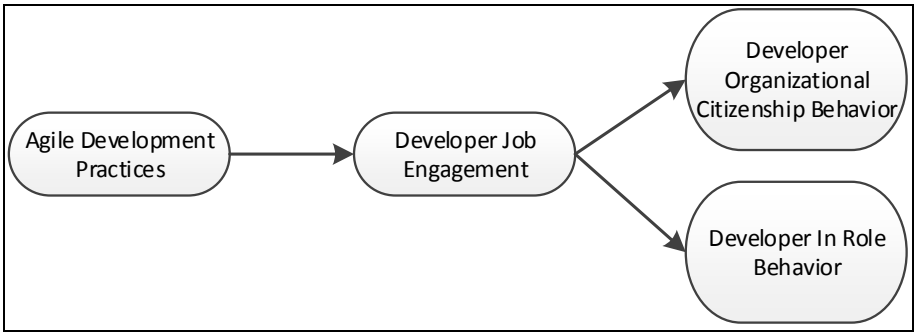
To begin, this model will propose that Agile practices influence higher levels of job engagement, which subsequently influences higher levels of in-role behaviors. In-role behaviors are considered foundational to the specific role or job function the employee was hired to perform. If Agile practices lead to favorable levels of job engagement, and higher levels of in role behaviors subsequently emerge, then managers should feel confident in their decision to adopt Agile practices.

H1: Job engagement mediates the relationship between Agile development practices and Software developer in role behaviors (IRBs).

In addition to performing expected job roles, employees may also engage in activities which are affiliative and promotive towards their co-workers and the overall organization. Such behaviors are usually voluntary in nature, and are "above and beyond" normal duties. This model proposal will adopt Organizational Citizenship Behaviors (OCB's) to characterize these extra-role behaviors. OCB's, according to Podsakoff and Mackenzie (1997), are believed to enhance organizational dimensions such as co-worker/managerial productivity, resource availability, and coordination efficacy. Employees demonstrating OCB's can be thought of as the all-stars who make the bench players around them perform at higher levels. If Agile practices lead to favorable levels of job engagement to the extent where OCB's emerge, then managers should feel confident in fostering those practices.

H2: Job engagement mediates the relationship between Agile development practices and Software developer organizational citizenship behaviors (OCBs).

Figure 1 - Research Model



METHODS

A professional sample of software developers and their supervisors will be needed for this study. A survey instrument will be administered using scales adapted from the following studies:

1) Tripp et al. (2016) – Agile project management practices which facilitate interactions with other employees – Burndown, iterative delivery, Stand ups, and Retrospectives. The intent of these items would be to measure the extent to which the individual perceives

his/her work group participates in these practices. These can be aggregated to a second order construct.
2) Rich et al. (2010) – Job engagement scale (JES), which is intended to capture the specific vigor, dedication, and absorption dimensions perceived by the developer in his/her work. The JES captures the original dimensions of job engagement proposed by Kahn (1990).
3) Lee and Allen (2002) – OCBO and OCBI scales commonly used in organizational research. These measures should be collected from supervisors to mitigate against single source bias. OCBO and OCBI's can be optionally aggregated to form a second order construct known as "OCB."
4) Williams and Anderson (1991) – In role behavior scales commonly used in organizational research. These measures should also be collected from supervisors.

Control variables used in the study will be age, job tenure, years of software development experience, and gender.

Model Measurement and Hypothesis Testing Options

Partial Least Squares (PLS) is an appropriate technique for theory-building models that employ small sample sizes and second-order factors (Gefen et al. 2000). PLS is also robust to data having non-normal distributions. In this theory-building study, job engagement will be measured as formative, second-order construct, and the sample size is not known. According to Gefen et al. (p. 9), a rule of thumb for PLS sample is to have at least 10 times the number of items in the most complex construct. Since job engagement has 18 items in total (sum of items in Vigor, Dedication, and Absorption), it is assumed a sample of at least 180 would be required for utilizing PLS in this study. Each Agile practice will be measured as its own first-order construct.

Wetzels et al. (2009) provides a set of guidelines for analyzing hierarchical (second-order) models using PLS, as originally suggested by Marcoulides and Sanders (2006). Included is a mediation analysis of direct and indirect effects. Those guidelines are summarized as follows:

1) Report the summary statistics and distributional properties of the manifest variables.
2) Specify a null model for the first order latent variables to assess psychometric properties.
3) Report the intercorrelations of the first order latent variables.
4) Calculate the composite scale reliability (CR) and average variance extracted (AVE)
    a. CR should be > than .80 and AVE should exceed .50 (per Fornell and Larcker 1981).
5) Calculate square root of AVE
    a. Should exceed the intercorrelations of construct "X" with other constructs in model
6) If the first-order model passes the criteria tests above, then construct model with the second-order factor (Job engagement) – this is by relating the to the block of the underlying latent variables. The remaining variables remain first-order constructs.
7) Calculate the CR and AVE of the second order model, and verify the criteria above for CR and AVE is still met.
8) If the second-order model passes the criteria tests above, now calculate the path coefficients in the model to test hypotheses.
    a. A test of direct and indirect effects can be conducted to assess whether job engagement mediates the relationship between Agile practices and the outcome variables. This involves measuring the direct effect of the antecedent (Agile practices) on the outcome variable (IRBs, OCBs). Then introduce the mediating

variable (Job engagement) to see if this direct effect changes significantly. Little to no change implies an absence of mediation. A modest change in the Beta coefficient implies partial mediation. A complete absence of a direct effect in favor of a direct effect implies full mediation.

b. Shrout and Bolger (2002) method can be used to test the standard error of the indirect effect.

9) Report all path coefficients (95% confidence interval) and p-values.
10) Introduce control variables to understand whether R^2 changes significantly.

DISCUSSION AND CONCLUSIONS

The following limitations are inherent in this proposal:

1) Cross-sectional research design may introduce concerns with direction of causality.
2) Convenience sampling will limit generalizability.
3) Agile software development measures are based on assessments of the group rather than the individual.
4) Task characteristics and specific performance outcomes are not measured.

Opportunities for Theoretical and Practical Contributions

Engaged employees successfully cope when faced with challenges and demands. Software development in Agile environments can be challenging, demanding, and complex. Understanding whether Agile practices contribute to engagement can unlock many opportunities for future research. Furthermore, employees who demonstrate citizenship behaviors are "good soldiers," and can help promote and cultivate higher levels of organizational effectiveness. A model of software developer job engagement and citizenship behavior can be the starting point for further research which (1) examine the variance in engagement/behaviors over time (2) integrate additional individual and organizational level factors and (3) measure specific individual, project, or organizational outcomes.

From a practical perspective, findings from this study can inform managers in terms of how Agile practices influence meaningful outcomes among individual contributors. If significant results are found, practitioners using alternative software development methodologies or "tailored" Agile may want to consider adopting the practices examined in this study.

APPENDIX

Proposed Survey Items

Author(s)	Construct	Respondent	Scale	Item
Tripp et al. (2016)	**Burndown**	Developer	Likert (1-7)	Our team utilizes visual indicators (charts, graphs, etc.) of how well we are progressing DURING a work cycle.
				We use visual tools that allow team members to easily tell if the work is being completed on schedule.
				We plot our work completed against work planned on a chart.
	Ierative Delivery	Developer		At the beginning of each work cycle, the team and business owners agree on what will be delivered during the work cycle.
				The team gives input as to how much work can be completed in a work cycle.
				The team estimates the amount of work each feature will require to be completed.
				Our team lets business people make business decisions about releases, and technical people make technical decisions about releases.
	Stand-up	Developer		The team has a short meeting every day to discuss what is going on with the project
				Each day, all team members share with the team what they are working on.
				The team discusses issues together daily.
	Retrospective	Developer		On a regular basis, the team reflects on previous work and looks for ways to improve team performance
				At the end of each work cycle, the team asks itself "what went well" during the last work cycle.
				At the end of each work cycle, the team asks itself "what could be improved" during the next cycle.
Rich et al. (2010)	**Job engagement (Vigor)**	Developer	Likert (1-5)	I work with intensity on my job.
				I exert my full effort to my job.
				I devote a lot of energy to my job.
				I try my hardest to perform well on my job.
				I strive as hard as I can to complete my job.
				I exert a lot of energy on my job.
	Job engagement (Dedication)	Developer		I am enthusiastic about my job.
				I feel energetic about my job.
				I am interested in my job.
				I am proud of my job.
				I feel positive about my job.
	Job engagement (Absorption)	Developer		I am excited about my job.
				At work, my mind is focused on my job.
				At work, I pay a lot of attention to my job.
				At work, I concentrate on my job.
				At work, I focus a great deal of attention on my job.
				At work, I am absorbed in my job.
				At work, I devote a lot of attention to my job.
Lee and Allen (2002)	**OCB-I items (OCB's oriented towards individuals)**	Supervisor	Likert (1-7)	Help others who have been absent.
				Willingly give your time to help others who have work-related problems.
				Adjust your work schedule to accommodate other employees' requests for time off.
				Go out of the way to make newer employees feel welcome in the work group.
				Show genuine concern and courtesy toward coworkers, even under the most trying business or personal situations.
				Give up time to help others who have work or nonwork problems.
				Assist others with their duties.
				Share personal property with others to help there work.
	OCB-O items (OCB's oriented towards organizations)	Supervisor	Likert (1-7)	Attend functions that are not required but that help the organizational image.
				Keep up with developments in the organization.
				Defend the organization when other employees criticize it.
				Show pride when representing the organization in public.
				Offer ideas to improve the functioning of the organization.
				Express loyalty toward the organization.
				Take action to protect the organization from potential problems.
				Demonstrate concern about the image of the organization.
Williams and Anderson (1991)	**In Role Behaviors**	Supervisor		Adequately completes assigned duties.
				Fulfills responsibilities specified in job description.
				Performs tasks that are expected of him/her.
				Meets formal performance requirements of the job.
				Engages in activities that will directly affect his/her performance evaluation.
				Neglects aspects of the job he/she is obligated to perform. (R)
				Fails to perform essential duties. (R)

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DECISION SCIENCES INSTITUTE
Staff Knowledge-Sharing Behavior: Qualitative Perception

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ABSTRACT

Employees believe that during the process of knowledge sharing, they may waste their time and resources. To protect their capital, investment, and power, employees believe hiding their knowledge from coworkers is one option that is available within the organization. This research focused on describing the experiences of why people do not share knowledge between their coworkers.

KEYWORDS: knowledge sharing, tie strength, communication, self-efficacy, attitude, trust

INTRODUCTION

Knowledge sharing is an organizational process defined as the knowledge provider sharing ideas, information, and suggestions based on personal experiences with a knowledge receiver (Rusly, Corner, & Sun, 2012; Teng & Song, 2011; Titi Amayah, 2013). Recently, scholars (Kane, Alavi, Labianca, & Borgatti, 2014) have defined the relationship between a knowledge provider and recipient as the provider controlling the recipient's ability to know and access the provided content while customizing the shared knowledge to the recipient's needs and situation (Ho & Ganesan, 2013).

Employees often assume that they may waste their time and/or resources during the knowledge-sharing process. To protect their intellectual capital and investment, and sustain power, employees often hide their knowledge from coworkers and view it as one behavioral option available within the organization (Connelly, Zweig, Webster, & Trougakos, 2012). However, knowledge sharing is highly important in today's business environment. The sharing and reuse of knowledge not only helps firms gain a competitive advantage but also increases the effectiveness of work (Gee-Woo, Zmud, Young-Gul, & Jae-Nam, 2005; Lee, Kim, & Kim, 2012). A firm's performance often relies on managers' skills and experience in using knowledge gained through knowledge sharing with colleagues rather than managers' individual or social skills (Kukenberger, Mathieu & Ruddy, 2015; Massingham, 2015).

A frequent concern of employees is the necessity of knowledge sharing with colleagues. Employees consider their knowledge part of their personal capital, investment, and power (Lam, Huang, & Chan, 2015). However, as prior research (Beck, Pahlke, & Seebach, 2014; Titi

Amayah, 2013) suggests, knowledge providers' motivations to share their knowledge are pressing factors that determine a person's motivation to contribute knowledge to others. Such motiviations include personal expectations of economic rewards, reputation benefits, normative considerations, and interpersonal and culture barriers and trust.

Many researchers have studied the motivational causes that explain knowledge sharing between providers and recipients. However, the lack of a theory-practice considering both providers and recipients represents a gap in the literature (Miao, Choe, & Song, 2011; Ragab & Arisha, 2013; Rusly et al., 2012) regarding the actual process of knowledge exchange. For example, how knowledge providers share knowledge may increase their reputation and lead to later reciprocal behavior (Connelly et al., 2012). It may also impact how staff behavior is affected by subjective norms (Bock, Zmud, Kim, & Lee, 2005).

A few employees feel that, the more knowledge is shared with their competitors, the greater the potential that threats to a provider's social capital, investment in time, and power will have future consequences. In addition, when knowledge providers can create or innovate new knowledge in knowledge management processes, they sometimes treat the processes as a strategic weapon in the organization (Heeseok & Byounggu, 2003). Consequently, knowledge providers and receivers can find themselves in a position that can deter or enhance the likelihood they will be laid off or promoted.

What are the actual experiences of sharing knowledge with colleagues? How and to what extent does motivation, strong/weak ties, organizational climate, organizational identification, and relationships potentially influence the sharing of knowledge among colleagues? The current research will be from the viewpoint of both knowledge providers and knowledge receivers where both are colleagues—in other words, coworkers and managers. This research focuses especially on motivational causes that explain knowledge sharing between providers and recipients. In addition, we posit that organizational learning factors impact an employee's knowledge-sharing intentions and constraints/opportunities.

What are the experiences of sharing knowledge with colleagues? How and to what extent does motivation, strong/weak ties, organizational climate, organizational identification, and relationships influence the sharing of knowledge among colleagues? The research will be from the viewpoint of both knowledge providers and knowledge receivers where both are colleagues—in other words, coworkers and managers.

LITERATURE REVIEW

Definition of knowledge

The knowledge-management literature can be roughly divided into two streams. The first stream regards knowledge as an asset capable of being stored, combined, and disseminated; the second is defined by the idea that knowledge is embedded in relationships and cannot be separated from actions (Nakano, Muniz Jr., & Dias Batista Jr., 2013). These streams distinguish between explicit and tacit knowledge. Explicit knowledge (EK) can be copied and stored in various formats, making it easy to transfer and share (Stevens, Millage, & Clark, 2010). Tacit knowledge (TK) develops incrementally based on personal experience and relies on personal judgment (Insch, McIntyre, & Dawley, 2008; McIver, Lengnick-Hall, Lengnick-Hall, & Ramachandran, 2013). Kane et al. (2014) defined the relationship between a knowledge provider and recipient as one where the provider controls the recipient's ability to know and access the provided content but must customize the shared knowledge to the recipient's needs and situation (Ho & Ganesan, 2013).

Knowledge-sharing intention

Knowledge sharing involves the exchange of both explicit and tacit knowledge relevant to the task, which includes communication, interaction, and the implicit coordination of the knowledge provider, who knows what to share with the receiver (Buvik & Tvedt, 2017). Knowledge sharing consists of the horizontal integration of dissimilar knowledge. That is, a comprehensive knowledge base delivers diverse knowledge interfaces among functional units and often includes reciprocal exchanges—including both providing and receiving knowledge—between staff members (Foss, Minbaeva, Pedersen, & Reinholt, 2009). This theme focuses on tacit knowledge at a personal level and proposes that knowledge providers can accept any challenge only if they feel comfortable that a knowledge or experience has been examined many times (Dingle, Stark, Cruwys, & Best, 2015). Only then are they willing to share that knowledge with recipients who could be motivated by group identification (Dingle et al., 2015). Gino, Argote, Miron-Spektor, and Todorova (2010) examined the effects of learning from different types of prior experiences (direct and indirect). They found that direct experience leads to higher levels of team creativity and product component divergence than indirect experience. Thus, prior experiences build a base for knowledge sharing across different areas (Cui & O'Connor, 2012).

Self-efficacy

Per social cognitive theory (SCT) (Bandura, 1986), there are two cognitive concepts: self-efficacy and outcome expectations. Both lead human behavior. This research defines self-efficacy as knowledge providers' perceptions of their own ability to share experiences and knowledge or the belief that they possess the skills and resources necessary for the recipient's success. Lin and Chen (2013) believe that self-efficacy defines employees' belief in their capability to learn effectively. George and Prybutok (2014) recognize that self-efficacy is an individual's belief in a person's ability to succeed in making important decisions. Salanova, Rodríguez-Sánchez, Schaufeli, and Cifre (2014) argue that self-efficacy beliefs clearly influence how people perceive both challenging tasks and the skills needed to successfully complete those tasks. The ideal situation to discuss this phenomenon is to have staff try tasks with which they feel comfortable given their knowledge, experience, and control rather than implementing tasks in a new area for them. (Ventura, Salanova, & Llorens, 2014).
In summary, whether organizations can successfully implement knowledge management is largely based on an organization's self-efficacy, how the executive level utilizes knowledge management, and the self-efficacy of the individual.

Tie strength

To maintain productive interpersonal relationships in an organization, employees need to trust each other and engage in frequent contact over a long period of time (Dahlander & McFarland, 2013; Uzzi, 1997). Over the past two decades, most social network researchers have focused more on the quality of personal relationships. If an individual believes the relationship is very important, involving more frequency, it is defined as a strong tie relationship. On the other hand, a weak tie relationship is less important, so the interaction is less frequent (Baker, Donthu, & Kumar, 2016). An area requiring more research is "intra-organizational task relationships and the factors leading to their formation and persistence" (Dahlander & McFarland, 2013).
Theory of Planned Behavior (TPB), Subjective Norms, and Attitude toward Sharing
"Subjective norms" are included as a direct determinant of behavioral intention in both the theory of reasoned action (TRA) (Fishbein & Ajzen, 1975) and the subsequent theory of planned behavior (TPB) (Ajzen, 1991). Such norms are defined as the perceived social pressure to

either perform or not perform a behavior and have received significant practical support as an important precursor to behavioral intention (Ajzen, 1991).
TPB states that three evaluation criteria—attitude (ATT), subjective norm (SN), and perceived behavioral control (PBC)—influence behavioral intention (BI), which, along with PBC, determines technology usage (use) (Ajzen, 1991). Intention is influenced by people's attitude toward a behavior, which is a function of their beliefs about the consequences of that behavior. This attitude, in turn, translates into either positive or negative feelings. Scholars (Marta, Pozzi, & Vignoles, 2014; Schwenk & Möser, 2009) have noted that an idea central to TPB is that it seeks to explain the relationship between an people's attitudes and behavior, and their behavioral intentions.
Recently, similar arguments have been made. Scholars believe that TPB "is the premise that a person's intention or stated plan is the most proximal predictor of behavior… [and that] intention is influenced by three sets of belief-based social cognitive constructs, namely, attitudes, subjective norms, and perceived behavior control (PBC)" (Hagger & Chatzisarantis, 2012, p. 198). Many empirical studies (Ajzen & Sheikh, 2013; Gissel, Thompson, & Pond, 2013; Levine & Strube, 2011; McPhee, Sears, & Wiesner, 2014; White, Thomas, Johnson, & Hyde, 2008) have indicated that attitudes, subjective norms, and PBC are all significantly and positively related to behavioral intentions.

Organizational communication

Collyer (2016) argued that face-to-face communication is a more effective way than X to eliminate the confusion. Recently, employees of all ages rely on new technology such as video/teleconference and social media tools (e.g., Twitter, Facebook, and Google Plus) to communicate in the organization. Especially, "Gen X and Gen Y business professionals are quite likely to consider that social networking tools will be the primary tools for team communication in the future" (Cardon & Marshall, 2015). Kodish (2017) emphasized that both communication and interaction provide the necessary background for building and sustaining trust.

Knowledge hiding

Employees who try to protect their competitive advantage in an organization have various ways to avoid directly answering the knowledge requester's question. The key to employees doing this effectively is that other employees cannot point to significant evidence to catch someone in the act. For example, those protecting their competitive advantage can just say, "Sorry, I just forgot," or, "This has been classified confidential, and I am not allow to share with you."
We define knowledge hiding as the knowledge provider withholding knowledge that has been intentionally requested by the knowledge recipient (Connelly et al., 2012). In addition, ČErne, Nerstad, Dysvik, and ŠKerlavaj (2014) believe intentionally hiding knowledge in a organization not only inhibits the creativity and productivity of other staff, but also increases the distrust between knowledge provider and receiver.

Trust

This research defines trust as a complex phenomenon that involves positive or confident expectations between knowledge providers and receivers based on a willingness to accept vulnerability and belief that the behavior between them is honest, sincere, and fair (Buvik & Tvedt, 2017; Ismail, 2016). At the organizational level, trust has been linked to staff satisfaction (Edwards & Cable, 2009), performance (Colquitt, Scott, & LePine, 2007), teamwork (Sargent &

Waters, 2004), leadership effectiveness (Gillespie & Mann, 2004), and negotiation success (Olekalns & Smith, 2007).
Trust in organizations involves the staff's willingness to be vulnerable to the entire organization's actions. This can enable cooperation and collaboration with the firm, which is examined in this research on inter-organizational knowledge sharing. This willingness exists only when an organizational climate clearly communicates its actions to staff through the environment. Thus, trust has become an important influence on knowledge sharing (Buvik & Tvedt, 2017), making it a key concept in this study on knowledge sharing.
There are three different types of trust: economy-based trust, information-based trust, and identification-based trust. All three must be established consecutively to reach to identification-based trust; then the identification-based trust positively affects knowledge-sharing intention (Hsu, Ju, Yen, & Chang, 2007; Ozlati, 2015).

Organizational learning

Empirical studies have found that organizational learning processes help to facilitate the development of IT innovations (Salaway, 1987), lower the knowledge barriers to the adoption and assimilation of innovations (Attewell, 1992; Fichman & Kemerer, 1997), overcome difficulties in implementing the innovations (Argyris, 1977), and enhance organizations' overall performance outcomes from innovating (Tippins & Sohi, 2003). Given this, the common empirical finding of improving organizational performance through learning from experience is argued to be effective only because greater organizational experience provides greater opportunity for organizational failure (Sitkin, 1992). However, existing evidence that failure is more important than success for organizational learning is entirely anecdotal (Cannon & Edmondson, 2001; Tax & Brown, 1998).
The bulk of prior organizational learning researchers have examined learning from aggregated organizational experience (Argote & Epple, 1990; Darr, Argote, & Epple, 1995; Ingram & Baum, 1997). Recent work, however, has begun to explore organizational learning from prior failure experience, disaggregated from total prior experience (Baum & Ingram, 1998; Haunschild & Sullivan, 2002; Miner, Kim, Holzinger, & Haunschild, 1999).

METHODS

Methodology

Our qualitative research was conducted utilizing grounded theory, as formulated by Glaser and Strauss (Glaser, 2017; Glaser, Strauss, & Strutze, 1968). Grounded theory is an integrative methodology. The approach is based on new theory being constructed from "past and present involvements and interactions with people, perspectives, and research practices" (Charmaz, 2006, p. 10). This research method helps the researcher uncover and understand the meaning of participants' lived experiences. It does so by applying an analytical process to derive theoretical understanding and uncover patterns and conceptual frameworks aimed at adding to the body of knowledge in both academic and practitioner communities (Patvardhan, Gioia, & Hamilton, 2015).

Sample

To understand the subjective experience of knowledge-sharing behavior, we conducted in-depth interviews with 29 interviewees who were selected from the researcher's personal social network. Interviewees included 20 people who work for a private company and nine students who are studying at local state university in California with at least three years of full-time job experiences. The average years of working experience was 20.6 years, and 35% of interviewees were female and 65% male.

Data collection

The interviews lasted 60 minutes on average. All interviews were digitally recorded with permission and were professionally transcribed. The interview protocol is shown in Appendix B. Most interviews were conducted face to face for the students who live in Sacramento County in order to guarantee interviewee privacy. If meeting face to face was impossible, the interviews were conducted over Skype.

Data analysis

Corbin and Strauss (2008) introduced an open-coding approach that included processes for selecting, categorizing, and labeling direct statements, such as first-order, informant-centric codes. Thus, this study implemented this concept for data analysis because it could be built to include more theoretical concepts, such as second-order, researcher-centric themes (Patvardhan et al., 2015). Finally, we could condense data analysis into more general theoretical concepts, such the overarching dimensions (Patvardhan et al., 2015). In the beginning, we coded by reviewing interview transcripts and identified all of the words that characterized basic ideas or concepts. Later, the next analyses implicated axial coding (Corbin & Strauss, 2008)—synthesizing and clustering the previous codes into higher-order themes. At this stage, we used constant comparative methods from Glaser and Strauss (1968) and compared data over time and across codes. Finally, this study applied grounded theory to convert the previously static and dimensions into a comprehensive diagrammatic summary. We used the qualitative data-analysis software NVivo to manage the transcripts and the data corpus, and we used constant comparative methods to compare and contrast data to establish the codes (Glaser, 1978). After uploading all the transcripts, we started reading through each transcript to understand content and to add memos on NVivo.

While working through key nodes of interest to us, we began to see differences in how interviewees talked about their knowledge-sharing experiences and stories. For now, we have coded these stories as tacit knowledge that may be potentially beneficial for their future careers. Figure 1 displays the ordering and structuring of the data that identify the codes, themes, and dimensions that capture the early (prologue) stages of the knowledge-sharing processes. We accumulated the informant-based, 121 first-order codes into 14 researcher-induced second-order themes, which we further distilled into seven overarching theoretical dimensions.

Figure 1. Prologue to the knowledge-sharing data structure

RESULTS

Many knowledge-sharing stories were reported during the interview processes, resulting in seven overarching theoretical dimensions that impacted knowledge-sharing behavior: self-efficacy, attitude, tie strength, organizational communication, trust, knowledge hiding, and organizational learning. Interviewees are referenced in both the Findings and Discussion sections.

Finding 1: Being an employee with a strong self-efficacy (13 of 29 interviewees' quotes support this finding)
This finding includes the knowledge providers who have a strong self-efficacy in their knowledge-sharing processes. Scholars define self-efficacy as individuals' beliefs regarding their own ability to both realize an action and to manage tasks and situations (Battisti, Gilardi, Siletti, and Solari, 2014; Mesurado, Richaud, & Mateo, 2015). Both knowledge provider and receiver believe they feel more confidence in the knowledge-sharing processes.

Example Quotes:
"When I trained people I felt like I trained them the best in a way. Because I was really candid about what they expect." (Interviewee 11)

"That was a positive to me to know that my manager trusted me enough to train someone new and expect that I would pass on that information to them." (Interviewee 15)

"…then we created a very excellent website to house all of those things so that the potential students, the potential future teachers, the potential people that would engage with this project could begin to believe that this was something that they wanted to be a part of." (Interviewee 21)

"But they could and would have had the confidence in me that we could have gotten that job done in 10 months. But because I think the cascading." (Interviewee 8)

"I feel very comfortable and happy at the same time because I knew I have more knowledge than she did." (Interviewee 1)

Finding 2: Being an employee with a positive attitude toward sharing knowledge (22 of 29 interviewees' quotes support this finding)
This finding includes the knowledge providers and/or receivers who have a positive attitude toward sharing their knowledge. TPB (Ajzen, 1991) suggests that the behavioral intention to perform a particular behavior is predicted by the attitude toward the behavior. This research defines that attitude toward performing the knowledge-sharing behavior from knowledge provider to receiver.
Example Quotes:

"She wanted to know who did it and she was not aware of that software, how to look it up, how to use it so I teach her how to use it and then she used it after that all the time." (Interviewee 2)

"She shared it to everybody and she explain it but she encourage everybody to go…"

"By sharing the information with my deputy chiefs, they were able to start project planning on a collaborative basis with our police unions and our supervisors." (Interviewee 3)

“He literally took out a pad and pencil a notepad and started taking notes.” (Interviewee 25)

“I've been a team player and it was my every intention to help the team and to position the team in the best light.” (Interviewee 6)

“My coworkers reach out to me I always have a very positive sharing my knowledge with my coworker and training them to give their experience on what I have been going through, it always is a very pleasure for my coworker.” (Interviewee 7)

“The biggest regret that you will have is not trying. You won't regret because you try it and you fail. You will regret because you never tried." So I said, "You might as well figure out how, I mean, do the math, see how much you need and do what you can to save.” (Interviewee 21)

Finding 3: Building a good relationship (13 of 29 interviewees’ quotes support this finding)
If the knowledge provider and receiver believe the relationship is very important, involving more frequency, it is defined as a strong-tie relationship between both the knowledge provider and receiver. From this study, the tie strength could be defined based on the frequency of interactions between both the knowledge provider and receiver (Hong, Pavlou, Wang, & Shi, 2016).
Example Quotes:
“If I feel like that person has a pretty close relationship with me, I would sit down with them.” (Interviewee 28)

“I'd say that the knowledge that he gave me was helping me understand how the university works. He would give me this knowledge in—we would have weekly one-on-one.” (Interviewee 3)

“When it comes to relationship—building in that environment—the better your relationship with your clients, of course, the better your project, or your outcomes or your sales, or whatever it is may be.” (Interviewee 27)

“And then there was a lot of background about the work environment in making them feel comfortable introducing them to co-workers. I think the positive out of that was kind of building a relationship with a new trainee.” (Interviewee 11)

“Thinking about it now it's probably a really positive experience because I was really sad that I couldn't spend my holidays with my own family but I spent it with my Marie Callender's family. I think despite all the turmoil and the frustrations of the holiday dealing with horrible customers, it brought everyone together. At the end of the day.” (Interviewee 10)

“We had a very candid honest one-on-one discussion. And help him to reflect and to be honest to himself.” (Interviewee 25)

Finding 4: Being a good communicator (26 of 29 interviewees’ quotes support this finding)
This study defines organizational communication as fundamental in working environments when associating between knowledge provider and receiver, and enabling organizations to achieve the knowledge-sharing processes (Musah, Zulkipli, & Ahmad, 2017). Organizational communication comprises how employees communicate multifaceted details—such as emails

(Cardon & Marshall, 2015), meetings, trainings, and appointments—in formal or informal situations (Stephens & Barrett, 2016).
Example Quotes:

“This is a good communication and the result of good communications and also the trust it established between us.” (Interviewee 24)

“The best important thing is the communication. If you have a good communication for everybody, you can quickly talk—reach to them and if there is a mistake you share with them. If there is an error, if there is a negative experience, you should reach them very quickly.” (Interviewee 29)

“I took that information, I not only shared it with my team or my deputy chiefs. I have two deputy chiefs of police. I shared that information with them in order to begin project planning.” (Interviewee 17)

“The way that he communicated to me was that I let the team down because I was not responsive to the request. He didn't seem to want to want to hear that there could have been a miscommunication, a misunderstanding, but clearly what was not at play was my commitment, my sincerity, or my integrity.” (Interviewee 8)

“It was miscommunication but I also think that it was a mischaracterization. With respect to my underline intentions, my underline commitment, or my underline diligence, I think that was mischaracterized and misperceived by my boss, and it left me feeling a bit alienated, mischaracterized, and misjudged because I felt he was making a judgment about my character rather than my actions.” (Interviewee 9)

“That, to me, was a great information share with my executives, because I knew how to talk to them with the way wanted to get information.” (Interviewee 18)

“If he wasn't very efficient at communicating precisely and clearly, then a lot of time would be wasted and so he had to explain a lot of information in a very short amount of time, to a lot of people. And so he had to develop that skill of communicating that way.” (Interviewee 10)

Finding 5: Being an employee that exhibits knowledge hiding behavior (12 of 29 interviewees’ quotes support this finding)
Scholars (Connelly et al., 2012) defined “knowledge hiding as an intentional attempt by an individual to withhold or conceal knowledge that has been requested by another person” (p. 65). ČErne et al. (2014) believe intentionally hiding knowledge in an organization not only inhibits the creativity and productivity of other staff, but also increases the distrust between knowledge provider and receiver.
Example Quotes:
“In a big company, you would see people hold information back, knowledge back because they wanted to deliver that information in a meeting. They wanted to be the one that looked the smartest or they wanted to be the one that everybody looked to or their knowledge would help them get a promotion.” (Interviewee 28)

“I had the feeling and impression that the person did not want to teach me how to do it.” (Interviewee 22)

“They didn't respond. They told him that it was just not okay, but they never explained to him why it was not okay or what the reason behind it was. They just said, "Employee, that's not okay.” (Interviewee 11)

“I felt like, that information had been hidden from me, had not been fully disclosed, had not been shared so as to forewarn me, so as to position me, and so as to educate me on the level of discontent, on the level of frustration and the level of lack of confidence in my leadership. I felt like there had not been full support, unity, and loyalty supporting my leadership. I felt let down.” (Interviewee 9)

“One negative experience with the peers is that it's more of a evil thing. If the person are the same level trying to provide any trainings or knowledge, they might feel that, ‘I know better than him,’ that is one negative experience with the peers. They don't try to… because they think, ‘I know better than this guy,’ or that kind of equal thing is one negative experience.” (Interviewee 2)

“So that, basically, the don't pay attention thinking that, ‘Oh, I know what this guy ... This guy is trying to provide training because he wants to prove his management, his doing some relational activities beyond his job to promote himself or to get a better reputation with his boss.’ That's how they feel, rather than trying to focus on what is in the training, or knowledge session.” (Interviewee 5)

“It's same across peers and colleagues. Same thing. Even if they are peers, same thing. Here it's more of a, because of the job security. Sometime people not tend to share the knowledge.” (Interviewee 7)

Finding 6: Building up trust in the organization (14 of 29 interviewees’ quotes support this finding)
Trust is the most important criterion between knowledge providers and recipients, and makes it more likely for knowledge sharing to occur through the knowledge transfer process (Gooderham, Minbaeva, & Pedersen, 2011). Trust is a feeling one person has regarding another person’s capability and reliability, as supported by that person’s past actions. From this study, we defined knowledge provider (the trustor) willingness to be vulnerable to knowledge receiver (the trustee) on the basis that the trustee will act according to the trustor’s confident expectations (Mayer, Davis, & Schoorman, 1995; Schoorman, Mayer, & Davis, 2007).
Example Quotes:
“This is a good communication and the result of good communications and also the trust it established between us.” (Interviewee 29)

“Some colleagues of you give you some wrong information. You as a receiver the first time you trust your colleague, because he's your friend because your colleague, he won't tell you wrong things.” (Interviewee 2)

“You should process anything that comes to your to your colleagues and to your friends. You know that's a trusted person, but before you share with other people, you should process that.” (Interviewee 3)

“I felt I could trust them, and I could rely on them and I knew that they would help me no matter what and I would do the same for them.” (Interviewee 4)

“I shared with him because I have trust in his leadership, in his intention, in his thoughtfulness.” (Interviewee 9)

“Because I have trust in the Chief's intentions and knowing his thoughtfulness towards building community.” (Interviewee 12)

“I trust each of you enough within our team that you should have some of this confidential information because I know you're not going to go out and spread it anywhere.” (Interviewee 18)

Finding 7: Building an organizational learning working climate (15 of 29 interviewees’ quotes support this finding)
Organizational learning involves not a simple sender-to-receiver transmission (Ingram 2002), but sophisticated processes mediated by environmental entities, such as populations, geographic regions, and the communities of interests. Organizational learning theorists have long held that organizations learn primarily through processes of “problematic search,” which they engage in only after experiencing failures (March & Shapira, 1992).
Example Quotes

“I had to teach my immediate manager because she was just new, she just got hired, how to use some software on the company.” (Interviewee 22)

“I shared to another new employee, I was training her and she came in and I showed her and I said, "Grab a piece of paper, make sure you write this down because you will forget about it.” (Interviewee 23)

“Sometimes where you have a colleague, and he doesn't know about the sensitivity of the issues and you share with him some issues that.” (Interviewee 24)

“I mentioned that the colleagues should be educated, should be informed, should be properly educated about the issue you wanted to mention.”(Interviewee 12)

“I took that information; I not only shared it with my team or my deputy chiefs. I have two deputy chiefs of police. I shared that information with them in order to begin project planning. But beyond that, Tony, I shared it with the City Police Chief to inform him of our intention and our progress towards gaining a grant to implement the body-worn camera.” (Interviewee 17)

“For that I interacted with my senior professor and my junior professor. We collaborate through online, asking questions, getting responses. Also I send that information to other people who are not in the meeting, going back and forth to come up with a finalized set of learning goals and objectives. Is that an example of collaboration?” (Interviewee 5)

“Normally I need give them by the difference task or different jobs, to give them the appropriative knowledge when I deliver to them.” (Interviewee 8)

CONCLUSIONS AND FUTURE DIRECTIONS

It appears that the pressure of managerial expectations associated with company policies and management reduces the intrinsic satisfaction of sharing knowledge with others. In the presence of highly subjective norms, the motivating influence of a favorable attitude toward

sharing knowledge is weakened throughout the organization. This section analyzes the factors that impact knowledge-sharing intention at both the personal and organizational level.

At the personal level, interviewees believe that building a strong relationship with other staff is a necessity for an organization because they can gain trust from each other. Based on the findings, this research emphasizes trust as the core component that influences all factors for sharing knowledge between the knowledge provider and receiver. Trust was tied to individual relationships, and it is the fundamental condition for the knowledge-sharing process (Nelson, 2017). During the knowledge-sharing process, effective communication always improves the sharing of knowledge, and trust is established between knowledge provider and receiver. Max Evans (2015) posits that building trust using communications is important for sharing tacit knowledge.

Previous scholars have mentioned that trust is a key factor affecting knowledge sharing between the personal and organizational level (Buvik & Tvedt, 2017). Staff in particular easily build up strong ties and trust when they all experience the same pressure from work during a busy holiday season. For example, they sacrifice the opportunity to stay with their families because of work. On the other hand, a miscommunication causing misperceptions is often a disaster during the knowledge-sharing process because it can cause misjudgments by an organization's decision-maker.

Both knowledge provider and receiver feel they have a pretty good relationship with one another. They like to start the knowledge-sharing process because they have first built up trust. Sometimes, if one person is closed to another person, they would move to having lunch or a beer to have straightforward communication in an informal situation. Based on his own experiences, one interviewee believes that informal knowledge sharing has more efficiency than formal knowledge sharing. Kodish (2017) also believes that trust is the key component of the organizational process that jointly with communication channels to the environment. Further, both misunderstandings and miscommunication can cause a trust issue that leaves both knowledge provider and receiver feeling frustrated (Ferguson & Peterson, 2015).

Attitude is also an important subject influencing knowledge-sharing intention. Employees who have the appropriate attitude toward subjective norms always have good motivation to share their knowledge with others. Bandura (1997) defined attitude as a person's general beliefs that a target behavior will result in certain desirable outcomes that are conceptually similar to outcome expectancies. TPB is an extension of the theory of reasoned action (TRA) (Ajzen, 1991), which assumes that most human social behavior is under volitional control and therefore can be predicted from intentions alone.

TPB states that three evaluation criteria—attitude (ATT), subjective norm (SN), and perceived behavioral control (PBC)—influence behavioral intention (BI), which, along with PBC, determine technology usage (use) (Ajzen, 1991). Intention is influenced by people's attitude toward a behavior, which is a function of their beliefs about the consequences of that behavior. This attitude, in turn, translates into either positive or negative feelings. Scholars (Marta, Pozzi, & Vignoles, 2014; Schwenk & Möser, 2009) have noted that a central idea of TPB is that it seeks to explain the relationship between an individual's attitudes and behavior and their behavioral intentions.

From our findings, a knowledge provider with positive attitude always toward to share their knowledge to receiver, and a receiver always with a positive attitude toward to obtain a knowledge from providing. If an employee does not want to say anything against other employees, an inappropriate attitude always impacts the knowledge sharing with a negative intention among employees and frustrates the whole organization. Not only does this neglect and underestimate the cohesive power of the entire organization, but also the inappropriate attitude damages the trust between employees and breaks their ties. Per TPB, all of the attitudes toward sharing or toward learning to influence behavior intention.

Both knowledge provider and receiver gain self-confidence during the knowledge-sharing process. For example, one of the knowledge providers in the study felt he had trained the receivers to the best of his ability, and he believed he was candid about what the receivers expected. A self-efficacy was built in his mind after the knowledge-sharing process. Kauppila and Tempelaar (2016) emphasized that self-efficacy (GSE) is the most important psychological trait that reinforces individuals' behavior. Per our findings, knowledge providers' beliefs in their capability influence both the organizational expectations they set for themselves and their obligation to challenges during the knowledge-sharing processes. Bandura (2015) associated both social cognitive theory and goal theory, and that has been confirmed by our findings—the higher individual self-efficacy, the higher the goals people set for themselves.

Because knowledge receivers provided the knowledge provider with feedback that the knowledge was communicated relatively well, good communication was necessary. Another interesting phenomenon from the knowledge provider is that she felt very comfortable and happy after the knowledge-sharing process because she knew she had more knowledge than the receiver.

Knowledge hiding was the only factor that negatively impacted knowledge-sharing behavior in this study. The knowledge receivers felt that the knowledge provider did not want to share information with them and refused to explain the reasons; it is difficult to speculate on the reasons behind this behavior from the knowledge provider. Knowledge hiding behavior not only breaks the strength of ties but also destroys trust, causing the knowledge provider to be unwilling to share anything more with the receiver (ČErne et al., 2014). One of the interviewees who worked at a software company for many years emphasized that knowledge hiding is a very common behavior in the information technology field. Staff used to share knowledge in front of the manager to make a favorable impression. The reason for this behavior is that staff may have a psychological safety issue, such as worrying about being replaced in the organization.

Organizational learning is the only environmental factor that impacts the knowledge-sharing intention. Many of the interviewees believe it is a manager's responsibility to create a policy that rewards knowledge-sharing behavior and to build up an organizational learning environment to encourage staff to share knowledge with each other to improve the performance of the entire firm.

This study has several limitations that should be addressed in future research. First, this research did not go in-depth into the possible influences of managerial solutions to resolving knowledge-sharing issues. For example, an inappropriate attitude and lack of communication both cause a barrier to knowledge sharing in the organizational climate. In addition, one of the interviewees believes technology is not a necessary tool for improving the knowledge-sharing process. For example, staff like to use telecommunication in their training courses, which has created many issues, such as poor signals or background noise between the knowledge provider and receivers. Secondly, our samples included the U.S.A. and an Asian country, so this study represents responses based on Eastern and Western cultural behavior. For example, comparing a few Asian samples and American samples, such as a family business from each culture, may make our findings more culture-specific. This study did not closely analyze diversity. Although the operational and managerial practices may be similar to other countries, "Chinese culture has the tradition of viewing one's politeness in social interactions as a virtue" (Wang, Liu, Liao, Gong, Kammeyer-Mueller, & Shi, 2013, p. 1001). Thus, more multi-cultural and ethnic environmental samples may make this study more interesting in future research.

This research study proposes that organizations must recognize when members embody feelings of knowledge-sharing behavior that could potentially increase the firm's overall competitive advantage. It is recognized that it is difficult to create adequate rewards to encourage knowledge providers. Given this, it is a challenge for the management level to consider how to reduce these negative feelings for knowledge providers and to encourage the

mutual social exchange relationships that are important for driving a knowledge-sharing organizational climate. Considering that inter-organizational knowledge sharing is an issue that has inspired a great deal of research, its benefits to knowledge providers have not been explored well.

Knowledge hiding is another challenge the management level must resolve, and this issue is more difficult to deal with because it is a feeling that knowledge receivers have but lacks significant evidence to prove. Knowledge hiding has overall impacts, such as ethics and performance issues, which affect the firm. Since trust is a core component that can be defined as a personal factor, it is included with other personal factors, such as tie strength, self-efficacy, attitudes toward sharing knowledge, communication, knowledge hiding, and impacts on knowledge-sharing intention. In addition, trust also influences environmental factors, such as organizational learning, which impacts knowledge-sharing intention.

This study provides a useful theoretical framework for understanding how trust interacts between the SCT, TPB, social networking theory (SNT), and organizational learning theories. Specifically, "the SCT suggests that the effects of personal attitudes (including optimism) are often determined by their interaction with important behavioral and environmental factors" (Hmieleski & Baron, 2009, p. 473). Based on SCT, this research offers a framework grounded in TPB to discuss the intention of organizational learning within a given enterprise.

There are theoretical and empirical gaps between TPB and SNT, and knowledge hiding/hoarding with SNT because literature seldom addresses this phenomenon. Attitude toward sharing is one of the important concepts from TPB, and we assume that a better and/or closer relationship exists between knowledge provider and receiver, which influences the knowledge provider's attitude toward sharing his/her knowledge with the receiver. We also assume that a stronger relationship exists between knowledge provider and receiver, which influences the knowledge provider's attitude toward hiding and hoarding his/her knowledge from the receiver. We expect that future empirical research can explore these areas.

The issue of evaluation is likely to play an important role, but because this study focused on organizational support for individual knowledge sharing, further elaboration and refinement are needed. Further research needs to substantiate the practical evaluation models and effective review processes to connect individual knowledge sharing to the knowledge process at the firm level. Next, it should tie team knowledge to firm performance. In addition, the results of this study led to the belief that service providers, customers, and/or vendors could be both knowledge providers and recipients. It would be interesting to know whether all three play this role and how this influences their firms' overall performance.

Because Bandura's SCT is based on a collaborative relationship between environmental, personal, and individual behaviors, it provides a useful theoretical framework for the understanding of the self-regulatory processes and self-efficacy concepts, and can be applied in many areas. Specifically, SCT suggests that the effects of a personal disposition (including optimism) are often determined by their interaction with important behavioral and environmental factors (Wood & Bandura, 1989). In our seven overarching theoretical dimensions, we can define organizational learning as an environmental factor, and self-efficacy, attitude toward sharing, tie strength, organizational communication, knowledge hiding, and trust as individual factors to examine the interaction to behavior intention. This future research can evaluate whether our findings can apply to both social cognitive theory and goal theory.

Another interesting topic for future research would be to examine how expertise (i.e., personal reputation) is highly valued in an organization, while mentoring or assisting others is not. In this case, do knowledge-sharing providers still have a high motivation to share their knowledge?

APPENDIX

Interview protocol

Introduction (interviewer): "Hello my name is Tony Tung. I am a doctoral student at Case Western Reserve University. Thank you so much for taking the time to meet with me today. I really appreciate it. Before getting started, there are a couple of things I would like to cover."

Purpose and Format for the Interview (Interviewer): "As a current student in the Case Western Reserve University Doctorate of Management (DM) program, I am interested in developing a greater understanding of the influence of intra-organizational staff attitudes toward sharing knowledge with their colleagues as both providers and recipients. I will ask you a series of open-ended questions on this topic, and I will also ask one or more follow-up questions as you respond. The interview will last approximately 60 minutes."

Confidentiality (Interviewer): "Everything you share in this interview will be kept in strictest confidence, and your comments will be transcribed anonymously – omitting our names, anyone else you refer to in this interview, as well as the name of your current organization and/or past organizations. Your interview responses will be included with all the other interviews I conduct."

Audio Taping (Interviewer): "To help me capture your responses accurately and without being overly distracting by taking notes, I would like to record our conversation with your permission. Again, your responses will be kept confidential. If at any time, you are uncomfortable with this interview, please let me know and I will turn the recorder off."

"Any questions before we begin?

The background: Knowledge sharing is an organizational process defined as the knowledge provider sharing ideas, information, and suggestions from his or her own experiences with a knowledge receiver.

1. Tell me about yourself and your career.

- Education - Highest Degree
- Family
- Job History and Current position, organization and culture
- The years of experience since you began working in California State?
- Anyone else influence your choice?

2: Please tell me about a time when you had a positive experience sharing knowledge to a peer.

- Describe the experience
- How important was the knowledge
- Describes Challenges
- Describes Successes
- Describe Frustrations
- Describe the positives
- Describes the negatives

3: Please tell me about a time when you had a negative experience sharing knowledge to a peer.

- Describe the experience
- How important was the knowledge
- Describes Challenges
- Describes Successes
- Describe Frustrations
- Describe the positives
- Describes the negatives

4: Please tell me about a time when you had a positive experience receiving knowledge from a peer.

- Describe the experience
- How important was the knowledge
- Describes Challenges
- Describes Successes
- Describe Frustrations
- Describe the positives
- Describes the negatives
- Etc…

5: Please tell me about a time when you had a negative experience receiving knowledge from a peer.

- Describe the experience
- How important was the knowledge
- Describes Challenges
- Describes Successes
- Describe Frustrations
- Describe the positives
- Describes the negatives

Conclusion

“Thank you so much for our conversation! I've had an enjoyable time and I hope you have as well. This has been extremely helpful. We have covered a lot of ground, but if by any chance I have missed anything, would it be OK to contact you again for a brief clarification on any particular points, if necessary?

One last thing - Is there anything else that we haven't discussed that you would like to add before we finish?

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An Exploratory Case on Early Humanitarian Operations in Islands and Coastal Regions: Lessons from Tropical Cyclone Ockhi

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ABSTRACT

The relevance and demand for humanitarian operations is increasing every year, as evidenced by highly erratic climatic patterns and frequent natural disasters such as landslides, earthquakes, droughts, floods, and hurricanes. In this paper, we discuss the case of "Ockhi", a Category 3 tropical cyclone that hit the Indian Subcontinent in late 2017. The magnitude, spontaneity, and, severity of such events, which are referred to as *force majeure*, puts enormous pressure on humanitarian organizations and supply chains globally, which are often constrained with limited resources, but entrusted with multiple functions, including but not limited to roles of information dissemination, evacuation of people, search & rescue, coordination & control, agile deployment, mobilization of forces, logistics, salvage, recovery, and reconstruction. This paper is a pilot work, employing case study method that explores issues in Early Humanitarian Operations during high uncertainty scenarios in islands and coastal regions. The research findings reveal critical issues in: (1) Effective Synchronization between information systems and field operations, (2) Responsiveness due to access cut-off (black out) between command center in mainland and islands or remotely located coastal regions hindering supply chain agility during early phase of humanitarian operations, and (3) Flexibility of Operations due to inadequate preparedness, safe and robust cross-docking facilities, and shelters to endure peaks of cyclonic flooding conditions during the disaster at island territories. The data has been triangulated with two other cyclonic flooding disasters in 2018 for validation. The results and key takeaways are summarized; limitations and directions for future research are discussed.

KEYWORDS: Humanitarian Supply Chains, Early Phase Disaster Management, Information - Operations Synchronization, Supply Chain Agility, Cross Docking, Case Study Research

INTRODUCTION

The World Disasters Report (Sanderson & Sharma, 2016) issued by the International Federation of Red Cross and Red Crescent Societies, is dotted with grave calamities since the turn of the new millennium; the South Asian Tsunami (2004), Hurricane Katrina and Rita (2005), Sichuan Earthquake in China (2008), the Ebola Outbreak in West Africa (2014) and multiple cyclones of very-high severity in the Indian Ocean, to name a few. Around the world, over 6000 disasters were reported in the last decade, with 771911 people killed, 1.9 billion people affected, and US $ 1.4 trillion (2015 prices) of estimated damages. The frequency, scale and severity of these catastrophes, which are referred to as *force majeure*, or 'Acts of God', puts enormous pressure on humanitarian operations and supply chains globally, which are often constrained

with limited resources, but entrusted with multiple functions, including but not limited to the roles of information dissemination, evacuation of people, search & rescue, coordination & control, agile deployment & mobilization of forces, logistics, salvage, recovery, and reconstruction. According to data from Centre for Research on the Epidemiology of Disasters (CRED), there has been a sharp spike in the frequency of floods and cyclones since the mid-1990s (Peduzzi, 2005) with significant impact on human lives, particularly for people living in low and middle income countries, and endangering the existence of island nations and coastal states. Table 1 shows the Top 10 countries in the world with the highest human impact due to natural disasters in the year 2016. It is evident that highest number of the deaths in absolute numbers, and per 100,000 inhabitants are in countries that are coastal states or islands, while 4 of the top 5 countries that were affected (on per capita basis) are island nations. More recent data from CRED (2017) also paints a similar picture, but the economic costs were much higher during recent disaster events particularly related to cyclonic storms and floods. In 2017 alone, 84.6% of the damage due to natural disasters was accounted by storms (cyclones, hurricanes or typhoons as they are referred to in different geographies). While hurricanes Harvey, Irma and Maria caused significant economic loss and damage in the Americas, particularly in the Caribbean region, India witnessed the highest number of deaths due to natural disasters in 2017 with 2,300 casualties and over 22 million affected inhabitants. Tropical Cyclone Ockhi, the case-in-context of this paper, inimitably stands out as one the most catastrophic of cyclonic disasters that hit the Indian subcontinent in the last decade, particularly affecting island territories, both in terms of human casualties and economic damage.

Tropical Cyclone Ockhi was a first in over 40 years to have travelled over 2000 kilometers around the west coast of peninsular India, starting as a depression in south-west Bay of Bengal on 29th November 2017, and moving up along the west coast where it finally dissipated off the coast of Gujarat on 6th December 2017, wreaking havoc and destruction along the way in Sri Lanka, Maldives, Lakshadweep Islands, and the southern states of India. It was impromptu, and held out as an aberration in the Disaster Response efforts which had seen continual improvement in the last decade, in terms of casualty prevention through early action; critical to this being early warning systems, rapid information dissemination and agile deployment and early evacuation in disaster prone areas.

Table 1 – Top 10 countries in the world with the highest human impact due to natural disasters in 2016

Deaths (number)		Deaths per 10^5 people		Affected (in millions)		Affected per 100,000 people	
China	1,151	Haiti	5.56	India	331.2	Micronesia	96,113
India	884	Fiji	5.16	China	13.0	Haiti	54,076
Ecuador	686	Ecuador	4.25	Ethiopia	10.2	Somalia	43,571
DPR Korea	598	DPR Korea	2.39	Malawi	6.5	Fiji	39,792
Haiti	596	Macedonia	1.06	Haiti	5.8	Marshall Islands	39,628
Pakistan	310	Rwanda	1.00	Somalia	4.7	Malawi	37,759
Italy	299	Sri Lanka	0.97	Zimbabwe	4.1	Mongolia	32,611
Indonesia	251	Taiwan	0.90	S. Sudan	3.6	S. Sudan	29,352
USA	250	Nepal	0.63	Vietnam	3.6	Swaziland	27,196
Taiwan	212	Italy	0.49	Bangladesh	3.2	Zimbabwe	26,277

Source: Created by the authors based on data from CRED (2016)

LITERATURE REVIEW

Humanitarian logistics and supply chain research is still an emerging and continually evolving field of study. It is still being defined, mapped in literature, and contextualized to reflect realities and specific phenomena on ground. Since 2005, there has been a spike in research on humanitarian operations, logistics and supply chains. Researchers including Gupta et al. (2016), Kunz et al. (2017), Starr & Wassenhove (2016), Van Wassenhove (2006), Kovács & Spens (2007) have outlined the major gaps, broad directions and challenges for research in humanitarian logistics. In the last decade, there have been several pioneering efforts in this field, including case studies on organizational partnerships (Tomasini & Wassenhove, 2009), analysis of trends, developments and unique features of humanitarian logistics (Holguín-Veras et al., 2012; Kovács & Spens, 2011), application of Operations Research techniques for humanitarian logistics (Özdamar & Ertem, 2015; Wassenhove & Martinez, 2012), solutions to fleet management issues (Martinez et al., 2011) and problems related to vehicle procurement policies (Eftekhar et al., 2014). However, much of the research work is scattered and isolated in silos with few interlinkages; and to the best of our knowledge there is little grounded, empirical or case based research on recent developments in early phase of humanitarian operations with a focus on supply chain agility. The literature on early humanitarian operations is even scarcer in the Asian context, particularly from the Indian subcontinent that has been severely affected by cyclonic events from time to time. This is profound considering the number, frequency and intensity of cyclones that hit the North Indian Ocean region (refer Table 2) in the last decade, especial the coastal belts of peninsular India. The list represented in Table 2, was compiled by the authors from secondary sources, and comprises of cyclonic storms in the period from 2007-2018, with sustained 3-min. winds having speed greater than 65 km/h. The list includes severe cyclones, and those that would fall in the 1-5 Category Hurricanes, according to the classification by the National Hurricane Centre (NHC). Tropical depressions and deep depression systems were excluded from this list as they weren't disasters by themselves. Only when depressions picked up water vapor beyond a threshold value, gained strength, wind speed and intensity, would they become disastrous, meriting inclusion in the list that has been compiled. However, it may be noted that, for meteorologists and weather forecasters, deep depressions are important considerations in their "watch-list", as they could become potential tropical cyclones or hurricanes of higher intensity. It may observed from Table 2 that in the last decade , there was one Super Cyclone (Category 5) 'Gonu' in 2007, 9 extremely severe cyclones (Hurricane Category 3-4), 6 very severe cyclones (Category 2-3), 5 severe cyclones (Category 1), and 21 cyclonic storms (tropical storms as referred to by NHC) in the Indian Ocean. In this paper, the case-in-focus is Very Severe Cyclonic Storm "Ockhi" that hit the subcontinent in Nov 29 – Dec 6, 2017. The name, Ockhi, meaning "eye" in Bengali, was suggested by Bangladesh. Ockhi was a Category 3 major Hurricane that caused over US $ 5 billion of estimated damages, with fatalities numbering 245 deaths and 661 missing people.

The focus of this paper is Supply Chain Agility in Early Humanitarian Operations in Islands and Coastal regions. It is an underrepresented area in literature with very little done on research humanitarian operations in general, and supply chain agility of early operations related to disaster preparedness in particular. Although there have been studies on supply chain agility in commercial context (Gligor et al., 2015; Fayezi et al., 2017; Braunscheidel & Suresh, 2009; Swafford et al., 2008; Liu et al., 2013), there is little research on supply chain agility with focus on disaster preparedness, early action and information systems – field operations integration for early phase of humanitarian operations in island territories, which forms the basis of our first research question.

Table 2 – Cyclones in North Indian Ocean Region from 2007- 2018

Year	Name	Dates Active	IMD Category	Wind Speed	Areas Affected	Damage (USD)	Deaths
2018	Sagar	May 16 – 20	Cyclonic storm	85 km/h	Yemen, Somalia, Eritrea, Djibouti, Ethiopia	$80 million	52
2018	Mekunu	May 21 – 27	Ext. Sev. Cyclone	175 km/h	Yemen, Oman, Saudi Arabia	Unknown	11
2017	Maarutha	Apr 15 – 17	Cyclonic storm	75 km/h	Myanmar, Andaman and Nicobar Islands, Thailand, Yunnan	$23.4 thousand	4
2017	Mora	May 28 – 31	Severe Cyclone	110 km/h	Sri Lanka, India, Bangladesh, Myanmar, Bhutan, Tibet	**$1.36 billion**	135
2017	Ockhi	Nov 29 – Dec 6	Very Sev. Cyclone	155 km/h	Sri Lanka, India, Maldives	**> $5.07 billion**	245
2016	Roanu	May 17 – 22	Cyclonic storm	85 km/h	Sri Lanka, East coast of India, Bangladesh, Myanmar, Yunnan	**$2 billion**	227
2016	Kyant	Oct 21 – 27	Cyclonic storm	75 km/h	Andaman Islands, Myanmar, South India	None	None
2016	Nada	Nov 29 – Dec 2	Cyclonic storm	75 km/h	Sri Lanka, South India	$16 million	12
2016	Vardah	Dec 6 – 13	Very Sev. Cyclone	130 km/h	Sumatra, Andaman and Nicobar Islands, Thailand, Malaysia, Sri Lanka, South India	**$5.87 billion**	38
2015	Ashobaa	June 7 – 12	Cyclonic storm	85 km/h	Oman, United Arab Emirates	Minimal	None
2015	Komen	July 26 – Aug 2	Cyclonic storm	75 km/h	Bangladesh, Myanmar, Northeastern India	$21.1 million	170
2015	Chapala	Oct 28 – Nov 4	Ext. Sev. Cyclone	215 km/h	Oman, Somalia, Yemen	Unknown	9
2015	Megh	Nov 5 – 10	Ext. Sev. Cyclone	175 km/h	Oman, Somalia, Yemen	Unknown	18
2014	Nanauk	Jun 10 – 14	Cyclonic storm	85 km/h	Pakistan, Oman	None	None
2014	Hudhud	Oct 7 – 14	Ext. Sev. Cyclone	185 km/h	Andaman and Nicobar Islands, India, Nepal	**$3.4 billion**	124
2014	Nilofar	Oct 25 – 31	Ext. Sev. Cyclone	205 km/h	India, Pakistan	Minor	None
2013	Viyaru	May 10 – 17	Cyclonic Storm	85 km/h	Indonesia, Thailand, Sri Lanka, India, Bangladesh, Myanmar	>$5.14 million	107
2013	Helen	Nov 19 – 23	Severe Cyclone	100 km/h	India	$800 million	11
2013	Lehar	Nov 23 – 28	Very Sev. Cyclone	140 km/h	Malay Peninsula, Andaman and Nicobar Islands, India	None	None
2013	Madi	Dec 6 – 13	Very Sev. Cyclone	120 km/h	Sri Lanka, India, Maldives	Unknown	None
2013	Phailin	Oct 8 – 14	Ext. Sev. Cyclone	215 km/h	Malay Peninsula, Andaman and Nicobar Islands, India, Myanmar, Nepal	>$658 million	45
2012	Murjan	Oct 22 – 26	Cyclonic storm	75 km/h	Yemen, Somalia	Minimal	None
2012	Nilam	Oct 28 – Nov 1	Cyclonic storm	85 km/h	Sri Lanka, India	56.7 million	75
2011	Keila	Oct 29 – Nov 4	Cyclonic Storm	65 km/h	Oman, Yemen		14
2011	Thane	Dec 25 – 31	Very Sev. Cyclone	140 km/h	India	235 – 275 million	46
2010	Bandu	May 19 – 23	Cyclonic Storm	75 km/h	Somalia, Yemen		1
2010	Laila	May 17 – 21	Severe Cyclone	100 km/h	India	118 million	65
2010	Phet	May 30 – Jun 7	Very Sev. Cyclone	155 km/h	Oman, Pakistan, India	780 million	44
2010	Giri	Oct 20–23	Ext. Sev. Cyclone	195 km/h	Bangladesh, Myanmar, Thailand, Yunnan	$359 million	157
2010	Jal	Nov 1 – 8	Severe Cyclone	110 km/h	Thailand, Malaysia, India	392 million	117
2009	Bijli	Apr 14 – 17	Cyclonic Storm	75 km/h	Eastern India, Bangladesh, Myanmar		3
2009	Phyan	Nov 9 – 12	Cyclonic Storm	85 km/h	India	$64.9 million	28
2009	Ward	Dec 10 – 16	Cyclonic Storm	85 km/h	Sri Lanka, India		
2009	Aila	May 23 – 26	Severe Cyclone	110 km/h	India, Bangladesh	$553 million	330
2008	Rashmi	Oct 25 – 27	Cyclonic Storm	85 km/h	India, Bangladesh	Unknown	28
2008	Khai Muk	Nov 13–16	Cyclonic Storm	65 km/h	India (Andhra Pradesh)	$314 million	0
2008	Nisha	Nov 25–29	Cyclonic Storm	85 km/h	Sri Lanka, India (Tamil Nadu)	$594 million	204
2008	Nargis	Apr 27 – May 3	Ext. Sev. Cyclone	165 km/h	Andaman and Nicobar Islands, Bangladesh, Myanmar, Thailand, Laos, Yunnan	**$12.9 billion**	138,366
2007	Akash	May 13 – 15	Cyclonic Storm	85 km/h	Bangladesh, Myanmar, India	$982 million	14
2007	Yemyin	June 21 – 26	Cyclonic Storm	65 km/h	India, Pakistan, Afghanistan	**$2.1 billion**	983
2007	Sidr	Nov 11 – 16	Ext. Sev. Cyclone	215 km/h	Bangladesh, West Bengal, Northeast India	**$2.21 billion**	~15,000
2007	Gonu	Jun 1 – 7	Super Cyclone	235 km/h	Oman, Iran	**$4.4 billion**	78

Source: Compiled by the authors

This gap is supported by recent research on disaster preparedness (Oloruntoba et al., 2018) wherein the case for further empirical case studies has been made, considering the needs of disaster preparedness in specific contexts, relationships and partnerships between stakeholders for synchronization of information systems and ground operations of early humanitarian operations. Based on the above gap, we formulate our first hypothesis:

H1: *The level of integration between Disaster Information Systems & Field Operations mediates relationship between Resource Capacity and Effectiveness of Early Humanitarian operations.*

Hypothesis 1 follows from the gap in understanding relationship between resource integration between multiple stakeholders involved in early humanitarian operations.

Disaster Information Systems are operated by multiple agencies including National Meteorological Department, Military Meteorological Agency and other private organizations. Authentication of reliable information and deployment of field forces is a critical link in effectiveness of Early Humanitarian operations. Field forces carrying out the operations, such as National Disaster Relief Force, Navy and the State Police, often operate under different structural hierarchies, affecting the level of resource integration between participating agencies (Fawcett & Magnan, 2002). This makes supply chain integration more of rhetoric than reality. The first research question explores the relationship between resource integration and effectiveness (a dimension of supply chain agility) of early humanitarian operations.

Charles et al. (2010) in their pioneering work on defining and measuring supply chain agility formulated agility – maturity framework for supply chains. They demonstrated the use of this framework for the case of Yogyakarta earthquake that hit Indonesia in 2006. However, this case, like most other illustrations of supply chain agility in extent literature, is on post-disaster relief, including reports from the US Navy (McCall, 2006; Byman et al., 2000; Margesson, 2005; Siegel, 1990) on Humanitarian Aid in Pacific region. We observe lacunae in research on agility of humanitarian supply chains for pre-disaster and early phase of humanitarian operations in general, and those concerning island territories in particular. This needs a specific focus as early humanitarian operations in island territories come with a different set of challenges. The time pressures notwithstanding, during cyclonic disasters, island territories are usually cut off from mainland command centers making access, communications, information coordination, logistics and last mile connectivity (Balcik et al., 2008; Kovács & Spens, 2007; Stapleton et al., 2009) extremely difficult or near impossible. According to the classification of disasters and operational complexity by Apte et al. (2015), Cyclonic Storms in Island Territories would fall in the Fourth Quadrant (refer Figure 1), the most extreme of conditions. This makes humanitarian operations in island territories the most difficult to manage according to this classification as the locations are dispersed and the onset of time is sudden.

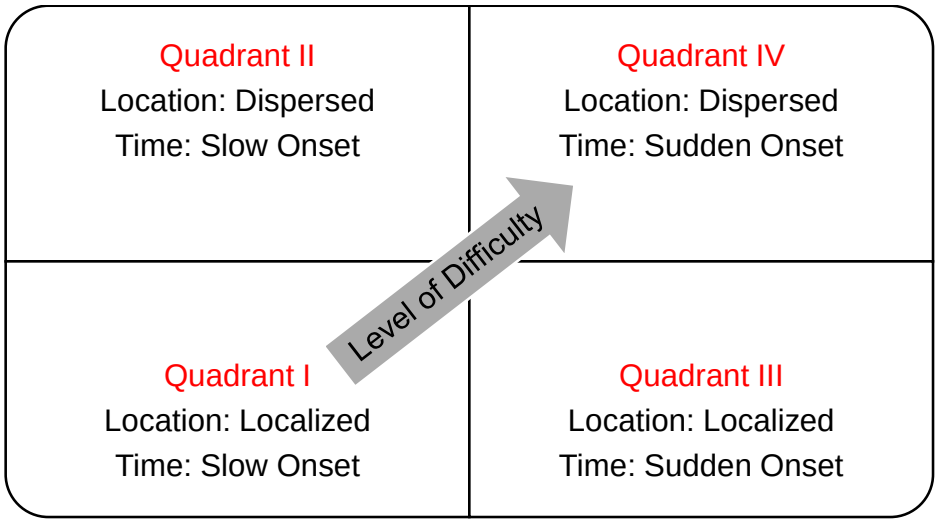

Figure 1 - Classification of Disasters and Operational Complexity (adapted from Apte et al., 2015)

Furthermore, early humanitarian operations particularly the evacuations, search and rescue operations warrant high levels of responsiveness (another dimension of supply chain agility), requiring the operations to be performed in a few hours (refer Figure 2 for Phases of Humanitarian Operations) to be successful. From Figure 2, it may be noted that the agility warranted during assessment and deployment phases are critical as these activities during these stages, which include, authentication and issue of warnings, preemptive evacuations, search & rescue, activating cross-docking facilities and pre-stocked inventories need to be carried out in a period of few hours or 1-2 days. It follows from this that agility of early humanitarian operations in island territories and remote or isolated coastal regions can become the deciding factor between the number of lives saved *versus* human casualties. This is because access and supplies to island territories are cut-off during the blackout phase when the cyclonic disaster strikes, usually at peak magnitudes.

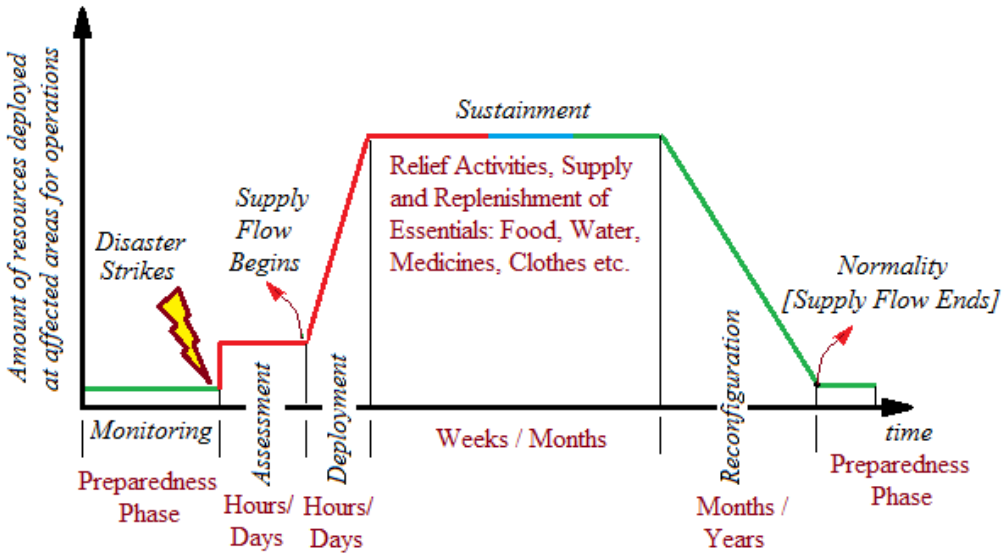

Figure 2 - Phases of Humanitarian Operations

Source: Modified from Balcik & Beamon (2008) and Charles et al. (2010)

It therefore follows, in light of the above, that the responsiveness (Kim, 2014) dimension of agility for humanitarian supply chains at nodal points in dispersed island clusters gains prominence due to the peculiar nature of island territories. Whether standalone supply chain capabilities at nodal points in island clusters (without leveraging mainland supply chain networks during early phase) affects the responsiveness of early phase of humanitarian operations, forms the basis of our second research question. The ability to evaluate, quickly respond and cover needs (captured by variable - *velocity*) in isolated island clusters and coastal zones without external help, which often comes with a time lag, is the focus area for our second hypothesis, which is thus formulated:

H2: *Standalone Nodal Resource Characteristics (size, type of fleet units for logistics, and training of stationed field forces) in Island Territories moderates the relationship between Velocity and Responsiveness of Early Humanitarian Operations.*

In the Blackett Memorial Lecture (Van Wassenhove, 2006), Humanitarian Logistics is described as Supply Chain Management in "High Gear". The efficiency, agility (inclusive of the three dimensions, namely effectiveness, responsiveness and flexibility) and resilience demanded from humanitarian operations make the nature of such operations crème-de-la-crème of all supply chain activities. Supply chains with high level of maturity, are necessarily built in with product-volume-delivery-mix flexibilities (Charles et al., 2010), in addition loading thresholds on the dimensions of responsiveness and effectiveness (refer Figure 3).

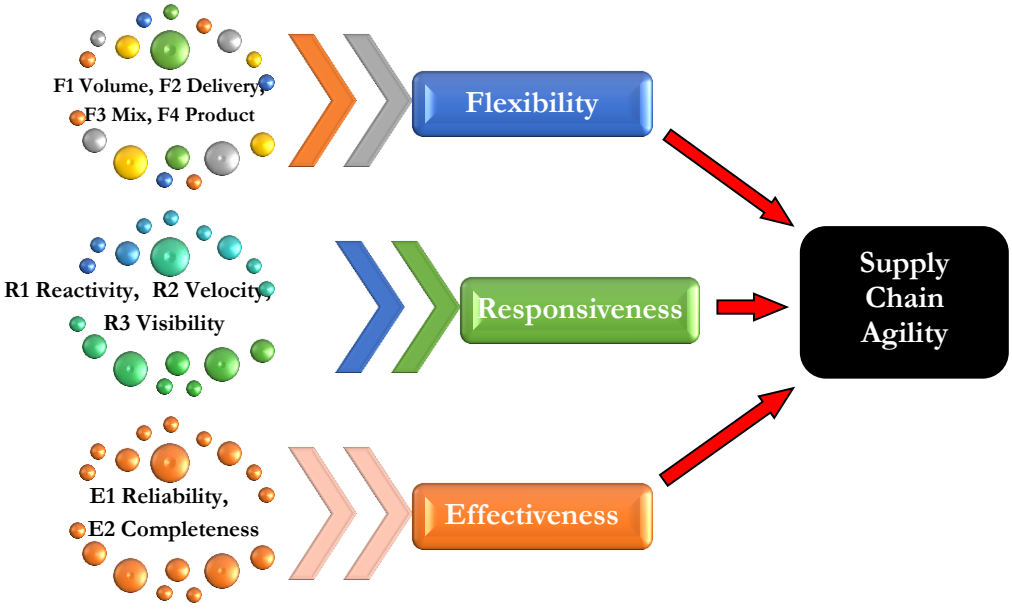

Figure 3 – Dimensions of Supply Chain Agility (adapted from Charles et al., 2010)

Supply chain literature (Power et al., 2001; Christopher & Towill, 2001; Yusuf et al., 2004) identifies Flexibility as a key dimension for supply chain agility. In humanitarian context, the sub-dimensions of Flexibility, namely, Volume Flexibility & Delivery Flexibility gain prominence (Charles et al., 2010; L' Hermitte et al., 2015; Beamon & Kotleba, 2006; Martinez et al., 2011; Gralla et al, 2014). Early phase disaster operations in dispersed island clusters and remote coastal regions implies field forces need to organize into self - directed work teams with minimal supervision and hierarchy, adapting to conditions of uncertainty and be flexible in its operations.

Often special disaster field force units are programmed to work under such conditions. This is because of the need to quickly adjust (ramp up) capacity, have built-in volume flexibilities to cater to vital demands (food, clothing, medicines etc. – refer Figure 4 for Humanitarian Supply Chain) at short notice. Such demands often emanate from cross-docks (high speed warehouse) handling large volumes and distributing relief material to shelter homes, relief camps or muster stations during early humanitarian operations phase. Strategic locations of Cross-docks in a network are imperative for effective distribution and quick response (Barsing et al., 2018), as they function as the *de facto* "fulfilment center" connecting inbound and outbound logistics. It is to be noted that unlike in commercial supply chains under normal conditions, or humanitarian supplies in mainland, early humanitarian operations in islands, particularly during peak cyclonic conditions come with a new set of challenges. First, inbound logistics from mainland to island territories is effectively cut off during the peak of the disaster. Second, the variety of material to be distributed at demand points need to be sorted, bundled and kitted from a safety stock or relief supply at a centralized distribution center (cross-dock). In such scenarios, the presence of a functioning cross-dock, in an island cluster often affects the volume flexibility of early humanitarian relief operations. Thirdly, the outbound delivery from distribution centers (cross-docks) in island territories and coastal regions is constrained by the number of last-mile-delivery vehicles (Balcik et al, 2008). A specific set of challenges arise in coastal regions and island territories, wherein access to end user is constrained by reach of last-mile-delivery vehicle from the supply hub or cross-dock. Often larger boats or ships, do not have higher draft (depth of water required to float) requirements in comparison to the water depths in shallow draft zones around the islands or coastal regions. Furthermore, the maneuverability of larger boats is limited in the narrow waterway labyrinths in coastal regions and island clusters. Helicopters, smaller boats (including motor powered ribs) thus become critical in last mile delivery. This has a bearing on delivery flexibility, which is the ability to make multiple deliveries at different locations in a region within a span of time. Within the island cluster, the stochastic demand patterns arising from demand centers require the supply chain to have delivery flexibility. It therefore follows from the above arguments that, the activation levels of functioning cross docks and number of last-mile delivery vehicles in island clusters affect the flexibility of early humanitarian operations, particularly on the respective sub-dimensions of volume flexibility and delivery flexibility. The hypotheses on flexibility dimension of early humanitarian operations are thus stated:

H3a: *Activation Levels of Functioning Cross-Docks in Island Clusters positively affects the Volume Flexibility of Early Humanitarian Operations.*

H3b: *The number and type of last-mile-delivery vehicles in the fleet positioned at the island clusters positively affects Delivery Flexibility of Early Humanitarian Operations.*

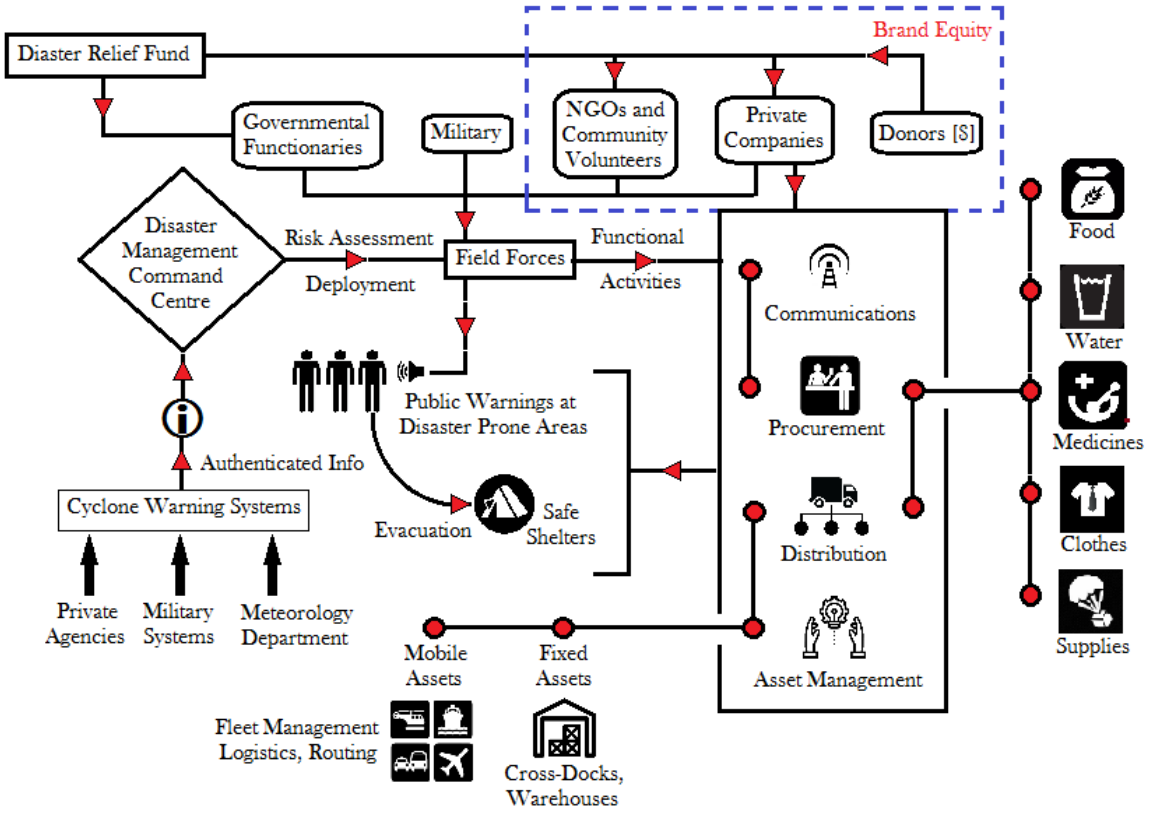

Figure 4 – Humanitarian Supply Chain

Humanitarian supply chains (refer figure 4) are complex, coordinated mechanisms formed from the amalgamation of multiple stakeholders with differing objectives. In this paper, we study the relations ships between different variables and constructs in the humanitarian context. First we study, the integration levels between information systems and field forces. From figure 4, it may be observed that multiple agencies (military, federal government controlled meteorological departments, and other private players) have their own dedicated information systems for observation, assessment and early warnings. However, it is often observed that the field forces deployed at site may not have their own in-house information systems. The trigger for search and rescue, evacuation etc. may be based on inputs from a partner in the humanitarian supply chain. For example, in India, during the Tropical Cyclone Ockhi, the field forces such as the Navy, Disaster Relief Force and Coastal police act upon the trigger provided from the information systems group of the National Meteorological Department. Although, the Navy has its own in-house Meteorological Systems, civilian evacuations are based on governmental requests after information authentication. Our first hypothesis explores the integration of information systems and field operations, as time lag in procedural formalities and lacunae in synchronization impacts the effectiveness of early humanitarian operations.

Secondly, the field forces, their machinery, equipment and assets are normally positioned at base locations. When disaster strikes, the access to island territories and remote coastal locations are usually cut off. This is due to high seas, rough weather and harsher operating conditions. Furthermore, early humanitarian operations such as search and rescue, evacuations etc. have to be done in the first eight to forty-eight hours. The responsiveness of the early humanitarian efforts is dependent on the ability for field forces to cover the needs quickly

(velocity of operations). In the second hypothesis, we explore the moderating effects of Standalone Nodal Resource characteristics in Island Clusters on the relationship between velocity and responsiveness. It is observed that during the blackout phase at peak of the disaster, relocating and mobilizing external resources to the island clusters is tardy, and affects the responsiveness of early humanitarian efforts in the isolated island clusters.

Thirdly, we explore the 'Flexibility' dimension within the agility construct. According to research literature (Charles et al., 2010), sub-dimensions of Volume Flexibility and Delivery Flexibility gain prominence in humanitarian supply chain operations than commercial supply chain operations. This is due to the need to exponentially increase the supply volumes to demand points of relief material during crisis scenarios. Also, the higher uncertainties associated with humanitarian operations over commercial operations imply that the variation in stochastic delivery distributions are much more, requiring higher levels of delivery flexibility. It is to be noted that new product and product-mix flexibility sub-dimensions do not take precedence in early humanitarian operations, as the focus is on survival and subsistence, rather than introducing novel products or bundling different types of product components. In this study, we explore the effects of activation levels of cross-docks in island clusters and last-mile delivery vehicles, respectively on volume and delivery flexibilities during early humanitarian operations.

With reference to Figure 4, our study studies the interaction between Information Systems and Field Forces, Effect of Standalone Resource Characteristics on Responsiveness (covering needs – Flood, Water, Medicines, Clothes, and other supplies) of Early Humanitarian Operations in Island Clusters, and Effect of Activated Fixed Assets (Cross-docks / Warehouses) and Mobile Assets (Last-Mile-Delivery-Vehicles) on Volume Flexibility and Delivery Flexibility, respectively. The methodology of the case study is described in the detail in the next section of this paper. While this case, as a pilot work, explores specific research questions related to early humanitarian operations in island clusters and coastal regions, the data from the study may also used to explain and validate extent theories in the domain of humanitarian supply chains.

METHODOLOGY

This research started in early December 2017, quite serendipitously. The author of this paper, at that time was working with a marine boat manufacturer as a research consultant, when there was a request from the Navy to join their team to assess the impact due to Cyclone Ockhi, and the damage it inflicted on property, assets and systems in Laccadive Islands in the Arabian Sea. Cyclone Ockhi had made landfall on 2nd December 2017 at Laccadive Islands, a territory of India located around 200 nautical miles west of the Kerala coast on the mainland. '*Laccadive Islands*' is the anglicized form of '*Lakshadweep Islands'*, meaning 'Thousand Islands' in local dialect. Cyclone Ockhi, developed from tropical depression to a 'Category 3 Hurricane' in less than 48 hours hitting a geographically dispersed island cluster, practically isolated from the mainland. This makes the complexity of operations 'most difficult' as per the classification of disasters (refer figure 1).

Before the field visit, there were several briefings with personnel in the Navy including 2 Commodores, Captains, officers, divers, and other members of the team. It was instructed during the brief that the visiting field researchers were not allowed to take pictures at site due to the confidentiality of sensitive pictorial information, but were allowed to make diagrammatic representations or take field notes (Van Maanen, 1998). The research questions at that point of time were broad: (1) To study the nature of humanitarian operations in island systems, with a

focus on information systems and field operations coordination, (2) To assess the operational characteristics of assets, their capacity, and responsiveness of standalone resources deployed at the island cluster, (3) To assess the extent of damage of fixed and mobile assets, and their activation levels in wake of the disaster.

We base our method on an empirical, grounded theory approach (Eisenhardt, 1989). While our case study is exploratory in nature, addressing research gaps related to early phase of humanitarian operations at island territories and coastal regions, the data collected during the research is explanatory (Dubé & Paré, 2003). Hence, our research data may also be used to reinforce existing theories and validate extant literature. While this pilot study is unique, in the sense, it addresses a peculiar set of challenges associated with early humanitarian operations in island territories and coastal regions; the data collected is qualitative, limiting quantitative analysis. The theoretical focus of this exploratory research is on agility and its dimensions during early humanitarian operations, which has been elaborated in the literature review.

The data was collected in three stages. First, during the field visit to Laccadive Islands from December 3 – 5, 2017, the author of this paper, who was accompanied by two colleagues from a marine boatbuilding firm, took notes of the briefings and discussions with consultants, officials at site, navy personnel and inhabitants at the islands. The discussions were semi-structured in nature, but connected to the broad research questions described above. At the end of each day, the three field researchers summarized the each day's discussions and the collated transcripts. The list of interviews conducted during the field visits, the respondent profiles and the codified themes from the transcripts are represented in Table 3. The first part of the data collection (Gersick, 1988) included observations of personnel with whom we interacted during the field trip. Data collection through multiple field researchers (Pettigrew, 1988) who individually collected information and then exchanged notes was useful in building holistic perspectives and limiting personal bias. The field notes were taken from observation and discussions with 17 respondents whom we interacted during the first week of December 2018.

The second stage of data collection was through in-depth personal interviews post the Tropical Cyclone. The interviews were conducted face to face from January 2018 to July 2018. While the field data from the first stage was archived and setup for analysis, the second stage of data collection proceeded, with some overlap between the two stages (Gersick, 1988), enabling refinement of research questions (Harris & Sutton, 1986). A total of 18 respondents representing the Navy, National Disaster Response Force (NDRF), National Meteorological Department, National Informatics Centre, State Fire & Rescue Department, Coast Guard, Coastal Police, Naval Meteorological Department, Non-Governmental Organizations, State Government Hospital Administrators, Army Medics, Search & Rescue Field Operatives, Private Companies with Meteorological Information Systems, Drone Manufacturers (Aerial Assessment), and 1 Navy Captain previously interviewed during the field trip, participated in the second stage of data collection. All the stakeholders who were interviewed were directly involved during the Early Phase of Humanitarian Operations related to Cyclone Ockhi, and the memories of the events in the past few months were fresh in their minds, and they could recollect case facts without the need for much probing. The details of respondents, including profiles and the codified themes from the interviews are represented in Table 4. During the interaction in the second stage, anecdotes, and themes for cross-case analysis (Miles & Huberman, 1994) from similar past experiences emerged from respondents. This not only strengthened the empirical validity and reliability (Eisenhardt, 1989; Benbasat et al., 1987) of the data collected, but also reinforced extent literature (Yin, 2017), providing a fertile ground for testing theories (Kuhn,

1970) particularly relevant to the research questions in focus, and refining and synthesizing hypotheses (Sutton & Callahan, 1987). The second part of the data collection process was performed by the author of this paper who during this period had joined an academic institute, and the two field research colleagues were pre-occupied with routine business at the boat manufacturing firm. The longitudinal data collected from the first and second stages, was archived and codified for within-case analysis and preliminary theory generation (Eisenhardt, 1989; Dubé & Paré, 2003). It is to be noted that the second stage of data collection included pictures of hardware, and equipment, supplementing transcripts, as there weren't restrictions in the type of data gathered, unlike in the first stage of data collection.

At this stage, a deficiency of this research was unavailability of direct empirical evidence for cross-case analysis. We had anecdotal evidence from respondents in stage 2 of data collection, about past experiences of similar case scenarios. But lack of empirical grounding for triangulation, using cross-case analysis, posed as a challenge on the epistemological basis for validity and reliability for theory building, until the fall of 2018. The third stage of data collection was performed in the months of August and October 2018, from direct personal experience, field survey and secondary sources. In the month of August, the state of Kerala, a southern state on the west coast of India, was hit by the greatest deluge in 100 years. The author was involved in early phase of humanitarian operations including activating cross docks, and distribution of relief materials in the coastal state. This was followed by a survey conducted in October 2018 in flood affected regions in Kerala. The survey was administered by 98 graduate students from the author's affiliate institution as part of the Flood Impact Assessment. One of the objectives of the survey was to capture the disaster response mechanisms in place and the agility of early phase of humanitarian operations, in coastal regions, islands and atolls. 1997 respondents participated in the quantitative survey representing a total of 7867 people from their respective households. This data was archived and used for cross-case analysis.

Another direct empirical evidence for cross-case analysis was from personal experience of the author. In the first week of October 2018, while in Florida, a Category 4 Hurricane "Michael" developed in Gulf of Mexico, the trajectory of which was projected to hit Florida Panhandle. We gained evidence of early humanitarian operations in islands and coastal regions, and some of the best practices in synchronization of information systems & field operations, evacuations, and agility of distribution systems in the 48 hours before "Hurricane Michael" made landfall. This triangulation approach through cross-case analysis is in line with research practice (Grütter et al., 2002; Lewis, 1998) for data validation, reliability (Koners & Goffin, 2007), formulating and extending theories (Eisenhardt, 1989).

Finally, we ground our observations and findings in existing literature, improving constructs definitions and relationships, building internal validity and sharpening generalizability. Bringing in more cases for cross-care analysis and theory testing is desirable until theoretical saturation levels. At this stage, we draw this research to a closure, providing research insights, managerial implications, limitations and future direction for research. These are deliberated in subsequent sections that follow, starting with the narrative of the case-in-context.

CASE IN CONTEXT: CYCLONE OCKHI

On November 28, 2017, on the South East coastal belt of Sri Lanka, a poorly organized disturbance with ill-defined low level circulation center developed amidst moderately warm weather tropical conditions. The Meteorological Department of Sri Lanka predicted heavy rains for the next few days, however, did not issue a cyclone warning citing insufficient data to that

effect. On the 29th of November, the storm organized into a depression, further developing into a deep depression and then gaining characteristics of a cyclonic storm – Ockhi. The storm tracked along the south and south-western coastlines of Sri Lanka, causing massive devastation in regions near Matara, Galle, Ambalagonda, and suburbs of Colombo. Gale force winds exceeding 80 kmph destroyed coastal infrastructure, disrupted power transmission lines, uprooted trees and obstructed mobility. On 30th November, Red Alert was declared in Sri Lanka with schools suspended, and search and rescue operations launched by the armed forces in conjunction with state agencies and Red Cross Society. By December 1, 2018, Ockhi intensified to Very Severe Cyclonic Storm (Category 3 Hurricane) moving up north under favorable conditions of cyclonic formation. It hit the southern states of Kerala and Tamil Nadu in India, causing extensive damages to structure and property. It is estimated that Kerala and Tamil Nadu suffered losses of about $2.3 billion and $2.0 billion respectively due to Ockhi, with total death tolls amounting to 245 persons, with 661 persons missing. The southern districts of Kerala namely Trivandrum and Kollam, and the coastal districts in Tamil Nadu, namely Nagarcoil, Kanyakumari, Thirunelveli and Tuticorin experienced torrential overnight rains with heavy winds uprooting over 550 trees and 950 electric poles. The Meteorological Department had issued warnings to coastal communities, and fishermen at sea were alerted to return to safety. It was reported that over 2500 people were evacuated from cyclone prone areas with the joint efforts of Navy, Coast Guard and state agencies, and over 400 fishermen stranded in outer seas were rescued. While few naval officers reported incidents of fishermen refusing to return to shores despite warnings, some members of coastal communities who were interviewed in the aftermath of the cyclone denied getting timely information or relief assistance. According to one of the doctors who work at a health center in an affected district in Kerala, “This situation is very grave. The infrastructure is severely damaged. Families are broken because people were washed away. This year the communities here had no Christmas. The social costs are very high”.

Ockhi, subsequently spread out to the west, into the Arabian Sea (refer Figure 5 for Ockhi Trajectory), and at the peak of its destructive power, with wind speeds exceeding 63 knots rummaged over Maldives and India’s Laccadive Islands in the Arabian Sea, in the wee hours of 2nd December, 2017. One of the authors, present at site in Laccadive Islands, 2 days after this event recounts the damaged embarkation jetty, fluttered road boulders, ripped-off building rooftops, and a thousand fallen coconut trees in the southernmost island of Minicoy. The scene with the fallen trees and devastated infrastructure reminisced the aftermath of a giant spinning top with peripheral blades that pulverized a beautiful tropical island. None except one Government owned PSU (public sector undertaking) cellular (telecom) operator was active. Cross-docking centers in the island (away from mainland) for distributing relief materials (food, medicines, clothes, supplies etc.) were to be setup. Several fishermen who were rescued by the coordinated efforts of Navy, Coast Guard, and Commercial Shipping Liners were brought to shore and attended to be medical personnel. In order to cater to the logistical necessities in the islands, the Navy re-routed it fleet from bases on mainland west coast to demand centers, including islands of Kavaratti and Kalpeni. While on the drive to take stock of some critically damaged site in the island, the driver of our jeep, who was present on the island, when Ockhi struck during the night of December the 1st, 2018 narrated, “We were sitting huddled in the hospital building. Trees were falling all over the place, and I was wondering when it was going to fall on us. Cows, goats and other animals were flying in the air, and big trees were being uprooted, and flown away by the sea wind. I never thought I’d see this day.”

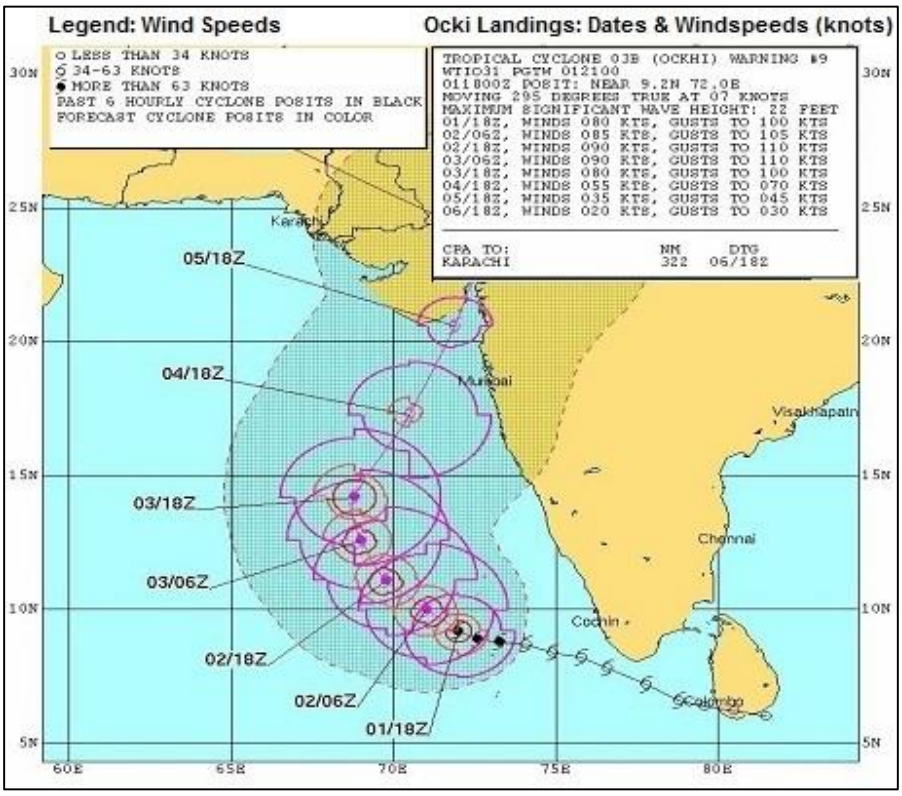

Figure 5 – Ockhi Trajectory

Source: Adapted based on information from Joint Typhoon Warning Centre (JTWC)

On December 3rd, 2018, Ockhi moved away from Laccadive Islands further westwards into the Arabian Sea, and into areas with no human habitations, and then drifted eastwards on 4th of December, heading towards the Gulf of Cambay near Gujarat on the west coast of India. Coastal cities such as Goa and Mumbai experienced heavy rainfall, which was unusual during this time of the year. While some areas reported of with coastal soil erosion due to Ockhi, other places near Mumbai reported ocean wastes dumped on the beaches by the cyclone. By December 6th, 2017, Ockhi subsided considerably due to unfavorable conditions near the subcontinent including high wind shear, and declining latency due to dry and cold wind from the mainland, which dissipated the storm as a low pressure phenomenon. Although, Ockhi was not a Super cyclone (Category 5) or Extremely Severe Cyclone (Category 4), it stands out as the worst Category 3 cyclone that hit the subcontinent in the last decade, causing more than U$ 5 billion of economic damages and 245 casualties and 661 missing people. The number of casualties or persons missing in the Laccadive Islands is not declassified, and not publically available.

KEY TAKEAWAYS FROM THE FIELD TRIP AND IN-DEPTH INTERVIEWS POST OCKHI

The research findings from the field trip to the affected areas and insights from the in-depth interviews with participating stakeholders are summarized in this section. Prima facie evidence from the field trip indicates that the operationalization of humanitarian efforts in the Laccadive Islands is problematic and crippled due to issues of access, communication, and mobility to the islands which is located around 200 nautical miles off coast of mainland India, in the Arabian

Sea. Severe Cyclonic activity imminently cuts off movement between mainland and the islands, necessitating adequate bunkers, and safe houses for island natives to take refuge when disaster strikes. Furthermore, adequate silos and cross-docking facilities (high speed warehouses) to store inventory and distribute supplies and relief material for the island cluster is essential. The case also throws light on the importance of agility of early assessment and evacuation response, which needs to be carried out in a few hours. This calls for higher level of synchronization between the information systems (MET agencies that handle forecasting, predictive analytics, and information diffusion) and operations on ground (field forces, including military, government agencies, humanitarian organizations and community volunteers). Flexibility in supply chains processes, including product mix, delivery flexibility and volume flexibility when multiple stakeholders are working together under the command of lead agency (in this case the military) are also key improvement areas.

It may be noted that while major urban metros like Kochi (in the state of Kerala) with geographical advantages, and are well connected with other supply-hubs command higher supply chain visibility (shared resources, information and tracking systems), other locations are often cut off during crisis situations. In our case, the remote villages in the southern districts of Kerala, and the Laccadive islands are effectively cut off from the cluster of hubs that activated during disaster scenarios. This calls for reorganizing of clusters so that humanitarian rescue and relief activity can reach out to remote locations as well, particularly with high population density.

Brief excerpts from in-depth interviews with some of participating stakeholders in humanitarian operations for Cyclone Ockhi are summarized below:

Military Personnel on the Field: "We can mobilize our forces at short notice. Early action in the first few hours is critical for the success of the operations. For emergencies, we have portable equipment, including mobile operation theatres, rehabilitation equipment, food and medical supplies that can be airlifted to base station from where we carry out the rescue and relief operations". Figure 6 shows some military hardware used for humanitarian operations.

Figure 6 – Military Hardware for Humanitarian Operations

Top Left: Mobile Operations Theatre; Top Right: Mobile Dispensary;

Bottom Left: Mobile Resuscitation Equipment; Bottom Right: Naval MET Forecasting System

National Disaster Response Force (NDRF): Units from 12 battalions of NDRF are deployed to crisis centers. The number of hierarchies in decision making is kept to a minimum for quick response. The Prime Minister of the Country is the Chair of the National Disaster Management Authority, and the Union Home Ministry connects directly with the State Chief Secretaries and the District Collectors for coordination and swift action. Over the last few years, the NDRF has been working with local communities to enhance disaster preparedness and to train volunteers.

Coastal Police: Operating under the state government, the Coastal Police has basic equipment like inflatable boats, life jackets etc. for basic search and rescue operations. Under relatively milder conditions such as depressions or heavy rains, the Coastal Police perform relief operations, and supports NDRF and military during more severe disasters, for which higher level of competency is warranted.

Fire & Rescue Department: Operating under the state government, the Fire & Rescue Department Unit normally attends to civilian emergencies such as Fire in a Building, Explosion etc. and provides safety clearance. While they perform tasks at district level, there is much scope in integrating operations with other forces, particularly in the area of information sharing and local support.

Meteorology Department & National Informatics Centre: The Meteorology Department is mandated to provide early warning and forecasts that are long term as well as short term (detailed and localized), and to alert the forces and other stakeholders to take early action. While in recent years, it has been difficult to accurately predict partly due to changing climatic

patterns, there has been serious flaws in synchronizing information systems and operations particularly with the state functionaries in the federal system. While the Meteorological Department works under the Central Government, the Police Force, and State Disaster Response Teams work under the state government.

Non-Governmental Organizations & Private Players: NGOs and private players such as retail chains, and commercial distribution networks have stepped forward as good corporate citizens in recent years, sharing resources including facilities to be used as cross-docks, and fleet for transport of goods, supplies and volunteers. Most of the work by NGOs and Private Organizations are in the relief, reconstruction and rehabilitation phase.

DISCUSSION AND CONCLUSIONS

The vitality of disaster preparedness and supply chain agility are the defining points of this case. The authentic relay of reliable information early enough by nodal agencies and the quick deployments of forces to alert affected areas, evacuation, and search and rescue operations can decide the fate of the operations (Day et al., 2012), and limit the magnitude of the consequences. Lack of coordination between central and state functionaries, in sync with the military and other critical functional machineries can also lead to delayed responses. In the case of Ockhi, while mass evacuations were effective in urban areas and its suburbs, particularly in localities such as Chellanam, Chellambararam, Kannamaly and Edavanakadu near the major port city of Kochi, mechanisms to evacuate were less effective in the hardest hit areas in the Southern Districts of Kerala and Tamil Nadu. Lack of preparedness in these regions, particularly the rural coastal districts can cripple disaster response efforts (Howden, 2009). The preparedness phase should include working with communities to build capacity and resilience to respond to a calamity, and to create public knowledge of evacuation options, pre-positioned emergency relief supplies and to work in coordination with participating agencies. The Joint Humanitarian Assistance and Disaster Relief (HADR) exercise conducted by the Navy in conjunction with central and state government forces, other participating agencies in April 2018, is a positive step in this direction.

The importance of hierarchical clusters for effectiveness of relief operations is noteworthy. In the case of Ockhi, while access to coastal districts on the mainland was possible, the islands were practically out of reach during cyclonic conditions. Even during normalcy, the commercial passenger and cargo liners are the sole lifelines of these islands which are no more than a few kilometers in length and over 200 nautical miles away from the mainland. The availability of robust cross-docking infrastructural facilities, and bunkers, which are resilient during harsh conditions are vital for flow of materials, people, and relief supplies (Ben-Tal et al., 2011; Barsing et al., 2018). Furthermore, the functional competencies of different players participating in the humanitarian operations vary. According to a retired Vice Admiral, “While the coastal police and stage agencies can handle emergencies of smaller magnitude such as tropical depressions or heavy rains, they do not have the logistical infrastructure to deal with hurricanes or events of higher magnitude. The armed forces are mandated to step in during such events. Even then, the NGOs, and community support groups have a role to play in implementing the centrally coordinated efforts at district and locality levels. We are conducting joint exercises to create awareness and enhance our preparedness.”

The role of private companies and willing donors in humanitarian efforts has been gaining significance in recent years. While the intentions of benevolent donors and volunteers are appreciable, it complicates the already complicated, urgent and important operations in an

environment that is uncertain, frustrating and at best chaotic. Factoring in selective and independent funding to specific disaster affected areas, avoiding duplication of efforts and making best use of all available resources from multiple agencies with varying objectives are difficult choices. While many private companies such as Facebook (Safety Check Feature), DHL (fleet sharing), Airtel (Communication Systems), Ola Cabs (LifeSaver in partnership with Apollo Hospitals) etc., work in partnership with UN agencies such as World Food Program (Food Supplies and Managing Depots), to mitigate, avert or to provide relief during disasters, the integration of functional competencies with nodal agencies has been a challenge. On the flip side, there have been cases where help during dire circumstances were refused. For example, during the devastating Yargis cyclone that hit Myanmar in 2008, the military regime refused aid and relief supplies in ships that were anchored off the coast of the Rakhine state. In a free economy, multiple forces are at play; while resources are precious and all-hands-available-on-deck are welcome to contribute in humanitarian operations, companies voluntarily contributing to the response, relief, and reconstruction efforts could experience an upside in their brand equity. Figure 4 represents a humanitarian supply chain with multiple stakeholders with varying functional competencies. While government functionaries and military work on a welfare state mandate, and obliged to provide relief, private companies may choose not to participate. During the Ockhi cyclone, certain private players partnered in the relief response, salvage and reconstruction efforts. While the benefits of these may not be immediate, sustained partnership may have an impact on the brand equity of these companies. While eyeing increased brand equity as the motive for volunteering may not be necessarily humanitarian, humanitarian necessities demand more corporate volunteers to share our humane responsibilities.

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DECISION SCIENCES INSTITUTE
How Knowledge Arbiter manages AI and Human Assets in KiM

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ABSTRACT

Creating knowledge and transforming it into innovations is a daunting task. Expanding upon the KiM (Knowledge in Motion) Model by Datta (2007), we propose a semiotic view of the KiM model (S-KiM hereon). Using semiotics as the theoretical lens to define and segregate levels of knowledge, the questions we ask are as follows: What are the different levels of knowledge and how do they correspond with various levels of AI and human capabilities required to absorb and cycle knowledge within organizations? We use Knowledge Arbiter (KA) as a fictional firm to exemplify the cycle of knowledge transformation in an age of AI and Analytics.

KEYWORDS: Knowledge Networks, Case, Innovation, Tacit Knowledge, Explicit Knowledge, Intermediaries, Artificial Intelligence, AI.

INTRODUCTION

In the world of big data, large-scale analytics, and AI, there is a knowledge management paradox. Sticky knowledge, defined as the difficulty of disseminating tacit knowledge within organizations (von Hippel, 1994), is a bad recipe for companies. Sticky knowledge is confined and insular and does not contribute to knowledge sharing. while stickiness of returns implies retaining economic gains from "unsticking" knowledge without eroding competitive advantages from leaky knowledge. While the prosperity of firms hinges on identification, mobilization, and application of knowledge for sticky economic returns (Stewart 1997; Eisenhardt & Martin, 2000; Gupta & Govindarajan, 2000), the topic mired in fragmented and mired in anecdotes. As Davenport et al (1998) note, a failure to justify economic returns from KM investments often leads to an early demise of KM initiatives, leaving a bitter aftertaste. This issue is acute. Increasingly, it is becoming mandatory for firms such as Chevron and Mitre to document the return-on-investment for KM projects for maintaining executive sponsorship (Turban et al 2001). Interestingly enough, although research and practice have implicated that KM efforts are successful only when KM investments are linked to demonstrable performance viability, the underlying process is far from transparent. Unless organizations understand the key elements in the KM process, KM projects are likely to remain an ambiguous investment, and knowledge, an elusive asset.

LITERATURE REVIEW

Agents and Knowledge Management Research

Agents are autonomous entities that perform intermediation tasks on behalf of an organization. In the context of KM, agents are either AI software artifacts or human entities (autonomous people or groups performing prescribed intermediation activities such as Nonaka and Takeuchi's "knowledge-creating crew") embedded in organizational knowledge flows.

AI and human agents in KM promote a context congenial to the creation, transformation, sharing, and utilization of knowledge. For example, AIs can embody complex functions that scan, collect, and structure data into visual depictions (e.g. cross tabs, pivot tables, plots) without the need for the user to learn the complex algorithms used in translation. Similarly,

human agents (e.g. interpreters) allow speakers to make extempore speeches in their own language without having to worry about the complexities of translation. Together, AI and human KM agents increase process transparency by facilitating knowledge sharing and transfers, relieving the user of understanding inherent translation and conversion complexities. An agent-mediated KM process thus enables sharing of knowledge and provides newer, better, and more accurate interpretations (Nonaka and Takeuchi 1995).

Altogether, rapid advancements in AI has allowed for embedding organizational data, routines, and processes into routines, repositories, and functions- creating opportunities for time-saving, duplication of effort, and consistency through rule-based reasoning. In AIs, rules and constraints are built using logic statements that can be easily validated, managed, traced, and enforced while ensuring reliability and integrity. However, it is important to note that the process of embedding logic to create AIs is constrained by limitations of syntax in capturing the overarching domain of understanding. As a result, the original meaning is lost. Only the syntax can be stored, not the semantic nuances that makes knowledge management such a rich and complex phenomenon. In the same vein, a AI can only analyze cues that are a part of its code, failing to dynamically learn and interpret cues offered by changes in the immediate environment. In that regard, AIs are better at analysis rather than interpretation and reinterpretation of content (Kogut and Zander 1992; D'Adderio 2003). Formal and standardized descriptions are core to AI development- creating objectivity and consistency in input output scenarios. Yet, these same characteristics also limit the ability of AIs to reconstitute the 'hows' and 'whys' of the KM process.

Artificial Intelligence (AI) versus Human Agents

In studying agent-mediated decision support systems, Hess, et al (2000) provide a set of agent attributes as characteristic features used to delineate different types of agents. They are homeostatic goals, persistence, reactivity, mobility, intelligence, and interactivity. We use these attributes to characterize agents on three broad attribute domains: individual, social, and organizational. Individual attributes are suggestive of the personality of the agent; social attributes are suggestive of how agents can operate in digital and organizational networks and hierarchies; organizational attributes are suggestive of the position, power, and goals of agents in an organizational hierarchy. When juxtaposed, persistence, reactivity, and intelligence correspond to individual agent attributes; mobility and interactivity correspond to social attributes; and, homeostatic goal corresponds to organizational attributes. Together, these attributes can be used to define agent effectiveness[1] and provide support for the choice of specific agents in various phases of organizational knowledge management..

Organizational Domain: Homeostatic Goal
Homeostatic goal is an organizational characteristic. It is a goal-state that an agent can attain and maintain as long as required by the organization. A homeostatic goal-seeking characteristic allows an agent to reduce variance in knowledge transformations by constantly readjusting itself to maintain equilibrium indefinitely unless and until the organization goal is redefined (Covrigaru and Lindsay 1991). As an example, if an agent is provided a goal of securing orders from different entities, the agent is expected to keep trying to secure orders unless and until the organization redefines the goal. Nonetheless, while homeostatic goal are common, goal-seeking behavior differs between AI and human agents. A AI will indefinitely parse all incoming content based on certain pre-specified parameters to ensure accomplishment of its goal with little

[1] *Agent Effectiveness = f(homeostatic goals, persistence, reactivity, mobility, intelligence, interactivity)*

variance. However, the variance exhibited by a human agent is likely to be relatively higher, particularly because a human agents' embedded logic is not as standardized as in AIs. As a result, homeostatic goal-seeking behavior that may require reproducing previous routines in the exact manner may be more difficult for human agents to replicate. On the other hand, non-routine and complex organizational goals such as strategizing on innovations for achieving competitive advantage are likely to be better addressed by human agents.

Individual Domain: Persistence

Persistence is an individual characteristic that refers to the ability of an agent to exhibit a sense of durability and continuity relative to its immediate span of execution. To exhibit persistence, an agent is not required to be constantly active and can remain temporarily inactive or cryogenic state (Bradshaw et al 1997). Persistence differs between AI and human agents, especially in regards to retained memory. While both AI and human agents have (or can have) the ability to save to organization memory, the capacity and the type of memory is vastly different. Organizational memory consists of declarative and procedural memory (Anderson, 1983). Declarative memory is representative of content derived from codified documents such as blueprints, spreadsheets, source codes. Procedural memory, on the other hand, resides in complex social structures and practices. While AIs are better at building declarative memory, human agents seem to be better at building procedural memory.

AIs can build and access declarative memory, i.e., a memory for codified material structures and practices in documents, databases, knowledge management and intranet systems. While AIs can create, store, and parse vast amounts of extremely specific declarative memory with unparalleled efficiency, they are extremely limited at creating procedural memory, i.e. memory for social structures and practices embedded in complex and tacit interactions, communications, culture, and other innate factors.

Individual Domain: Reactivity

Reactivity is another individual agent characteristic that refers to an agent's ability to perceive changes in the environment and respond according in a timely and reasonable manner. The reaction must be in accordance with its homeostatic goal and offer a degree of persistence. AIs react faster to minute shifts because it is easier to incorporate a vast number of variables and response conditions within event handlers. While it is true that AIs are less likely to utilize small subjective social shifts, it is exceptionally robust in capturing small changes as long as they are codified or declarative. For example, a AI is can assign very specific date-time stamps to subtle changes in currency rates, allowing them react in an extremely short time-period. Human agents are likely to find it more difficult to map up such infinitesimal shifts and schedule immediate responses. As Hess et al (2000) note, agent reactivity is a stimulus-response scenario and does not require intelligence. As along as more and more scenarios and corresponding actions can be built into the control structures of event handlers, AIs offer a faster response schedule and are thus better suited to responding to external stimuli. However, it must be realized that predefined control structures can limit reactivity to a wide variety of changes that have not been built into the agent logic. In addition, a AI uses a predefined and objective response logic that may not lead to an optimal reaction. A human agent would better able to distinguish between marginal bid increases and make a more optimal decision.

Individual Domain: Intelligence

Intelligence in one more individual agent characteristic, defined as an enabling feature of reasoning that allows an agent to pursue homeostatic goals efficiently and expertly without assistance from the user or designer (Hess et al 2000). For conditions stipulating intelligence from a standard iterative process, AIs are likely to perform very well. However, human agents are better substitutes as process conditions shifts to a less systematic and more random series of actions that require reconstructing the 'whys' and 'hows.' For example, AIs can easily collect

and analyze user clickstream data to specifically map navigational history; however, unlike human agents, AIs cannot explain the 'why' behind user navigation.

Network Domain: Mobility

Mobility refers to an agent's ability to migrate from one site in a network to another in order to perform requisite tasks (Hess et al 2000). Mobility of human agents is marked by their capacity to adapt to heterogeneous entities and interact with them on an ad-hoc basis. However, because human agents lack a standardized logic, it is tougher for a human agent to preserve its state in moving from one interaction point to another. Human knowledge agents are also less durable than AIs and thus have an uncertain organizational tenure. In contrast, AIs are both durable and stable. Their mobility is achieved by transporting code embedded in routines and functions using distributed object services.

The growing popularity of web and object services (e.g. CORBA, DCOM), portable Java code, remote procedure calls, Object Management Group (OMG) naming, and component integration architectures (e.g. OpenDoc, ActiveX)) are enhancing AI mobility. AIs have a greater ability to preserve their state in the process of being transported from machine to machine. Human agents are more adaptive and flexible in seeking and interacting with emergent participants in a network. Human agents are particularly prolific in loosely coupled social networks that require constant recontextualization of interactions. This interpretive flexibility that can be used to support heterogeneous functions is harder to embed in AIs that relatively more formal and inflexible (D'Adderio 2003).

Network Domain: Interactivity

Interactivity is another network characteristic that marks the ability of an agent to maintain communication between different network sites and entities. In order to function, agents must be able to initiate and maintain dialogues with other entities in one or more networks, mainly by creating uniform communication structure and standards, also know as a common agent-to-agent interlingua or 'agent bus' (Bradshaw et al 2004). Like AIs, human agents, too, must speak the same language and share a common set of operations and structures for maintaining communication. While human agents are limited by their lack of common language and structure, human agents are much more flexible with their interactions and able to adapt and learn languages and structures over time. In addition, human agents can also initiate the use of a common interlingua such as mathematical notations, audio-visual cues, and models to mitigate the constraints posed by the lack of a single set of communication protocols.

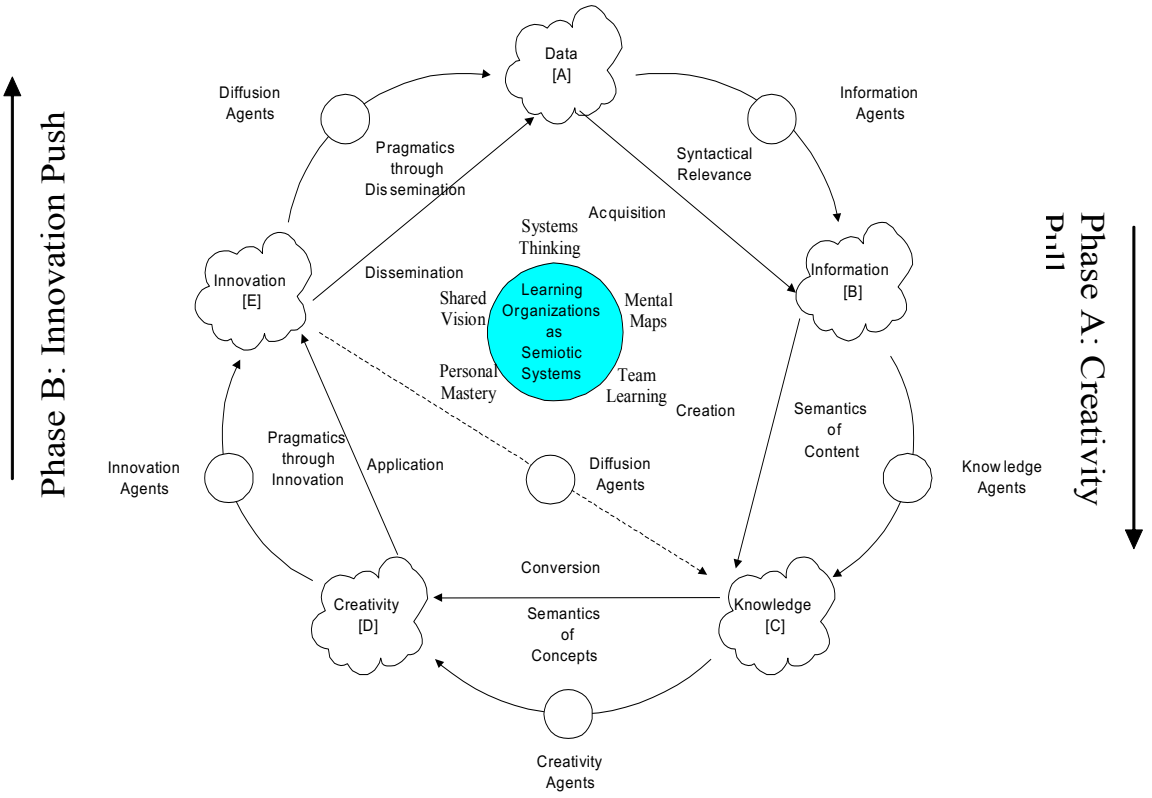
THE S-KIM FRAMEWORK AND THE CASE OF KNOWLEDGE ARBITER (KA)

We believe that knowledge management is a complex and multifaceted phenomenon that, when investigated using a single methodological paradigm, robs it of its richness and reality. The single method argument of paradigm incommensurability insists that researchers be captive to single set of assumptions stipulated by a specific paradigm of method, ignoring alternative cues from reasoning and reality. But, there is no single paradigm of method that captures the reality of KM. Knowledge is a multidimensional construct, embedded in workers, in the organization, in systems, and in processes; it is both objective and subjective, observed and experienced, assessed as a causal or a sense-making construct. Following Mingers' (2001) contention that "a richer understanding of a research topic will be gained by combining several methods together in a single piece of research" (Ibid: 241), we investigate KM using a cumulative, multimethod paradigm.

Data on best practices in KM was collected from a field study of six Fortune 500 firms over a period of a little over four months (Mid-November 2015 to Mid-March 2017). The criteria for site selection were drawn using the technique of theoretical sampling (Glaser & Strauss, 1967; Strauss & Corbin, 1990), a process by which a researcher selects certain informants and sites

based on theoretical relevance and purpose of the researcher. With respect to theoretical relevance and purpose, our site selection ensured a substantiation of KM efforts. The companies selected differ by sectors: one automobile firm, one biotechnology firm, two software firms, and two high-technology manufacturing firms. Each of these organizations was involved in KM and had, for over three years, invested and implemented KM systems to manage knowledge.

To mask firm-level differences, the S-KIM framework is exemplified using a fictional case of a learning organization (Senge 1990) called “Knowledge Arbiter” (KA) and envisioned as a firm that simultaneously creates and applies knowledge to reduce its innovation cycle. As a learning organization, KA believes in the five disciplines: systems thinking through the conceptualization of knowledge management as an interrelated multilevel system of transformations; mental maps where models are used as a representation of the KM phenomenon; personal mastery through the cyclical process of continuous innovation and knowledge; shared vision achieved by unsticking knowledge for creation and innovation; and team learning supported by agents to facilitate knowledge transformations through networking, dialogue, and dialectics. In summary, KA is informed by the best practices that constitute the S-KIM framework.



At KA, AI bots routinely access, filter, and validate its internal and external data sources and transform data into information. KA’s decentralized architecture allows data to be stored in federated warehouses rather than in a central location. KA’s federated data warehouse also allows other firms to link to distributed and heterogeneous data sources while maintaining network, location, and invocation transparencies. The criticality of this transformation phase lies

in the filtering and querying abilities of information agents who reduce terabytes of data into usable format.

Content as Meaning

Having generated information by filtering noise out of data, firms concentrate on transforming information into knowledge. According to Stohr & Zhao (1998), "Knowledge is the capacity to turn information into profitable action. Information, on the other hand, is data rearranged, sorted and aggregated so that it becomes suitable for input to a knowledge processor of some kind." At KA, executives understand the value of tacit knowledge. They believe that in order to share tacit knowledge, firms must try to interpret, articulate, and codify it into explicit knowledge. Truly, articulation of tacit individual thought processes and practices into more cognizant and replicable organizational processes is immensely valuable.

At KA, AI and human elements that make up the knowledge agents are synergistically bound. Knowledge agents conduct brokerage activities by searching, translating, and transforming available information into knowledge for future exploitation. These knowledge agents serve two purposes: to codify and to personalize (Hansen, 1999). KA uses a sequential strategy of codification followed by personalization in creating its knowledge database. Codification is a process by which explicit knowledge is created from information and stored in repositories for repetitive and routine querying. This process is carried out by KA's automated AI bots. Information generated from data, albeit relevant, is over-determined.

Concept as Meaning

To make knowledge actionable, organizations need to foster creativity as an extension of their base of knowledge (Dennard 2000). We define creativity as the inception of a new idea or perspective derived from a given knowledge base. Although creativity is often a result of combinations and re-combinations of existing but previously unconnected knowledge, it is a unique outcome—a knowledge artifact that extends and makes knowledge "actionable" and serves as a prerequisite for innovations (Von Krogh et al 2000; Sheremata, 2000). In applying existing knowledge to generate concepts that the organization can apply for economic returns, this phase is a first step towards sticking economic returns and "sticky" returns.

Once preliminary concepts are developed, KA organizes off-site creativity workshops where creative agents work intensively with individuals, groups, and subgroups to fill in the missing pieces and integrate concepts for creative synthesis. Final concepts are justified and systematically articulated in terms of feasibility (e.g. technical, operational, legal, and political), market appeal, and management priorities. These articulated and detailed reports are stored into an enterprise "concept base" consisting of product, service, and process concepts that are deemed to have future application potential. To summarize: in this phase, intensive interaction between tacit and explicit knowledge leads to collective reflections that are "finally crystallized into explicit concepts" by creative agents who instill idea-generation and help justify the value of such ideas and concepts (Nonaka and Takeuchi 1995: 86).

Conception to Commercialization

Transforming Creativity into Innovation: Pragmatic Sense-Making

In "The Frontiers of Management" Peter Drucker (1986) expounds: "[creative] ideas are somewhat like babies—they are born small, immature, and shapeless. They are promise rather than fulfillment. In the innovative company executives …ask, 'What would be needed to make this embryonic, half-baked, foolish idea into something that makes sense, that is an opportunity for us?'" From a semiotic standpoint, this phase deals with pragmatics concerning the use and outcome of creative concepts. Pragmatics asserts the need to increase organizational propensity to innovate by making their final concepts "actionable." Because knowledge is

localized, embedded, and invested in practice, it is only through its application as innovations can resolve limitations originating from inadequate and mis-specified semantics (interpretations) (Carlile 2002). In the process, concepts become more granular, valid, and justified as they are pushed towards commercialization. From converting concepts into commercial solutions to reducing resistance and putting concepts into action, the philosophy of pragmatics drives this transformation.

In transforming creativity into innovations, an organization needs the habitual assistance of another set of intermediaries: innovation agents. Innovation agents perform brokerage activities in the transformation process and have a vital influence in molding innovations (Henion, 1989; Strassmann, 1994). At KA, innovation agents are managers who evaluate concepts, assess feasibility (economic, legal, political…), allocate resources, and proactively assist in development and implementation efforts. Efforts from innovation agents, albeit driven by practical rent-generating aspiration, are carefully balanced in order not to compromise on innovation quality. Both the innovation outcome and process are mapped and documented by innovation agents into dedicated enterprise-wide innovation project databases. “In the process of turning innovative ideas into reality,” as Hargadon (1998:224) notes, mapping “[innovation] activities are invaluable because they generate a wealth of knowledge that’s a result of struggles, the agonizing way they went through to try to figure out what’s the right way to proceed.” At KA, the process of innovation is as important as the innovation outcome itself.

Diffusion of Innovations: Pragmatics of Dissemination

Innovations, although “sticky,” do not undergo obsolescence. Every innovation may be regarded as having a memory that incorporates its development and can be explicated as data in forms of patents, publications, and other materials that are disseminated via journals, trade magazines, academicians, and practitioners, among others. This is what is known as “innovation diffusion” (Rogers, 1995). Rogers (1995) describes innovation diffusion as a process by which an innovation is communicated through channels over time, leading to further unsticking knowledge and implicating the perpetuity of KM and the S-KIM framework. From a semiotic perspective, this phase is concerned with the pragmatics of innovation diffusion to further knowledge use and reuse, without compromising competitive advantage. Pragmatics realizes that innovations, like knowledge, are also localized and embedded in practice (Carlile 2002); selectively diffusing data from innovations once again reduces stickiness and signifies the pragmatics of reuse through dissemination.

Although innovation diffusion is an essential component in the S-KIM model, dissemination is never absolute but controlled. Diffusion agents, generally human, play an important role in controlling the innovation diffusion flow by internalizing mission-critical data while externalizing non-mission critical data. Disseminating mission-critical data can cost a firm its competitive advantage. At KA, diffusion agents periodically query and scan the enterprise innovation project database to delineate critical and non-critical parts of the innovation documentation into critical and non-critical parts. Non-critical parts of the innovation documentation are generally declarative and factual; critical parts of the documentation are generally procedural and cognitive.

DISCUSSION AND CONCLUSION

When organizations embark on KM initiatives, a common concern they face is deciding on a KM process that can lead to a fruition of their KM investments. Learning the process by which firms can secure “sticky” economic returns while maintaining the “non-sticky” or context-independent attributes of information and knowledge for continuous sharing and pollination is paramount to any successful KM. Addressing this concern, this paper combines technical and sociological

perspectives in KM research to present an agent mediated S-KIM process model informed by best practices. The objectives are met. The process of simultaneous sharing and appropriation of knowledge is explicated and empirically verified; contingencies are elicited by introducing the role and significance of agents in the transformation; and, finally, the S-KIM model is developed as a complementary agent-mediated KM framework.

This paper presents a systematic approach to unsticking knowledge and application. This paper also uses a process perspective that first draws from semiotics, information systems, strategic management, and organizational theory for theoretical support and then complements this support with current best practices to derive the proposed S-KIM framework for a holistic understanding of KM. This framework provides a unified perspective of the KM process by bringing together multiple strands of research and practice. Also, by striking a balance between theory and observation, the S-KIM framework lets us examine the complexities of resource transformations, agent-mediation, and event transitions inherent in the production and generation of "sticky" returns from "non-sticky" information.

The S-KIM model introduced in this paper may be extrapolated to organizations involved in KM and embodying structural devolution. As digital networks, globalization, and discontinuities in organizational environments propel organizations to substantiate collaborative "boundaryless" structures for seeking knowledge, and as harnessing returns from knowledge remain shrouded in ambiguity, there is a need to develop novel approaches that can breathe fresh perspectives into conventional KM paradigms. This paper is a step in this direction. The adopted approach synthesizes theory and practice to propose a new paradigm of actionable KM. The use of this approach here was particularly appropriate, generating critical insights and interactions that surface from the theory and practice of KM, elements that, to date, have remained fragmented or largely overlooked in KM literature. The S-KIM framework developed from these insights and interactions proposes a different approach to KM, promoting KM as a transitionally dynamic agent-mediated process that links unsticking knowledge and sticking economic returns . As creators, users, and disseminators of knowledge, researchers and practitioners should find the framework useful in their future quests to both explore and apply knowledge.

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Structuration Analysis of Accounting-Based ERP System Organizational Change

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ABSTRACT

Using Giddens (1984, 1990) notions of trust, agents' reflexivity, ontological security, dialectical of control and power, the study explores the implementation processes of Enterprise Systems known as ERP. The case study findings present that the accounting and accountability systems following the adoption of the ERP facilitated organizational members' reflexivity and critical reflection in re-assessing the pre and post ERP system ways of thinking. The findings also illustrate how trust (whether personal trust or system trust) plays a pivotal role in reinforcing the organisation power to change, and how the mistrust has become a source of power hindering organisational change.

KEYWORDS: ERP, customization, power, control, accounting practices

INTRODUCTION

This study examines the political behavior associated with the adoption of ERP in emerging economy country. The study extends on prior accounting-based ERP adoption literature that suggests that the ERP system has a limited or no impacts on accounting practices (Granlund & Malmi, 2002; Dechow & Mouritsen, 2005; Quattrone & Hopper, 2005; Kholeif et al., 2007; Cadili & Whitley, 2005; Hassan & Mouakket, 2016). For example, Arnold (2006) suggests exploring behavioral issues associated with the adoption of the ERP system. He suggests to examine: 1) how top management influence the adoption of the ERP system, 2) the processes of aligning organizational members' routines with the ERP requirements, and finally 3) exploring the (un)known motives of implementing accounting-based on ERP system. Chang (2014) recommends examining how organizational members' attempt to gain power, secure self-interests, and avoid responsibility is closely related to what he calls "political behaviour" during the information system development and adoption processes. Coad and Glyptis (2014) highlight that people political behaviour rests on the feelings of mutual trust in which people trust others and trust the system they use on daily basis, while Busco et al., (2006) believe that human political behaviour is an outcome of a balance between control and trust in business corporations.

The above studies concluded that future research should address how accounting practices are impacted by the interplay of conflicting interests of developers, users, and customers. They also identified the need of a solid theoretical framework to investigate how social structures, culture and agency are intertwined while capturing the diversity of agent interests. Our study addresses this research gap and examines a transforming public organisation employees' politics, trust, and control through a theoretical framework informed by the lens of Giddens (1979; 1984; 1990) structuration theory and his notion of trust. The study, therefore, contributes to prior studies in

several ways. The study is one that contributes in examining human political behaviors in an emerging market. The study contributes to prior studies which examine the effects of ERP systems on individuals (El-Sayed, 2006; Jack & Kholeif, 2008). The study also contributes to Fincham (1992) and Hardy (1996) frameworks of power since they do not underscore the power of "trust and/or mistrust". The empirical findings showed how trust is intertwined with Fincham (1992) and Hardy (1996) frames of power and what are the pillars that lie behind organisational trust and/or mistrust through the lens of Giddens' (1979, 1984) structuration theory. Following this introduction, the study critically reviews prior studies, discusses the theoretical framework, the methodology and the data collection methods. Then the study presents evidences from the case followed by some conclusions and implications that provide suggestions for further research.

LITERATURE REVIEW

The ERP system is an integrated enterprise-wide computing system. The system is a set of integrated software programs which are named as modules (Scapens & Jazayri, 2003). It automates business processes, shares common data across the organization departments and produces real-time data (Brignall & Ballantine, 2004), thus it improves the decision-making process, planning and control (Davenport, 1998). One of the key aspects of the ERP system is that the system includes the industry best practice in a computerized form. Another key aspect is that the system integrates traditional accounting transactional activities with processing activities associated other functions such as production, human resources management, and sales (Dillard, 2000; Dillard et al., 2005; Dillard & Yuthas, 2006). Under the ERP system, integration means that the entry of data in one software program (module) affects the data and the operations of some or all other software programs (modules) included in the system (Brignall & Ballantine, 2004).

The consequent of ERP implementation, therefore, would be changes in the individuals' behaviour. Yet there is paucity in the academic literature examining the political behaviour of organizational members involved in the implementation of the accounting-based ERP system. Scapens & Jazayeri (2003) examined the implementation of the ERP system at a division of a multinational American organization. They concluded that accounting-based ERP system organizational change has four attributes: integration, standardization, routinization, and centralization. These attributes, they argued, led to changes in organizational and accounting practices in the following ways: routine tasks were eliminated, line managers required more knowledgeable employees, and decision-making processes needed to be centralized in the hands of those who had access to the ERP system's shared databases.

Caglio (2003) examined the impact of an ERP on the roles of accounting and accountants for listed firm operating in Italian context. Caglio (2003) noticed that the ERP systems provided accountants with wide organizational knowledge, which, in turn, enabled them to be in charge of the organization's information systems. Quattrone & Hopper (2005) examined the how integrated system have had an impact on the distance between headquarters and branches. They argued that the use of relational (shared) databases eliminates the distance between the controller (headquarters) and the controlled (braches). They found that only one branch used the ERP system and the changes in accounting and accountability is due to functional prohibitory.

Yeh & OuYang (2010) carried out an exploratory case study of an ERP system adoption in a Taiwanese organization. Their study illuminates the cultural and political tensions raised during

the process of implementing the ERP system. They suggested that there is a need to balance power across different groups inside the organization during the processes of implementing the ERP system. Silva & Fulk (2012) examined the organizational power and politics in the Gulf Coast University where an ERP system was implemented. They explored the organizational members' political behavior through using Clegg's (1989) circuits of power to identify how the disturbances to the circuits of power create arise tension, and intensified to be power struggle, during the adoption of the ERP system. Chang (2012) explored how the manager of the Management Information systems department, depending on his expert knowledge in IS, adopts political tactics to achieve his goals of self-interest in information system development processes. Chang (2014) adopted a qualitative case data collected from an organization to analyze political behavior patterns during the information systems adoption processes. Based on Giddens' Structuration Theory (1979, 1984), Chang (2014) identified different patterns of political tactics when implementing a new information system and explored how these patterns interact and affect the organization and the outcome of the information system.

The above studies highlight the importance of revealing the political behaviour of organizational members linked to accounting-based ERP organizational change. The human actors political behaviour is rarely explored in emerging economies and how such behaviour emerge and formed is not yet fully explained by prior studies (Rom & Rode, 2007; Nwankpa, 2015). Prior literature does not examine the political behaviors associated with the adoption of the accounting-based ERP system organizational change. This study addresses this research gap and examines how patterns of political behaviors emerge during the interaction of a number of individuals as the result of adopting an accounting, accountability and ERP in an emerging market economy.

STRUCTURATION THEORY FRAMEWORK

Giddens' concepts of power and dialectical of control

Giddens (1979; 1984) argue that individuals have a capacity to change and achieve their goals when they use allocative and authoritative resources of power they possess. Allocative resources involve the rights of some individuals to hold command over material objects (e.g. factories, computers, information and ERP system) as well as knowledge of how to operate them (e.g. experience, skills, know-how) (Giddens, 1984). While authoritative resources comprise the rights of some individuals to command others to organize and co-ordinate the activities of other individuals. Giddens (1979) argue that power is a multi-directional and incorporates both freedom and collaboration representing *"dialectic of control"* which acknowledges the asymmetrical distribution of resources among members of social system (i.e. organization). This shows "subordinate" will have power such as means of production, skills, knowledge, experience which they can use to influence the actions of their "superiors". For example, accounting-based ERP system is designed and implemented to constrain the behaviour of subordinates, yet those subordinates have the potential to manipulate the system during the customization processes to their advantage.

Trust and agents' psychological make-up

There has been a number of scholars defining trust which is a concept that has been widely explored in the management literatures (Bachmann, 2001) and is also discussed in the accounting literature (Busco el al., 2006; Busco, 2009; Coad & Glyptis, 2014). For the purpose of this study, the conceptualization of trust is linked to what Giddens (1984) calls the agent's psychological make-up and the agent's need for routinization and ontological security. These

concepts incorporate a preference for a stable and predictable environment as well as the avoidance of the anxieties of change. Accordingly, trust is a mechanism that can increase coordination, reduce uncertainty and ease the functioning of organization and its accounting and accountability systems through the behavior of social actors, i.e. organizational employees (Bachmann, 2001; Busco el al., 2006; Coad & Glyptis, 2014).

Different scholars argue that the *routinization of activity,* and accounting and information systems routines are no exception, is the storage of organizational know-how and the creation of the feelings of trust (Busco et al., 2006, Busco, 2009; Coad & Glyptis, 2014). Organizational routines play a pivotal role in raising the feelings of trust across organizational members (Busco et al., 2006). Since systems are designed with an aim to fulfil management and sustain trust or otherwise. When the accounting systems sustain organizational routines, they are likely to support the organizational members' "confront zone" which is a necessary condition for the feeling of being 'safe'.

To Giddens (1979; 1984), agents are look, examine and evaluate others' and then "respond in term of the implicit stocks of mutual knowledge". Giddens (1984) defines this monitoring process by "agents' reflexivity" and argues that individuals' reflexivity rests on individuals' unconscious level. That motivation, Giddens (1984) states "maintain *ontological security* which refers to the individuals' need for regular social encounters to avoid anxiety". Giddens (1984) stressed on the importance of routinized behavior. Social systems, i.e. organizations, cannot exist without trustworthy routines (Coad and Glyptis, 2014). To some trusting is a major mechanism to control and coordinate. Giddens' (1984) comments on the significance of trust is neither based on the interaction between ontological security in the face of risk and uncertainty, yet it depends how individuals accept predictable routines. Trust is found in the deepest layer of ontological security (Giddens, 1984, p. 53). Trust, therefore, is described as an assumption of the continuity of that with which we are familiar, and is evident in the institutionalized routines. For Giddens, trust is defined as "confidence in the reliability of a person or system, regarding a given set of outcomes or events" (Coad & Glyptis, 2014).

When individuals change their organizations towards what they see as "something better", the role of trust becomes at the forefront. The complexity embedded in the process of organizational change requires what Giddens (1990) calls "personal trust" and "system trust" (Busco, 2009). Giddens' (1990) argues that trust rests on the intertwined across individuals. It addresses both the system and the individual with each is having their own view and familiarity with trust. Trust may be also rest on what is called as "system trust" which is the dependability and reliability of functioning of certain systems. It also does not requires individual face to face discourse and exchange of knowledge. There are two types of tryst that Giddens (1990) highlights: system trust and personal trust. The former is trust in principles, such as ERP technical or professional knowledge. This knowledge is always a kind of guaranteeing human expectations. Giddens (1990) equates this trust in the system with the trust in human and also equated abstract systems with societal and organizational institutions. These institutions take to form of a number of practices such as legal, educational, political and professional bodies. In this respect, confidence in accounting, accountability and auditing practices build in the ERP systems are both examples of systems trust. Trust, therefore, can be interpreted as the processes (Coad & Glyptis, 2014). This study examines how the accounting-based ERP organizational change has created uncertainties, or disrupted what Giddens (1984) "ontological security", and consequently make organizational members to cast doubts on the trustworthiness of the trustee.

METHODOLOGY AND DATA COLLECTION METHODS

This study utilizes an interpretive case study methodology (Scapens, 1990; Yin, 1994). The data collection methods included semi-structured interviews and documents. Date was collected during 2009-2010, and there were some follow up interviews during 2011. For confidentiality, authors name the organization undergoing the change as "Alfa". The depth understanding provided by the case study methodology enables to reveal the complex interactions between organizational members and the ERP.

RESULTS: THE CASE STUDY ANALYSIS

Since its inception, "Alfa" purchased an accounting system, named "Delta", to automate the processes in the Finance Department (FD). Delta was supplemented with another software named as Logsis to provide a full account of the required accounting information. A fundamental problem was the weakness of these systems' database. The MIS Department System Administrator stated:

> *"Data security under is the most important element to consider here."*

Because of the above weaknesses, "Alfa" decided to adopt the ERP system. Alfa top management used the language of efficiency, associated with the advanced technology to convince "Alfa" employees to adopt the ERP. For "Alfa" top management, the ERP system will cut cost. The automated system is expected to reduce costs The CEO stated that:

> "*We had to deal with the new ERP system problems because they are very important for the image of our organization."*

"Alfa" had two ERP project managers, first, a Project Manager (PM) affiliated to the steering committee and oversees the adoption of ERP system, second, the ERP system Manager affiliated to the FD and oversees the accounting-based ERP system customization problems. Giddens' (1984) notion of "dialectic of control" is evident here as shown in the above situations. The ERP system manager's accounting technical knowledge and the FD "know-how" of "Alfa's" accounting routines become, as Ocasio (1999), a source of organizational *inertia* and a guide for organizational *transformation* and change. Both used their power, i.e. technical knowledge and "know-how" of the accounting routines, to shift the accounting-based ERP adoption processes from the hands of the PM to their hands, i.e. FD and ERP system manager. The FD holds Alfa's "know-how" which is embedded in the organization's routines. The ERP system manager possesses the technical "know-how" and solutions of accounting-based ERP system customization problems. In fact, both have the power to deal with the organization's uncertainties resulted from the adoption of ERP system accounting module. Yet the PM utilized his hierarchical authority to bring back the power s/he lost. The Head of FD mentioned:

> *"The project manager rejected an access to the ERP. Consequently, the system manager became authority becomes very limited."*

Alfa routinely applies the UAE governmental accounting rules. Once the ERP accounting module is introduced, the FD employees raised many concerns about that module because it does not match with the existing governmental accounting routines. The ERP system Manager stated that:

> *"Fund accounting was not available in the old system. It is a unique feature in the ERP finance module. Users had problems with this new feature. They resisted that new feature because their responsibilities will increase."*

One FD employee gave an example of how "Alfa's" accounting routines were kept yet circumvent around the new module. Alfa's employees had personal and system mistrust because the system problems, the ERP system database security, and the controlling processes. The system manager stated that:

> *"Reprocessing was required. Departments requested too many missing functionalities that the system has to incorporate."*

On the one hand, the ERP system experts (PM and ERP system manager), see that the customization level is very high at the FD. On the other hand, FD members believe that those experts do not have the accounting background, and therefore they should not trust what they say. The above quotes show that Alfa's employees questioned the technical knowledge of the ERP system PM who represents what Giddens (1990) calls an *access point* to the system. Furthermore, FD employees through their face-to-face contacts with the PM and ERP system manager did not feel that the ERP system is a trustworthy one. Their trust in the ERP system was undermined, and therefore they were the subject of what Giddens refers to as "ontological insecurity". The RD employees had a number of technical complaints that casted doubt on trustworthiness of the ERP system. One mentioned:

> *"The ERP system module does not keep historical records of activities performed on the customer account. The system only keeps the results of the last transaction performed."*

A Customer Officer, in the RD department, raised another major issue related to the number of screens/windows/interfaces which must be competed to finish a single task. The Head of RD also expressed:

> *"Logsis was a much better system. We have never trusted the ERP system module. Until now, we double check every output from the ERP system module because we are not sure whether the figures are correct or otherwise. Some mistakes were found in the ERP system module output. We still rely on Logsis as a reference point to check customer accounts established before the execution."*

DISCUSSION AND CONCLUSION

The case study findings provide insights that inform: 1) how the object of change (accounting-based the ERP) is acted upon as a system of trust; 2) how forms of mistrust implicated in the adoption of accounting and integrated information systems; 3) how the new system altered the power relationships across Alfa's employees and 4) how the new system intermediated and provoked employees' feelings of trust and control during the customization processes. The case study evidence shows that the accounting-based ERP system created a discomfort episode, which facilitated Alfa employees' reflexivity and critical reflection in re-assessing the pre and post ERP system ways of thinking. The accounting-based ERP organisational change enabled Alfa employees to reflect on the processes of change and to assess the trustworthiness of the new system, the motives behind the transformation processes and consequently assessing the risks associated with such transformation. To recall, Alfa's top management purposively imposed the new system to create a new business image. The top management had a trust on the new system expressed in the languages of efficiency, effectiveness, cost reduction, single shared database, systems integration and improved performance and acted on this trust to make sense of its decision to adopt the accounting -based ERP system. Nevertheless, these

causes of trust turned to be sources of mistrust in our case organisation. To recall, the ERP system is costly to adopt, required highly skilled and knowledgeable employees and lack many operational benefits promoted under the banner of “automation” such as better data security and less workload.

The case study findings show the intertwined relationship between accounting-based ERP system and feelings of trust during the processes of organisational change. The new system created a complexity and uncertainty across Alfa’s employees because it requires system users to have the knowledge which they do not possess. To recall, Alfa’s employees lacked the technical knowledge of accounting-based ERP system, the ERP system PM lacked the technical knowledge in accounting, and this situation created feelings of uncertainly, organisational instability and consequently mistrusting in the new system. Alfa’s employees questioned and mistrusted the top management motives for change. To recall, they felt that top management motive for ERP change is to reduce costs through downsizing and reducing manpower (i.e. labor).

Although the study contributes to researchers interested in investigating political behaviour during the adoption of accounting-based ERP system, it has some limitations that provide opportunities for future research. First, the study explored how top management was persistent in its approach to implement the ERP system in a short timeframe, yet it is of importance to explore the effects of adopting the ERP system on users’ attitudes after a period of implementing the new system (i.e. longer timeframe effect). This exploration goes beyond the current study and represents an area for future research. Second, the study paid attention to “Alfa’s” employees’ political behaviour and their feelings of trust and control. Further research is recommend to examine the same yet across different stakeholders, inside and/or outside the organisation, interested in the adoption of ERP systems. Third, the study is a case study in emerging economy, the UAE, and therefore with limited generalization of the study findings. What mitigated this limitation is that our study is unique in that it has shown how power, trust and control are intertwined during accounting-based ERP system adoption in a non-Western context. Hence, our paper contributes to the limited number of studies exploring the political behaviour associated with the adoption of the ERP systems in Europe and North America. A direction for future research is that to compare the system adoption across different countries with different cultural values.

The study has a number of implications to the understating of power, trust and control during organisational change. The case study has illustrated how trust (whether personal trust or system trust) plays a pivotal role in reinforcing the organisation power to change, and how the mistrust has become a source of power hindering organisational change. To recall, the power of trust/mistrust lies on the individuals’ need for ontological security and uncertainty avoidance while being able to critically reflect, understand, monitor and evaluate what is going on during the process of organisational change. Trust, therefore, is a basis of power yet it is not necessarily sufficient to achieve the intended outcomes. Trust is understood as processes which incorporate both the causes and consequences for the human actions. This study has shown this dynamic view of trust and has contributed to the understanding of intertwined relation between trust and control and how they interact with each other outcomes during accounting, accountability and ERP system processes of adoption and adoption wherein multiple individuals become involved in networks of trust relations.

Researchers interested in organisational power can build future research upon our contributions in the context of accounting-based ERP systems. They can draw on our work to get a better

understanding and appreciation of how political behaviors emerge and intensify during the adoption of accounting-based ERP organisational change. In this regards, this study pursued a line of critical management accounting research which connects empirical findings to a theoretical framework informed by Giddens (1979, 1984, 1990) while explaining paradoxical findings (Alawattage et al., 2017). Although the study relies on structuration theory, the theory is not free from criticisms. Critical realists criticize Giddens (1979, 1984) structuration theory because of its conflation of structure and agency and his resolution by offering the concept of "duality of structures". What mitigates this criticism is that this study examined the "the position-practice relations" advocated by Ashraf and Uddin (2015) yet informed by Giddens notions of trust, ontological security, agents reflexivity, dialectical of control, agents knowledgeability and capacity to change through allocative and authoritative resources. Future research can pursue similar line research relying on Giddens' (1979, 1984, 1990) notions yet informed by critical realists approach.

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DECISION SCIENCES INSTITUTE

Student Perceptions and Insights on the Selection of Information Technology as a Major – A Pilot Study

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ABSTRACT

The demand for STEM-based positions continues to increase significantly. At the same time, the lack of availability of college-educated students entering the marketplace for these positions creates a recruiting challenge for employers. For decades, females have avoided majoring in technology during their higher education process. Even considering the starting salaries, number of positions and career advancement of a technology career, the number of females entering a technology career has not increased. This research compiled the perceptions of various indicators associated with first-year college students for analysis.

KEYWORDS: Career, Technology, Higher Education, Student Perceptions

INTRODUCTION

Background

The purpose of higher education institutions are to provide quality, skilled labor to business organizations. Students graduating from a higher educational institution and entering the labor market for an entry-level job usually have selected a career choice. Most career choices require a specific declaration of a major (and/or minors). For example, a student who desires to secure a position as an auditor will graduate with a business accounting degree; not a bachelor of arts in sociology.

However, there are many challenges before high school graduates begin their higher education journey. Unfortunately, in recent years, students are not engaging in career exploration and research. Colleges are encouraging prospective and entering students to “find themselves” by remaining “undeclared” for their beginning years in higher education.

Over the last decade, the use of technology has moved from the “back house” of businesses to the “front house”. The invention of … basic hardware devices such as laptops, tablets, smart phones … human-networked devices such as Internet of Things, voice assistants and smart home connectivity … and the consumer-faced applications such as social media, e-commerce and gaming … have all tightly integrated the functionality and social connections of our daily life with technology.

Coincidentally, students do not have a positive attitude or perception of information technology careers (Johansson, 2009). The National Academy of Sciences (2007) found that the percentage of high school students who express interest in becoming a scientist or engineer has sharply decreased. NAS believes that this trend could lead to fewer than 2% of U.S. high school graduates eventually receiving STEM degrees from four-year colleges and universities.

The issue? The decreasing interest in majoring in STEM based majors creates fewer graduates with the skills and knowledge necessary to promote technological innovation as well as the economy of the United States remaining competitive in an international marketplace.

This historical explosion of technology advancement requires skilled labor to design, build, test, manufacture, market and service information systems products. In addition, these professionals also require the ability to compile and integrate a successful strategic model to drive, expand and monitor the technology adoption fever for businesses. So the ability of labor, hopefully, skilled labor, is a critical factor for business organizations to manifest and realize the benefits of technology integration.

Research Objective

The purpose of this research is to identify the various influential characteristics on the intention to select information technology as an undergraduate major and, therefore, a career. For this initial research project, the insights of first-year undergraduates will be explored by gathering data through a survey instrument. The data will provide some knowledge on any influences relating to gender.

LITERATURE REVIEW

Labor Demand and Availability

Historically, U.S. businesses have encountered shortages of available information technology professionals for decades. In 1996, the Information Technology Association of America (ITAA) found that IT companies had about 190,000 unfilled IT professional jobs due to a shortage of qualified workers (Freeman, Aspray, & Computing Research, 1999). According to a 1999 Department of Commerce report the total number of IT professionals will grow to 2.6M in 2006; a 73% increase from 1999 (Handel & International, 2003).

The U.S. Bureau of Labor Statistics most recent data reports 6.25M computer-related positions in 2016; a large expansion over the 2006 estimate projections. As shown in Table 1, the outlook over the next decade reports an average change of 9.1%. It should be noted that while the BLS report has shown a decrease in the traditional computer programmers, there is a clear and rapid projected increase in software developers (applications and systems software) over the next decade. The application development category depicts the increase in applications for the various devices of tablets, IOTs and smart phones.

Occupational Description	Employment (in thousands) 2016	2026	Change, 2016-26 Number	Percent	Openings Annual Avg 2016-26
Computer and information research scientists	27.9	33.2	5.4	0.2	2.5
Computer systems analysts	600.5	654.9	54.4	0.1	44.9
Information security analysts	100.0	128.5	28.5	0.3	10.4
Computer programmers	294.9	273.6	-21.3	-0.1	15.5
Software developers, applications	831.3	1,086.6	255.4	0.3	85.7
Software developers, systems	425.0	472.1	47.1	0.1	32.9

Occupational Description	Employment (in thousands) 2016	2026	Change, 2016-26 Number	Percent	Openings Annual Avg 2016-26
software					
Web developers	162.9	187.2	24.4	0.2	14.6
Database administrators	119.5	133.2	13.7	0.1	9.3
Network and computer systems administrators	391.3	415.3	24.0	0.1	27.0
Computer network architects	162.7	173.2	10.5	0.1	11.7
Computer user support specialists	636.6	708.7	72.1	0.1	55.5
Computer network support specialists	198.8	215.2	16.4	0.1	16.5
Computer occupations, all other	287.2	313.8	26.6	0.1	22.4
Totals	**6,254.6**	**6,821.5**	**566.9**	**0.1**	**348.9**

Table 1 – Employment Trends in Information Technology Careers (https://www.bls.gov/)

Ironically, with all the discussion about shortages in technology professionals, the dominance in the marketplace is clear. According to the Census Bureau, the number of total information technology workers has expanded from 450,000 in 1970 to 4.6 million in 2014 (Beckhusen & Bureau, 2016). In the same period, the percentage of the civilian workforce has increased from 0.6% to 2.9%. The percentage doubled between 1990 and 2000 (1.2% to 2.5%). The increase in workforce could be attributed to the use of technology by e-business adoption as well as increased use of technology in small and medium sized businesses.

These increases are notable. However, it is more interesting to observe the radical change in the various positions and specialties within the information technology. In 1970, only three positions were identified; analysts, programmers and “other” (Beckhusen & Bureau, 2016). However, over three decades later, the number of positions skyrocketed to eleven; an increase in 267%. The expansion in the various technology positions reflects both the increase in complexity of managing the function within a business as well as increased specialization of duties and responsibilities.

Higher Education and Information Technology

The ability to project labor shortages can often be trended by using data from higher education institutions. While new entrants to information technology careers can pursue various post-high school alternatives, the greater majority of information technology professionals are being supplied by higher education.

According to the U.S. Department of Commerce, the number of computer science degrees between 1978 and 1986 increased to about 50,000 from 5,000 (Handel & International, 2003). However, the number graduates declined and remained constant in the early 1990s (approximately 35,000). The gender disparity associated with computer science graduates is more concerning. The availability of females available for entry-level information technology positions with a college degree is low. While females comprise approximately 60% of college graduates, only 18% complete their degree with a computer science major (Moore, 2015).

Gender Roles in Information Technology

Many studies have been compiled to understand the role of gender as it relates to attitudes and thoughts on technology (and STEM) careers. The negative perception of females on STEM focus on lower self-efficacy, intellectual and practical interest (de Vries, 2005; Endepohls-Ulpe, Ebach, Seiter, & Kaul, 2012).

At NASA, the number of aerospace engineers are men while less than one third of the agency's engineers are women (Moore, 2015). The Census Bureau reports that the U.S. civilian workforce of female information technology professionals trails all occupations substantially (Beckhusen & Bureau, 2016). From 1970 to 2014, the percentage of female workers for all occupations as compared to information technology was 47% to 25%.

The research relating to gender inequity in technology-related careers (and probably STEM-based jobs in general) suggests various causal possibilities ranging from violent electronic games or a boring view of programming (Anonymous, 2000). However, it is ironic that many of the early pioneers in technology and computer science were women. Grace Hopper (development of COBOL) and Adele Goldstine (wrote the first programs for the ENIAC computer) in the 1940s.

Adolescent males are more likely to "tinker" with computers in higher numbers (Mims-Word, 2012). Males are generally more inclined to utilize technology to explore and discover as a norm, with this engagement being introduced by a parent to develop an interest in technology.

Females appear to view technology in a transactional sense. In AAUW's research, it is interesting to note that adolescent females view technology as a tool as an extension of themselves while males (Anonymous, 2000). This insight may explain the lack of engagement for many females in relation to technology as a career. For example, they may use a car as a means of efficient transportation. However, they have no interest to explore or understand how the vehicle works beyond turning the ignition.

The dramatic difference in the female ratio is perplexing when considering earning potential. Since 1970, the median earnings of female information technology professionals are 80% more than all occupations (Beckhusen & Bureau, 2016). It is interesting to note that the position with the highest percentage of females is database administrators, a position that requires additional technical skills.

Therefore, with ample job availability and higher earning potential, the lack of female representation for roles in an information technology career are discouraging.

Attitudes and Perceptions of Students

In the last two decades, a great deal of research has been completed on the lack of interest in students choosing a career in the sciences. While there is a great deal of attention, popularity and adoption of technology, the attitudes toward a career in technology still lag. Some research suggests that student experiences relating to technology and sciences at school shape their perceptions (de Vries, 2005; Osborne & Collins, 2000; Stein & McRobbie, 1997). Research by Lindahl (2007) confirms that any interest in science or technology careers are generally determined by the age of 14.

Research by Ardies et al. (2015) found that as males transitioned into the second year of their secondary education their technology interest developed. Females regard technology as more of a masculine subject. Their findings also suggest that the gender bias develops a more distinctive difference.

Even after 44 years, the research of Coser (1974) relating to workplace issues is more popular than ever. As Coser identified the family and workplace as greedy institutions, the work-life balance issue has become a focus of discussion within business organizations and employees. Some research suggest that work policies are perceived to be less flexible in STEM careers. Specifically, engineering firms do not simplify the life balance issue enough, causing women to leave STEM careers (Gill, Sharp, Mills, & Franzway, 2008; McIlwee & Robinson, 1992). Students who define family flexibility as a factor when choosing their major are less likely to select STEM majors (Valentino, Moller, Stearns, & Mickelson, 2015).

Influencing Characteristics and Factors

A broad definition of perceived or subjective norm is "the perceived social pressure to perform or not to perform the behavior" in question (Ajzen, 1991). Finlay et al (1999) further describe a subjective norm can also be defined as an individual's perception or "opinion about what important others believe the individual should do". Students' choices can be prompted to perform behavior based on the influence of others.

In order to accomplish the research objective, it is important to determine the subjective norms, perceptions and thoughts that could influence selecting information technology as an undergraduate major. Therefore, an analysis of research was completed to gather the various constructs. The analysis resulted in twelve constructs as the foundation for the development of a survey instrument. The constructs and the related research citations are compiled in Table 2.

Construct	Research Citations
Aptitude to study information technology	(Joshi & Kuhn, 2011; Kuechler, McLeod, & Simkin, 2009; Walstrom, Schambach, Jones, & Crampton, 2008)
Interesting to use; Complete work with technology	(Heinze & Hu, 2009; Kuechler et al., 2009; Walstrom et al., 2008)
Difficulty of major; Requiring significant study time	(Kuechler et al., 2009; Walstrom et al., 2008)
Interest in information technology	(Joshi & Kuhn, 2011)
Availability of job positions	(Heinze & Hu, 2009; Joshi & Kuhn, 2011; Kuechler et al., 2009; Walstrom et al., 2008)
Gaining a high starting salary	(Joshi & Kuhn, 2011; Kuechler et al., 2009; Walstrom et al., 2008)
Influence of media	(Walstrom et al., 2008)
Importance of self-image; Image of information technology professionals	(Fox, Hindi, & Remington, 2001; Joshi & Kuhn, 2011; Kuechler et al., 2009; Walstrom et al., 2008)
Social image; considered a respectable career	(Joshi & Kuhn, 2011; Kuechler et al., 2009; Walstrom et al., 2008)

Construct	Research Citations
Influence of family, friends, professors, advisors and peers	(Heinze & Hu, 2009; Joshi & Kuhn, 2011; Kuechler et al., 2009; Walstrom et al., 2008)
Work environment	(Joshi & Kuhn, 2011)
Intent to major	

Table 2 – Research Constructs and Related Literature Review

RESEARCH METHODOLOGY

Survey Instrument

The survey instrument was compiled using two sources: 1) questions designed directly from past research studies and 2) designing questions to gather the students' accurate perceptions for the additional constructs.

To complete this research study, 37 questions were compiled to gain the insights and perceptions, including a question on the respondent's gender. The order of the questions in the survey was arranged so that the redundant (reworded) construct questions were not placed in sequence. The survey was pilot tested with both students and faculty in order to identify grammar and ambiguous wording. The pre-test feedback was analyzed and applied to compile the final version of the survey instrument. The survey was coded into an online survey tool (Qualtrics) to administer efficiently and eliminate response data entry.

The listing of constructs and associated number of questions are compiled in Table 3. Each of the questions were measured on a seven point Likert scale. The scale for each question is defined in the fourth column as Strongly Agree vs. Strongly Disagree (SA/SD) and Extremely Important vs. Not Important At All (EI/NI). In each scale, the value of one (1) is identified with the first scale (strongly agree or extremely important). In the discussion section, using the adjective "lower" is defined as a higher responses score, but lower toward the more negative scale (strongly disagree, not important at all).

Construct Category	Construct Name	Number of Questions	Question Scale
AP	Aptitude	2	SA/SD
AT	Attitude	2	SA/SD
DM	Difficulty of Major	2	SA/SD
IN	Interest in IT	5	SA/SD
JA	Job Availability	2	SA/SD
JS	Job Salary	2	SA/SD
MI	Media Influence	5	EI/NI
PI	Personal Image	2	SA/SD
SI	Social Image	2	SA/SD
SN	Subjective Norm	5	SA/SD
WE	Workload Environment	5	SA/SD
IM	Intent to Major in IT	2	SA/SD
	Gender	1	SA/SD
	Total	***37***	

Table 3 – Survey Construct Summary

Survey Population

First-year undergraduate students were selected as the population for this research study. Many undergraduate students have not declared their major. A study estimated the number of "undecided" students between 20 and 50 percent (Gordon, 2007). The scope of this research is to compile the perceptions for entering college students; as they begin their higher education experience and exploration.

Students registered in the first-year survey course in business were asked to complete the survey.

Hypotheses

Twelve hypotheses were compiled based on the perceptional constructs as well as the intention to declare information technology as a major. The hypotheses are listed in Table 4.

Hypothesis	Description
	There are no significant differences between gender based on the respondents …
H1	… aptitude in information technology.
H2	… attitude to gain a career in information technology.
H3	… perception of the difficulty to major in information technology.
H4	… interest in information technology.
H5	… believe that there are sufficient information technology positions available.
H6	… believe that salaries for information technology positions are high.
H7	… are influenced by various media environments.
H8	… have a positive personal image of information technology professionals.
H9	… have a positive social image of information technology professionals.
H10	… are positively influenced by others relating to information technology careers.
H11	… believe that a career in information technology has a positive work environment.
H12	… believe that they will intend to declare information technology as a major.

Table 4 – Research Hypotheses

Each of the eleven hypotheses will be evaluated using the responses of the students' survey completion. The evaluation will be completed by analyzing the response data through an analysis of variance (ANOVA). This statistical technique will measure the variation among and between groups of a population to determine any differences among group means.

In this research, gender will be used as the categorical variable to analyze each of the eleven hypotheses. The completion of the analysis will determine if differences, if any, exist by gender.

FINDINGS AND RESULTS

Survey Response

Three deployments of the survey were administered in the three semesters between Fall 2016 and Fall 2017. Over the three survey periods, 541 students completed the entire survey. Seven completed surveys responded to the gender question as the third item (no response) were omitted from the analysis. With the number of respondents for the analysis (534), the majority of respondents were male (63 vs. 37 percent). The institution's current male-to-female ratio (62 vs. 38 percent) of the entire first-year class accurately represents the survey response frequency distribution.

A summary of the survey response frequencies is shown in Table 5.

Semester	Male	Female	Total
Fall 2016	110	53	163
Spring 2017	131	68	199
Fall 2017	96	76	172
Total	337	197	534
Percent	63.1%	36.9%	100%

Table 5 – Survey Response Summary

Analysis of Variance Results

For each respondent, each of the individual questions associated with the construct was averaged. For example, the five media influence questions were averaged to compile an average score for the "MI" construct for all 534 responses.

The analysis of variance statistical tests were completed using SPSS. The ANOVA was completed by using the twelve construct average scores as the dependent list with the gender response as the factor.

The statistical results of the analysis of variance are compiled in Tables 6 and 7.

Construct	Gender	N	Mean
Aptitude	Male	337	4.32
	Female	197	5.15
	Total	534	4.63
Attitude	Male	337	2.90
	Female	197	3.57
	Total	534	3.15
Difficulty in Major	Male	337	3.35
	Female	196	3.85
	Total	533	3.53
Interest IT	Male	333	2.80

Construct	Gender	N	Mean
	Female	196	3.36
	Total	529	3.01
Job Availability	Male	335	3.06
	Female	196	3.19
	Total	531	3.11
Job Salary	Male	334	3.00
	Female	195	3.11
	Total	529	3.04
Media Influence	Male	334	3.65
	Female	194	3.51
	Total	528	3.60
Personal Image	Male	335	5.39
	Female	197	5.69
	Total	532	5.50
Social Image	Male	337	4.12
	Female	197	4.16
	Total	534	4.13
Subjective Norm	Male	336	4.67
	Female	197	5.09
	Total	533	4.82
Workload Environment	Male	333	3.15
	Female	195	3.17
	Total	528	3.16
Intent to Major	Male	335	5.30
	Female	196	5.79
	Total	531	5.48

Table 6 – ANOVA Frequencies and Means Results

Construct	F	Sig.
Aptitude	47.661	0.000
Attitude	30.179	0.000
Difficulty of Major	31.347	0.000
Interest in IT	40.384	0.000
Job Availability	1.838	0.176
Job Salary	1.111	0.292
Media Influence	1.571	0.211
Personal Image	7.809	0.005
Social Image	0.322	0.570
Subjective Norm	25.047	0.000
Workload Environment	0.094	0.759
Intent to Major in IT	18.251	0.000

Table 7 – ANOVA Frequencies and Means Results

Hypotheses Evaluation

The outcome of the ANOVA statistical analysis provided an evaluation of each dependent variable as it relates to the group factor (gender). The ANOVA results calculated the F-score, significance level and all means (group and grand).

Each of the p-values were evaluated based on the traditional ranges associated with previous research (p<.001, p<.01, p<.05). For the twelve hypotheses, seven were rejected for p-values calculated less than the accepted value (.05). Several of the research hypotheses (H1, H2, H3, H4, H12, and H14) were found to be highly significant (p<.001).

The results of the ANOVA statistical analysis found that there were highly significant differences between gender relating to aptitude, attitude, difficulty of major, subjective norms and intent to select information technology as a major. The remaining hypothesis (personal image) was found as significant in terms of differences between females and males.

The statistical results of the hypotheses evaluation is compiled in Table 8.

Hypothesis	**Construct**	Mean Grand	Mean Male	Mean Female	**Sig**.	
H1	Aptitude	4.63	4.32	5.15	p<.001	Reject
H2	Attitude	3.15	2.90	3.57	p<.001	Reject
H3	Difficulty of Major	3.52	3.35	3.85	p<.001	Reject
H4	Interest in IT	3.01	2.80	3.36	p<.001	Reject
H5	Job Availability	3.11	3.06	3.19	ns	Accept
H6	Job Salary	3.04	3.00	3.11	ns	Accept
H7	Media Influence	3.50	3.65	3.51	ns	Accept
H8	Personal Image	5.50	5.39	5.69	p<.01	Reject
H9	Social Image	4.13	4.12	4.16	ns	Accept
H10	Subjective Norm	4.82	4.67	5.09	p<.001	Reject
H11	Workload Environment	3.16	3.15	3.17	ns	Accept
H12	Intent to Major in IT	5.48	5.30	5.79	p<.001	Reject

Table 8 – Result of Hypotheses Testing and Evaluation

DISCUSSION AND CONCLUSIONS

Discussion

Even after decades of discussions, innovative teaching techniques, targeted promotions of STEM-based careers/majors, the perceptions (and probably reality) between females and males relating to information technology careers still remains distinctive. More than half of the hypotheses calculated significant differences between genders.

Aptitude: The results of the respondents clearly indicate that females do not consider their fit and performance as lower as their male peer group. The difference between the mean values (0.83) is not only highly significant, but also the lowest of all hypotheses constructs. The mean scores indicate that their visualization in an information technology position is much less positive than that of males; somewhat disagreeing with the question statements.

Attitude: The questions associated with this construct explored whether they believed that the use of information technology at work would be interesting. Coincidently, the attitude toward the technology use is also lower. While the differences between the gender means is lower than aptitude (.67), it remains very high. On a positive note, the range between the mean scores of attitude and aptitude increased more toward strongly agree. Although, the percentage decrease in the gender averages decreased more for males (49%) than females (44%). The differences remain significantly significant.

Interest in IT: In terms of the interesting in information technology and business, females indicate that their interest is lower than males. Male students scored the highest inclination toward interest in IT than any other construct composite; 19% higher average than females. The question probes the interesting in working in information technology, using software as well as working in a team, analyzing/presenting business problems. After reviewing the question, the responses may need to be separated for further analysis.

Difficulty of Major: One of the questions associated with this construct was written with a negative version of the other question. Therefore, to maintain accuracy of the statistical analysis, the data was recoded to the scale of the other question prior to the completion of the ANOVA computations. Anecdotally, the difficulty of STEM-based majors appears to a significant influence on the selection of those majors. Ironically, the mean scores (both overall and major) were lower than expected; trending between 3.35 (males) and 3.85 (females). The final mean values (grand and gender) are higher than the aptitude mean responses. The results indicate that even though the perception of their ability in information technology is lower they do not believe the major's difficulty is as negative.

Intent to Major in IT: Obviously, this construct is important as a reflection of their overall thoughts on an information technology major. Each of the mean scores are very low as compared to the other construct scores (the personal image construct averages) are very similar. However, while pointing to a very negative inclination to major in technology, the difference between the gender scores is the narrow than four other scores (aptitude, attitude, difficulty and interest); representing 9.2% difference in the mean scores. Still, it reflects an extremely pessimistic view of information technology careers (between somewhat disagree to disagree).

Subjective Norms: The influence from people on the student was found to be highly significant between genders. The difference in the gender mean scores was 9.2%; the same as the intent to major construct.

Personal Image: The perceived personal image of information technology professionals is considered "nerdish", anti-social and boring. Both questions were posed by suggesting words using the three words noted above; tending to focus on the negative words. The mean scores associated with this construct (grand and gender) are the lowest in the construct averages. However, based on the negative construct, the averages indicate between somewhat disagree to disagree. When considering these results, it is interesting that students are not as negative about the perceived personal image of technology professionals. Coincidentally, female students are lower than males, although by the smallest percentage difference (5.5%) and significant ($p<.01$).

Each of the remaining five constructs calculated no significant differences between males and females. This result would indicate that males and females think and act in a similar manner relating to the availability of jobs, high salaries, media influence, social image and workload environment.

Job Availability: Students are, for good reason, concerned embark on a career that have positions available upon completion of an undergraduate degree. The number of technology positions will be ample to find a positon and to maintain a successful career.

Job Salaries: The results associated with job salaries (high and satisfying) are very similar to the job availability results.

Media Influence: The current generation is affected by media; especially social media. Students were asked to provide the influence of five media experiences (career fairs, newspapers/magazines, job listings, social media and television/movies). There was no significant differences between males and females. The highest individual means were calculated (respectively) as 2.93, 4.04, 3.07, 3.82 and 4.12. The most influential are career fairs and job listings. The opposite end of the range averages indicate that social media, movies and newspapers are not ad influential as the other forms.

Social Image: The social image associated with information technology leading to a respectable career do not indicate any significant differences between males and females.

Workload Environment: The students were asked about the level of challenge and ability to obtain a leadership position in a business. It is clear that students (both male and female) have not been influenced in a negative manner by the workload associated with technology positions.

Conclusions

The results of this research are not surprising. Males and females have very delineated perceptions and thoughts about technology careers. Some interesting thoughts and insights are as follows:

- Both males and females believe that their use of technology is important. This perception may be the level of integration and use of technology in their daily lives as students and individuals. What is interesting is that level of technology use does not equate to the level of aptitude with technology. This disconnect may be due to their view of technology as an appliance and not a tool to gain market-based, functional skills to apply in their job. It is also possible that they believe they cannot develop those skills successfully.
- Ultimately, the results of this study clearly indicate that males are more influenced by professors, friends, peers and advisors than their female peers are. Does this result indicate that males more inclined to seek out advice? Or develop more relationships that gain advice organically?
- While both genders somewhat agree that the availability of jobs is suitable to start a career, there is a reasonable disconnect is present relating to the number of jobs actually available and high starting salaries. It is unfortunate that the discussion, in the

household between parents and college-age children, on gaining an entry-level position with high salary is not framed to include technology positions.

- Students do not seem to be affected significantly by the social image as much as the personal image associated with technology positions. This outcome would suggest that the perceptions, whether positive or negative, ascribed by others is not as important as their own personal image of a career selection. Anecdotally, this result may be specific to generational characteristic of self-absorption; that their personal image (at least for career) is more important in how they are perceived by society in general.

Other influences and perceptions may be permeating through the thoughts of young people. Do technology positions appear to be very compartmentalized within the information technology department/division? With no other contact outside of their career positions? Sales people meet with customers on a frequent basis. Marketing personnel promote products by collaborating with internal personnel (sales representatives, brand managers, etc.) and external resources (graphic designers, photographers, writers, research analysts). From the students' perspective, they may view technology positions as isolated and only collaborating in a small circle of positions and functions within a business.

Does that mean that students consider technology careers as too corporate? Too hierarchical? Too isolated from the business organization? Or that technology does not have the opportunity to collaborate with and present to management and organizational leaders?

In addition, students may believe that technology personnel cannot navigate and transition to other careers. Do students believe that the skills, experience and projects do not translate to other positions and careers? If so, students may believe that technology professionals are "pigeon holed" and remain as a technology professional for their entire career.

Limitations and Further Research

When completing this pilot study on the survey data, several issues were uncovered.

The results reveal a potential disconnect between aptitude and use of technology was fascinating. It would be interesting to probe further to separate and define what information technology students use and what technology they would utilize as an IT professional.

The other disconnect between the results and reality relate to the need for high-paying, available jobs and technology. With all the discussion of the high-cost of higher education and the ability to repay student loans, the entry level salaries and positions available should be able to "catch the eye" of students. For example, students selecting accounting as a major clearly know the starting salaries and jobs available upon graduation. No one is suggesting that a student enter a major or career they do not enjoy. However, it may be possible that students refrain from an open and objective exploration relating to technology based on the associated perceived negatives.

Future statistical analyses should be completed to develop potential correlation on the various influences and perceptions of students and the intent to major. It would be interesting to determine whether any specific constructs are more dominant over the intent to major in technology over other constructs.

From the results of this study, it is clear that there are clear and distinguishable differences between males and females. The endless discussion of the number of females entering technology positions (and STEM-based careers in general) remain important and requiring attention. Education leaders (from K-12 to higher education) as well as business leaders need to continue promoting, acting as role models and active advocates with young people. The increasing thirst for technology by businesses and individuals reflects the need to continue all efforts to promote technology as a formable and satisfying career. Our ability as a national economy will specifically depend on a) increasing the number of young people who desire a technology position and b) not allowing the trend to decrease.

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DECISION SCIENCES INSTITUTE

Sustainability commitment: A decision framework for innovating and examining transport practices.

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ABSTRACT

This paper reports on incremental findings from our investigation into rationales for sustainability practices. Three theory strands; resource-based view (RBV), stakeholder and relational corporate social responsibility (RCSR) theories are advanced to develop a conceptual model for logistics and transport sustainability. Qualitative methods are employed to collect and analyze data from 18 organizations in Sweden and Nigeria over a 2-year period, conducting 37 semi-structured interviews with management executives. Preliminary findings support the tri-combination framework as adequate for understanding sustainability practices by organizations, highlighting size and context as potentially moderating factors in the decision-making process. Findings offer incremental insights that enhance understanding of how logistics and transport organizations evolve practices to support their commitment to sustainability.

KEYWORDS: Sustainability Commitment; RBV; Relational CSR; Stakeholder Theory; Freight Transport

Research remains inconclusive about the role and responsibility of organizations within society. The common narrative presents the firm as a competitive unit with a primary objective of profiting (Freidman, 1962, Barney, 1991). However, recent studies have acknowledged internal and external factors that are impacting organizations towards other goals besides wealth creation (Aguilera et al., 2007; Palsson and Kovac, 2014). With these exerting pressures on organizations, the focus is on management for leadership, responsibility and accountability in terms of strategic directions for their organization. Managing for sustainability is thus a critical component of strategic management, requiring advanced stratagems for operating in different

climes across the world (Logsdon and Wood, 2002; Aguilera et al., 2007; Tob-Ogu et al., 2017). We note the importance of academic discourse and recognize the validity of the plethora of management theories that have provided useful and relevant guidance on firm strategies at meso, macro and supra levels; yet, recent scandals involving multinational and local organizations like Rolls Royce (Brazil) and Zara (Turkey) to mention a few, create uncertainties about the commitment of organizations to a sustainable future, with the British International Freight Association suggesting a 7% increase in whistle blowing within the logistics and transport sector (BIFA, 2018). We view commitment as tied to an understanding of the 'relationship' between organizations and society, where this understanding influences the decisions of management and the inviolability of the commitments on sustainability. To improve our understanding of the decision process that drives managerial decisions and actions in this regard, the following research question is posed; "Can management theory integration improve understanding of sustainable decision making by management in the logistics and freight transport sector?" In this paper, we review three prominent strategies/theories and advance a framework that unifies elements from different theories into a single perspective to examine the 'necessary' firm and society relationship framework to improve sustainability performance. The rest of this paper is structured accordingly: section two presents a review of the literature on sustainability; in section three, we review relevant theories; our research methodology is detailed in section four; whilst sections five and six see presentations of our results and conclusions respectively.

LITERATURE REVIEW

SUSTAINABILITY

Sustainability is a multi-faceted construct with a variety of conceptions centered on the idea of a better world (Gladwin et al., 1995; Behrends et al., 2008). In this study, the term is used to capture the tri-dimensional concept of sustainable development as protecting the opportunity for future generations to meet their needs by catering to people, planet and profits as an inclusive package (World Commission on Economic Development; 1987; Elkington, 1998). It thus represents activities, practices and impacts for creating positive societies and business outcomes within livable environs. Gladwin et al., (1995) advocated the acceptance of both objective and subjective values in assigning meaning to the concept, suggesting that clarity would improve over time as we developed consensus on characteristics, operational indicators and moral injunctions. They advance connectivity, equity, inclusiveness and prudence as principal components of viable sustainability definitions.

Accordingly, we recognize the validity of bespoke indicators and variations that are perhaps underlined by specific environmental pressures within specific firm contexts. However, sustainability initiatives and practices should at least aim to promote wholesome economic efficiencies, positive social impact and environmental preservation outcomes that improve the in-situ experience of the society where organizations exist or operate in (WCED, 1987). Economic efficiencies refer to the optimal allocation and use of resources to generate profit or output, positive social impact underlines the effect on individual feelings, thoughts or behaviors from the actions of others (Latane, 1981) and environmental preservation encompasses policies and practices that address concerns relating to climate change, wildlife welfare and ecological balance. It is permissible that adherence to these principles will enhance the attainment of the WCED (1987) construct on sustainability.

Despite the recognition of contextual pressures as potentially limited, for the typical logistics firm, contexts have both spatial and geographic implications stemming from globalization and information and communications technology (ICT) pervasion. This is true, even for most non-multinationals as increasing trade and globalization is leading to further interdependence

between organizations through a hydra-triadic web of relationships. Our remit precludes the debate on the universal conceptualizations of sustainability, however the preceding supports the foundation for examining the integration of sustainability practices into firm strategies, otherwise referred to as sustainability commitment in the paper.

SUSTAINABILITY COMMITMENT

A survey of 2045 professionals reported apathetical engagements between organizations and the United Nations Sustainable Development Goals (SDG) in 2016, with planned engagement by organizations at less than 50% (Ethical Corporation, 2016). Similar scandals relating to low pay and labor exploitation (Zara), gender inequality (BBC), environmental contamination (Shell Nigeria) and child labor (Apple, Marks & Spencer) raise questions about the commitment of organizations to sustainability (Guardian, 2014; Amnesty International, 2016; BBC, 2016). This unwholesome commitment to sustainability has engineered the term 'greenwashing' which represents the creativity of some organizations in managing their sustainability portfolio through a range of deflection strategies (Werbech, 2009; Laufer, 2003). As independent scrutiny increases, the onus falls on management to evolve, disseminate and enforce sustainability initiatives within their operations and supply chains. However, the common tendency seems to focus on evolving and dissemination as opposed to enforcement. As captured by Werbech, (2009) leading global organizations seem more focused on communicating green efforts as opposed to improving their practices. This practice is perhaps buoyed by the increasing availability of data to support competitive advantage through sustainable practices. There are a number of challenges that arise with this approach:

Accessibility: Information accessibility is at its highest level in the history of mankind, driven by advancements in ICT. Not only has accessibility improved, the capacity to disseminate to the largest audiences within the shortest possible time is immense. Organizations will eventually be like gladiators, whose fate will be decided by society based on observations in real time Coliseums.

Competency: Perfection through practice principles will apply. Organizations will probably develop superior competency in communicating sustainability efforts as opposed to competencies in sustainability practices. In the long term, they will lose any competitive advantage that arises from the implementation and improvement of sustainability practices as opposed to communication. Impairment: Ignoring the problem does not always address the problem. By relying on evidence that sustainability can support competitiveness, there is an implicit acceptance that sustainable practices offer value to customers and society at large. Greenwashing counteracts acquiescence of sustainable value streams with potentially dire consequences for future competitiveness.

Importantly, the literature is relatively limited on why organizations pursue non-sustainability strategies or green wash (Werbech, 2009, Palsson and Kovac, 2014). Millar et al., (2012) argue that despite global acceptance of sustainability, there is still a dearth of management models that support integration into business practices. This perhaps explains the antecedent of greenwashing by organizations and highlights gaps on sustainability integration within the literature.

Accordingly, we emphasize links between management knowledge and sustainable practices, where knowledge impacts practices. Importantly, the literature recognizes links between theory, strategy and practices (Anderson and Paine, 1975). For example, Sutcliffe (1994) established theory as promoting our understanding of links between firm practices and environmental inputs. Also progressing on Anderson and Paine's (1975) work, Beyer et al., (1997) went on to establish links between environments and management strategies, highlighting the role of perceptual factors (information) on businesses. Information assumes critical influence and it is plausible that managements' quasi-commitment to sustainability may stem from information

perceptions about their environments rightly or otherwise (Massis et al., 2013; Ozleblebici et al., 2015).
This link between theory and strategy can be multi-directional, i.e. we can explain business strategies through theory and we can evolve business strategies through theory. In the case of the latter, the outcomes engineer strategic innovation that supports management activities. In this study, we adopt a reflexive strategy to develop and review a framework for theorizing on firm's approaches to sustainability. Recognizing the epistemological limitations, our model offers adopting managers an innovative platform for evolving sustainable strategies that focus on recognizing, accepting and improving their sustainability practices.

THEORETICAL MODEL

Despite the progress and proliferation of management theories to support understanding, there are still significant gaps or limitations with individual theories. As a developing concept, theoretical explanations for sustainability practices fail to provide comprehensive understanding of why management decide and act to be sustainable. More often than not, theories are skewed towards one of the three pillars and this creates knowledge silos and limits our current understanding. To tackle this phenomenon, Mayer and Sparrowe (2013), accentuate the relevance of theory combination to management research, establishing four scenarios that justify the integration of theories in research:

I. Single Phenomenon - two theoretical perspectives: common dependent variable that allows for investigation from two vantage points. E.g. RBV and TCE on subcontracting.
II. One Phenomenon with two seemingly disparate theoretical perspectives – Identifying and employing seemingly conflicting theories to complement understanding of phenomena.
III. Adaptation – Applying one theory to the domain of another theory – E.g. Social theory and TCE to explore social relationships outside organizations or government behavior.
IV. Combining multiple streams of research sharing similar explanatory accounts – More than two different theory explanations are fused in dialogical contexts to integrate their explanations under one broad umbrella.

Palsson and Kovacs (2018) recognize the limitation and appropriate stakeholder and RBV theories to evaluate practices in transport. Whilst their study offered useful insight into the internal and external drivers of green practices by transport firms, it also validated the limitations of single theoretical lenses. Despite the usefulness of their findings, their sample did not reflect the diversity that is present in today's logistics and freight transport environment. Since we know that the complexities of sustainability and potentially conflicting firm epistemologies support theory integration frameworks that promote understanding. In this instance, we sought to build on their study by combining the resource-based view, stakeholder and relational corporate social responsibility theories to develop a suitable model for theorizing sustainability in logistics and freight transport. Such insights offer useful understanding of management decision influences and can help improve interventions.

Resource Based View: (RBV)

Barney (1991) is widely regarded and cited as the pivotal work in the emergence of RBV. In the foundational text, "Firm Resources and Sustained Competitive Advantage" Barney was reacting to the dominant positioning school of the 1980s, which focused managerial attention to external considerations, industrial structure for example.

In contrast, as illustrated by Hoskisson et al., (1999), RBV direct firm's attention towards internal resources in an effort to identity assets, capabilities, competencies and forms of coordination with the potential to deliver sustainable competitive advantage (Liu et al., 2010; Grant, 1991 Wernerfelt, 1995). The essence of RBV is captured in the notion that the differences in organizations' resource endowment result in differences in firm performance. Therefore, a key insight arising from the RBV approach is that organizations are made up of heterogeneous resources with varying importance and potential configurations; therefore, managerial effort must be dedicated to identifying core competencies though specific value-creating strategies (and causal relationships) for sustainable competitive advantages (Eisenhardt and Martin, 2000; Barney, 1991).

Furthermore, the "VRIN" framework popularized by Barney (1991) is the commonly accepted standard within the RBV as providing the basis for understanding resources that can be sources of sustainable competitive advantage. VRIN is an acronym for value, rare, inimitable and non-substitutability. 'Value' denotes the extent to which the combinations of a firm's resources match the external environment and enables it to exploit the business environment advantageously (Hoskisson et al., 1999; Barney, 1991). 'Rare' captures the perceived inaccessibility of a firm's resources in the market it competes in; 'inimitability' represents the difficulty of imitation without higher cost disadvantage and 'substitutability' addresses the availability of similar resources that are available to other organizations. Underlying the VRIN framework, that strategically valuable resources must be scarce, inimitability and non- substitutability (Barney, 1991; Bromley 2009), is the view of factor market as imperfect. But divided into the tangibles and the intangibles, several researchers have argued that intangible factors are likely to satisfy Barney's VRIN criterion (Johnsen et al., 2014).

Pertaining to the objectives of this study, RBV theories have been applied in studying responsibility of organizations to society and people that live in it (Litz 1996; Aragón-Correa and Sharma 2003; Colbert 2004; Sirmon et al., 2007). For example, Litz (1996) argued for recognizing that social and environmental dimension of organizations' activities could be sources of strategic advantage. Likewise, Sirmon et al., (2007) argued that environmental factors can affect organizations' strategic resources. One shortcoming of RBV approach in this regard is the 'direct' internal and short-term nature of its analytical language (Sanchez, 2008). In essence, various researchers (Porter 1991; Sanchez 2008; Prime and Butler's 2001) have shown that RBV suffers from both conceptual and practical deficiencies. Some of the conceptual deficiencies include the failure to provide an adequate conceptual basis for identifying resources that are strategically valuable to a firm in a given competitive environment, and the absence of chain causality in its language (Sanchez, 2008; Heene and Sanchez, 2018; Becerra 2009). Borrowing from the work of Stinchcombe (2000) and Johnsen et al., (2014), some practical deficiencies include the failure to supply critical investigation of how key capabilities are acquired; it also provides little guidance on how to develop resources to meet the set criteria.

Consistent with the objective of this study, the systemic nature of organizational capabilities and the "contingent" nature of resources establish the limitations of RBV as a single theoretical lens, because it views resources in isolation to the web of interactions that combined to produce them. Theories that seek to understand the edges of firm activities will increase the robustness of RBV and provide a complete language for the research phenomena of interest. We have selected stakeholder approach to perform this function: stakeholder suggests that organizations should formulate and implement processes with different stakeholders in mind.

Stakeholder theory

The essence of the stakeholder approach is captured in the notion that (1) shareholders are not the only party affected by the activities of organizations, and (2) the other parties (or

stakeholders) should be considered in firm management strategies. Robert Freeman (1983; 1984) is extensively regarded and cited as providing the basic analytical and conceptual framework on which stakeholder theory is based. In its original rendering stakeholders were defined as "those groups without whose support the organization would cease to exist" (Freemen 1984). Although this definition has undergone several refinements (see Friedman and Miles 2006), the basic idea persists. Alkhafaji (1989) developed the concept of dynamic stakeholders, arguing that the mix of stakeholders may change over time; nevertheless, there are some basic stakeholders like customers, employees, suppliers, communities, governmental bodies, political trade associations and trade unions.

For Freeman (1984; 2010), there are three level of analysis that must be consistent if the stakeholder concept is to make a difference in the way organizations are managed: the rational, the process and the transaction levels. At the rational level, an understanding of who are the stakeholders and the nature of their stake is necessary (Elias and Cavana, 2000). This does require an extensive research to understand the nature and the source of the interest of stakeholders. Freeman (1984) employed a generic stakeholder map for a starting point, but it is also possible to prepare stakeholder map based around a strategic issue. At the process level, it is necessary to understand how the organization implicitly or explicitly manages its relationships with its stakeholders, and whether this fits with the rational stakeholder map as well as the expectation of stakeholder (Freeman 1984; Deverka et al., 2012). Finally, the transaction level seeks to understand the set of transactions and negotiations between organization and stakeholders to determine whether these negotiations fit with the stakeholder map and the organizational processes (Elias and Cavana 2000; Carroll and Buchholtz 2012). Successful transactions with stakeholders are built on understanding the legitimacy of the stakeholder and having processes to routinely surface their concerns.

In relation to the current study, stakeholder theory as a firm-level intervention instrument may be relevant based on layers of complex interactions that usually conspire to provide the context of firm and resources. However, whilst stakeholder theory has enhanced management studies on sustainability and organizational practices, it has also attracted considerable criticisms (Nankervis et al., 2005; Weiss, 2004; Mansell 2013). Most importantly, a big limitation is the absence of time scales for managing stakeholder expectations as well as optimal decision making for simultaneously satisfying competing stakeholder interests, where they have similar power and interest on or within the corporation. In practice, organizations often end up serving the material interest of powerful groups in communities as copious examples from the developing world bears out. Additionally, stakeholder-mapping inaccuracies may often reflect and result in counter-productive outcomes for organizations and these further limits the unilateral application of stakeholder theory to drive sustainability strategies by management.

Corporate Social Responsibility (CSR)

At its core, CSR perspectives integrate the concept of responsibilities as well as discretion into a form of self-regulatory mechanism whereby businesses observe ethical standards as well as norms. Matten and Moon (2008) argues that CSR should reflect social imperatives and consequences of business success, articulating responsibility practices and policies as preferred by the corporation. This pro-organization focus highlights potential weaknesses of some CSR interpretations, which unlike stakeholder theories, fails to consistently integrate the perception or advice of specific groups (McWilliams and Seigel, 2000).

Authors like Garriga and Mele (2004) had classified CSR theories into four categories: instrumental, ethical, integrative and political, albeit with latent classifications. According to them, the instrumental theorists follow the traditional philosophy of organizations as an instrument of wealth creation and no more, the ethical theorists are at the other extreme with normative stakeholder principles, universal rights empowerment and sustainable development

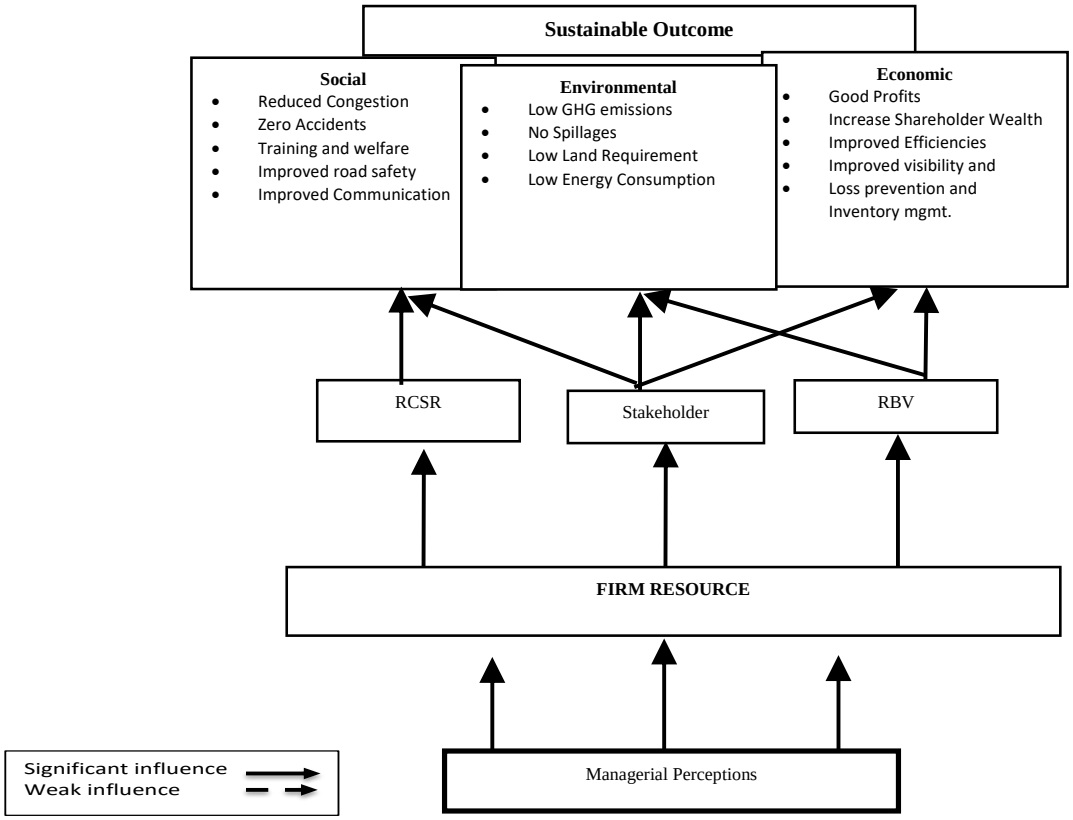
at the core of their constructs. The political and integrative theorists are compromises that fall between the extremes, acknowledging social responsibilities that confer management with social power (political theories). They also acknowledge the requirement of organizations to respond to social issues within their environment; integrative theories on corporate social performance (Carroll, 1979), public responsibility and stakeholder management (Emshoff and Freeman, 1984). Seechi (2007) condenses this framework into a more contemporary framework with three categories; the utilitarian, managerial and relational.

The utilitarian theorists re-echo the instrumental classification, emphasizing the role of organizations as an economic tool with no explicit social responsibility besides those that are functional or cost imposing on organizations (Coase, 1988; Friedman, 1970). The managerial theorists represent the compromise school where although avoiding the extremes of Friedman's postulation, they justify organizational philanthropy only if they will yield some economic benefit, tangible or intangible (Drucker, 1973). Effectively, this set of integrators began to drive studies around competitive advantage as a basis for CSR practices and this perhaps may be credited with the biggest acceptance of CSR theories within strategic management research at the time (Vogel, 2006). Finally, the relational school of thought conceptualizes CSR as emanating from the 'citizenship' construct with implicative benefits and responsibilities. It ties the corporations to the social contract theory where the operative cost-benefit scenario applies to the relationships with taxation being just one of many costs to organizations (Seechi, 2007; Woods and Logsdon, 2002).

The relational (RCSR) theory is adopted in this study as it offers the greatest departure from the traditional competitive theories. Our aim is to reflect and integrate reasonable differences in order to update management knowledge for sustainability strategies. According to Habisch et al., (2005), the discussion about CSR is very heterogeneous because stakeholders (consumers for example) have different conceptions of what makes a firm socially responsible: environmental standards, providing social amenities etc. Likewise, the approaches are also context-specific: corporate philanthropy, integrating social movement (like fair trade) etc. In this regard, CSR theories have been used for studying responsibility of organizations to specific societies (Carroll 1989; McGuire et al., 1998; Burke and Logsdon 1996; Ite 2004; Orlitzky et al 2003; Matten and Moon, 2008).

As previously highlighted, our conceptualization is that organizations seek a balance between social, environmental and economic viability in their quest to be sustainable (Palsson and Kovacs, 2014). This creates complexity challenges for management in decisions on sustainability and the extent of their commitment. These complexities also have implications for theory modeling to support our understanding of managerial decision-making processes when it comes to sustainable practices (Figure 1).

Figure 1. Conceptual Framework – Integrating Theories



To integrate these theories, we examined the literature to identify some key indicators across the triple bottom line categories; social, economic and environmental factors within the transport and logistics sector. The literature was then used to inform hypothetical links between different theories and some of the factors identified. For example, profits, efficiencies and energy consumption links had been identified by previous studies (Palsson and Kovacs; 2014). In some instances, there were no existing studies that had empirically tested some indicators or offered theoretical insight and we therefore apportioned indicators based on heuristic hypothesis of the indicator as relates to the constructs of the theory. For instance, although non-organizational training and welfare (Figure 1) had not been investigated with respect to theory, we examined this as a function of corporate social responsibility and thus established links. At this conceptual level, our goal was to provide links and there was no empirical evidence to support the strength of the connections between different theory nodes and the sustainability categories.

By combining these three leading theories into a single framework, it is perhaps plausible to get a better picture of managerial decision frameworks that can support theory evaluation across different contexts. For example, although convenient for exploring sustainability, RCSR does not directly integrate perceptions of selected individuals representing specific groups but assumes responsibility on the basis of known duty (McWilliams 2000). Branco and Rodrigues (2007) describe the stakeholder perspective of CSR as the set of views of corporate duty held by all groups with a relationship to the firm. Both theories are not adequate for explaining 'social performance' as a factor for sustainable competitive advantage, and thus they are complemented by the competitive focus of RBV (RBV alone fails to consider factors surrounding resources). Societal wellbeing in this sense is crucial for sustainable or long-term competitive

advantage of firm given the reliance of resources on surrounding factors. Integrating these three theories into a framework can allow for the positioning of different factors and a broader theory scope for understanding management decisions regarding sustainability practices to achieve economic efficiency, positive social impact and promote environmental preservation in their practices.

METHODOLOGY

To test our decision model, we identified high impact developing and developed country (Nigeria, Sweden) sectors and adopted a multiple case study strategy to collect data using purpose and snowballing techniques to capture industry polar types (Voss et al., 2002; Yin, 2003; Eisenhardt and Graebner, 2007; Jugdev and LaFramboise, 2010). This supported our emergent studies and promoted theoretical appropriation by capturing the heterogeneous perspectives within the industry.

In the first instance, we identified Nigeria as an emerging country with significant freight transport operations albeit understudied. A few publications highlighting high reoccurrence of freight and logistics incidents with high human costs (fatalities) made the environment interesting. One of the research team members had access to several multinational operators in the sector and this further informed our decision to include Nigeria as one of our comparative environments for the study. In contrast, Sweden boasts some of the safest and leading sustainability initiatives in the area of freight transport. Previous collaboration with the City of Stockholm council offered knowledge of sustainable practices within the country. To aid validity, the research protocol had been developed and pilot tested with a selection of industry and academic respondents. The proposed work was also presented at one European conference with feedback helping to inform the final research protocol.

Following the identification of potential organizations and the validation of the research protocol (Yin, 2009), 37 semi-structured interviews and observations were conducted with management level executives in 18 organizations. We conducted the first phase of interviews in Nigeria in 2015 and the second phase of the study in Sweden in 2017. The sample consisted of middle and top management executives in the logistics and transport sectors (6 multinational organizations, 2 public institutions, six medium and 4 small organizations). Additional data collections have been scheduled for the mid and last quarter of 2018, with another 10 organizations identified for inclusion in our study. We hope to attain data saturation at the conclusion of the fourth phase of data collection.

In addition to the interviews, we employed in-situ observations and extensive documentary review to achieve data triangulation. By comparing different data streams, we improved the validity and reliability of our current findings.

Data analysis involved the use of the protocol supporting the development of coding frame to support analysis. Coding was implemented in three stages to extract, structure data and generate themes. In the first level, narratives from transcripts were extracted using NVivo11. Using the query function, implemented text querying and cluster analysis but checking the 1000 and 100 most frequent words from the data, and used the cluster function to map connections between words. Once the 1st 89 nodes or most reoccurring words with meaningful connection to other parts of the data were identified, we then supported the process with further content analysis and nodal grouping of the data. This led to a reduction to 26 nodes following second level structuring to group data using word-tree functions that highlighted patterns, relationships and usage contexts for the first set of nodes. 3 researchers independently developed codes from the 26 codes and agreed on defining scope for the themes. This led to an aggregation and resulted in 5 thematic nodes that represented the sustainability commitment rationales from the

data. The use of Nvivo11 and subsequent independent evaluation by different researchers improved the reliability of the data analysis process.
Finally, the emergent themes were compared with existing theory constructs, evaluating for similarities and differences with reference to the conceptual framework presented. The discussion below summarizes our findings on themes that inform the commitment decisions of management within the firms surveyed.

RESULTS AND DISCUSSION

As previously stated, we identified five main themes on sustainability commitment from the data; *competitiveness, palliation, innovation, security and duty*.

a) Competiveness: emphasized management willingness to pursue sustainability as means to competitive profiting. In this regard, economic consideration was regarded as primary drivers for practices. For example, 5 executives in Nigeria and Sweden were of the opinion that "sustainability offered the opportunity for gaining a high market share". This thinking was tied to compliance and communication of green practices in order to influence consumer perceptions and win market orders. Contrastingly, we found that multinational executives in Nigeria were more likely to emphasize this competitiveness theme compared to their counterparts in Sweden. The converse was true for small and medium enterprises in Sweden, who emphasized competitiveness compared to their Nigerian counterparts. There have been suggestions that business culture may influence 'reported' sustainability commitment in different climes (Guardian, 2016), however, this does not address the absence of uniformity on competitiveness amongst similar category of organizations in different climes. It is probable that many big organizations in different contexts face different competitive pressures and are more likely to focus meeting those challenges that in turn reflect the nature of the sustainability engagement or commitment.
b) Palliation: relates to practices that mitigate the impact of firm practices on society. We identified three strands to this: proactive, reactive and responsive.
   In terms of proactivity, we found that some organizations had robust evaluation frameworks that guided their activities, actively promoting practices that helped to reduce any impact of their operations on their immediate community. For example, one of the organizations in Sweden had a robust 15-year planning framework that not only accounted for their operations impact but actively incorporated the impact of other members of their supply chain into their accounting system. This led to practices like setting up a consolidation center to manage the flow of goods into residential areas, investment in low emission and low noise trucks as well as multimodal access to the consolidation center. This had no competitive connotations and was done because the management of the firm believed that it was the right thing to do.
   In Nigeria, our findings were more related to reactive and responsive measures. Perhaps the history of socio-environmental disputes affected the practices by organizations in this regard. Responsiveness relates to ready commitment to address impact concerns as they arise, whilst reactive practices were those that followed through after some disputes. For example, we found that some community concerns were only addressed after series of disputes between the organizations and the community concerned. In some cases, monies were paid out to community personnel, in other cases there were infrastructural investments to support compensation. Interestingly, we found little evidence to suggest that organizations in Nigeria desisted from specific practices simply because of the impact.
c) Innovation: closely linked to competitiveness, innovation offered organizations the opportunity to distinguish themselves. Not every firm linked competitive practices with

innovation and we considered this worthy as a stand-alone them. Typical examples from the data stem from the use of unconventional equipment to support reliability, e.g. use of mobile phones by small organizations in Nigeria to improve traceability of client deliveries, thereby reducing incidents of theft product diversion. In Sweden, organizations were actively involved in collaborative relationships that engineered innovative distribution practices like the combination of an urban consolidation center for both distribution and retrieval of raw materials. What was perhaps most intriguing being that the partnership involved a real estate firm, a major logistics firm and a waste management firm. This was an unusual partnership for logistics solutions, but it was effective and provided value to all concerned.

d) Security: encompassed the guarantee of continuity both in terms of safety but also access to resource. This was mostly an issue that arose from the Nigerian context. One executive reiterated:

"*We offer solutions and structure our processes in a way that it creates a sustainable business environment and also we function in a way that it wouldn't impact so much on our business network and the environment. Also, sustainability incorporates quality, security, safety and all that. Therefore, being able to carry out activities in a way that you can continue doing them without affecting the business*" – Managing Director H.

Consultative meetings and concessions, investment in infrastructure, location decisions and price decisions were some examples of security themed practices related to sustainability. Duty: perhaps philanthropic, these were practices that were at the initiative of the firm, without any measurable link to improving competitiveness but borne out of a sense of duty. The sense of duty developed from social contract perceptions between firm and communities (Anderson and Paine, 1975; Seechi, 2007). We have also distinguished this from the palliative category because we found no evidence that these practices were linked to specific mitigation of practice of the firm. For example, some organizations offered employments to persons from certain areas out of a sense of duty as opposed to addressing a negative outcome of their operations whilst others provide donations to orphanages and invest in other community-based projects. As one executive alludes;

''*I will say we practice good business and also help our neighbors and local communities when possible. Some of the people employed here today are from the community and the business donates to good educational causes from time to time*" – Manager W1"

Whilst we have used differing lexes to classify our themes, the terminologies do not necessarily represent new ideas about sustainability rather their importance is attached to evidence of incremental difference from the extant literature in the application by organizations within different contexts. For example, although the literature has examined sustainability and competitiveness (Palsson and Kovacs, 2014), sustainability and size (Gallo and Christensen, 2011), the relationship between sustainability, competitiveness and size is yet to be discussed. Our findings already suggest that contextual factors may have intervening effects on this presumed relationship with useful knowledge implications for management. In linking theory, we explored the range of themes and matched them to each of the discussed theories; RBV, RSCR and Stakeholder (Table 1).

Table 1-Thematic and Theory Matrix

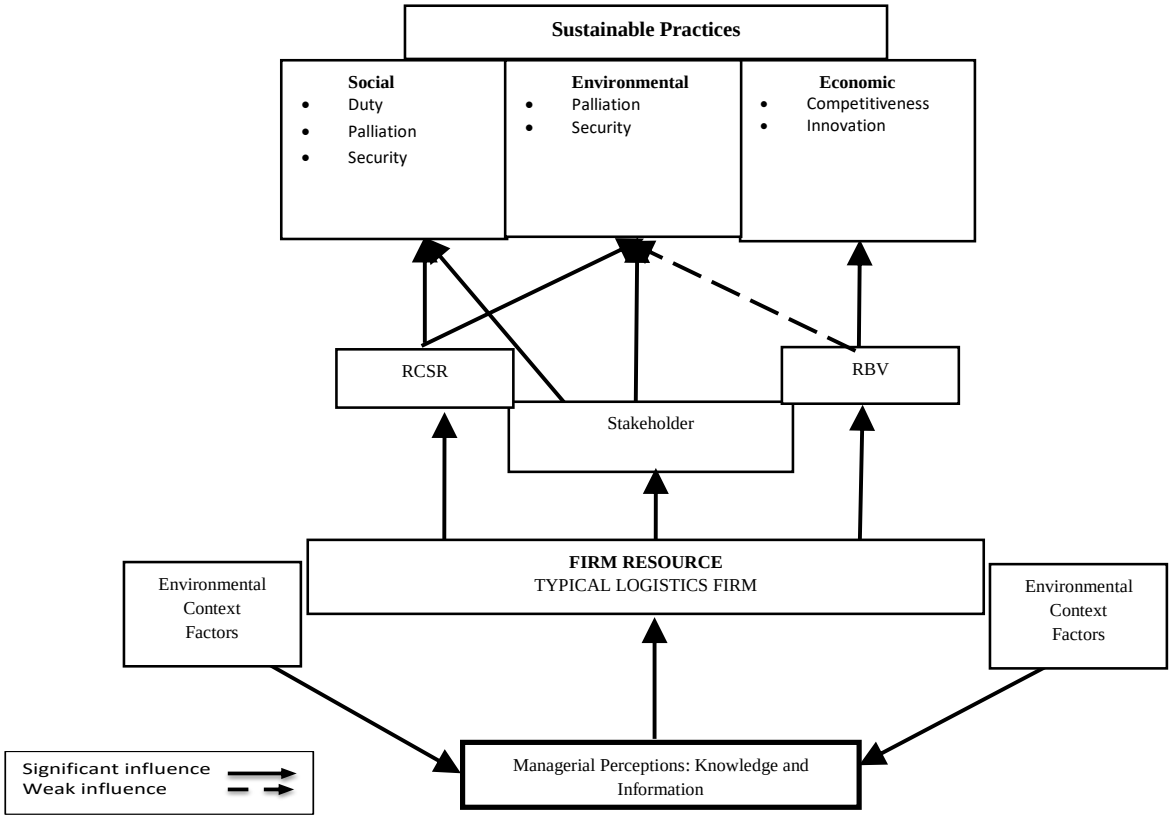
Theme / Theory	Competitiveness	Palliation	Duty	Security	Innovation
RBV	✔			✔	✔
Stakeholder	✔	✔		✔	✔
RCSR		✔	✔		

RBV proponents conceptualize the firm as a bundle of heterogeneous resources that are coordinated towards sustainable competitive advantage (Penrose, 1959; Barney, 1991; Hoskisson et al., 1999). Firm resources assume both tangible and intangible characteristics with emphasis on the ability of the firm to routinely coordinate these resources as a basis for competitive advantage (Grant, 1991). Sustainable practices are largely intangible and there are clear links between sustainability and competitive advantage through profits, operations efficiencies and cost leadership (Hall, 1993; Christmann, 2000; Barney 2001). However, we find no evidence to support RBV links with duty, security or palliation. As a largely introspective theory, RBV focuses on internal processes to support firm performance and we consider it an advanced threshold theory beyond normative thresholds (Grant, 1991; Palsson and Kovacs, 2014).

With regards to RCSR, the greater evidence points to its relevance to duty, palliation and security themes. In Sweden where the market context is considered more mature, it was surprising to note that only one of the organizations surveyed reported competitiveness through sustainable practices. We observed that despite claims to sustainability, logistics organizations surveyed largely pursued traditional practices if the option was permissible. Some executives spoke of sunk investments that were bespoken to their operations and the difficulties in measuring data returns from sustainable practices. Duty, palliative and security practice rationales focused on social contract performance as opposed to competitiveness for most firm. We observed differences in the practices across these contexts and even within local regions, affirming claims that contexts give rise to RCSR legitimacy and attendant practices by organizations (Seechi, 2007). Since these practices were outside the remit of competitive and regulatory requirements for these organizations, we linked their implementation to RCSR constructs of duty and legitimacy, stemming from recognized need to act as opposed to acting for competiveness or to comply with regulatory requirements (Marrewijk, 2003; Seechi, 2007). In terms of Stakeholder theory and the data, we observe the most pervasive relevance. With key constructs centered rational, process and transactional stakeholder strategies, we link some low-level competitiveness, security and palliation to stakeholder theory. For example, our findings on palliation and security where organizations actively establish rational relationships between them and certain groups as a basis for actions, is supportive of Freeman's (2010) rational and transactional perspective. In this case, these organizations establish that their activities impact on stakeholders like young persons, real estate holders etc., and undertake corresponding practices that help to mitigate the negative impact of their activities on these groups. However, we found no rational links with duty-based practices. For example, donations to orphanages and hospitals who had no direct relationship or impact from the activities of these companies have no logical links with the concerned organizations whether in terms of transactions, operations process or activity impact (Figure 2).

In revisiting our conceptual framework, the current findings support the value of theory integration in order to better capture sustainability commitment decision influences. We note that the stakeholder theory provides the greatest scope for evaluating sustainable practices and commitment by organizations although its limitations (mapping) can be addressed by the strengths of RCSR and RBV theories. The concluding parts of this investigation will explore the interdependencies of these theories in the conceptualizing sustainability commitment and practices of organizations building on the findings from this preliminary but promising initial result (Figure 2).

Figure 2. Conceptual Framework – Revised integration



CONTRIBUTION AND FUTURE RESEARCH

In this paper, we reflect on the summative findings of our inquiry into the rationales for sustainability commitment by management in transport and logistics organizations. Building on the literature's position regarding the role of information and knowledge on management strategies, we sought to examine theory appropriation for sustainable practices by organizations. We identified three theories; the resource-based view, relational corporate social relationship and stakeholder theories, as having scope for explaining sustainability practices by organizations. We offer a conceptual model to support our thinking, reflecting assumptions on theory scope.

Fundamentally, our findings highlight that the integration of different theories could offer more interpretative scope for understanding management decisions regarding sustainable practices. Similarly, our findings highlight probable impacts of contextual, size and competitive factors on

the sustainable practices of organizations. As a study in progress we cannot offer conclusive arguments in this regard, however, it offers scope for further investigation in the discourse on firm sustainability. The challenges and scope for sustainability remains complex and limit the efficacy of single theory inquiries. Theory integration can support more effective results that can be used to adequately influence management decisions in practice, leading to more rewarding outcomes. The tri-combination of theory constructs can be further refined into useful assessment tools for management application as knowledge bases for sustainability practices.

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DECISION SCIENCES INSTITUTE
Sustainable Operations Dynamics: Model and Analysis

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ABSTRACT

This paper studies sustainable operations dynamics and control with the focus on sustainable continuous process. We develop a dynamic system that describes interactions between different products and operations processes and optimal control model to identify the optimal operations strategies. Also, a bio-based operations system is provided to verify the proposed models. Performance analyses find that the quantities of initial inputs and raw materials flowing into operations systems affect the dynamics of sustainable operations. By controlling initial inputs and the flow rate at materials, we evaluate the impacts of sustainable operations dynamics on the overall operations performance and identify operations strategies.

KEYWORDS: Sustainable production dynamics, continuous process, optimal control, case study, and simulation analysis.

INTRODUCTION

Sustainable operations have received growing attention of policy makers, industrial companies, and researchers in recent years, with the emphasis on economic, social and environmental impacts of firms' operations. According to Lowell Center for Sustainable Production (2016), sustainable operations refers to" the creation of goods and services using processes and systems that are: a) Nonpolluting; b) Conserving of energy and natural resources; c) Economically viable; d) Safe and healthful for workers, communities, and consumers; and e) Socially and creatively rewarding for all working people." However, sustainable operations face new challenges because of dropping demand, fluctuating gas prices, and increasing environmental concerns (Burk, 2010). Therefore, the objective of this paper is to explore the behavior of sustainable operations process, thus effectively controlling negative environ- mental and social impacts and achieving the maximum economic benefits.

Preferably, we focus on the continuous process for sustainable operations such as producing biological products (Eisentraut, 2010), chemicals (Xiao, 2016) and pharmaceutical products (Braal, 2009; Benyahia et al., 2012), since it is more sustainable than batch process (e.g., low raw material use and wastes, and high-energy efficiency) and superior in high productivity and constant product quality. Sustainable continuous operations is a dynamic process because of interrelationship among distinct processes and interactions between products during operations. For instance, in the sustainable operations of industrial chemicals, when substrate flows into the reactors, all substances including raw materials and products affect one another. More- over, as the concentrations of products increase, they inhibit actual output rate and chemical reaction. In particular, toxic by-products reduce the out- put of desired products, pollute the environment, and cause workers' health and safety issues. Therefore, it is necessary to thoroughly look into the dynamic behavior of sustainable operations, explicitly

identify interrelationship and interactions among all entities in the operations systems, and thus de- sign operations controllers that receive feedback from output to optimize sustainable operations performance.

While much research has recognized the growing importance of sustain- able operations, little research in the literature focuses on the dynamics and operations control of sustainable continuous operations be- cause of its operations complexities. For instance, during sustainable continuous operations of bio-based products, the concentration of substrate has the adverse impact on the desired products as it increases to a certain level, while the toxic by-products inhibit microbial growth and the output of de- sired products, and adversely impact the environment and workers' health and safety. Hence, managing the flow rate of substrate and its concentration effectively can reduce the impact of substrate and by-products on desired products, the environment, and workers to improve the output of desired products and sustainability performance. We employ nonlinear dynamics models to formulate the dynamic, sustainable operations process. Dynamic models have widely applied in process system engineering for decades, since they can predict the transient response, and, therefore, can be used to de- scribe process dynamics behavior during operations. For example, dynamic models play a crucial role in the pharmaceutical industry to reduce costs, lower environmental impacts, and improve the quality of the pharmaceutical products, by implementing advanced model-based control. Moreover, we utilize multiple objective optimization techniques to develop an operations control model that can find trade-offs among economic, environmental and social impacts.

This study contributes to the following: a) a unified framework of modeling the dynamics and operations control of sustainable operations that can derive optimal operations strategies for reducing environmental, social impacts, and improving operations efficiency; b) a case study on the sustainable continuous operations of a bio-based product to simulate the proposed dynamics and control models, and to identify optimal operations strategies; and c) insights obtained by comparing empirical results with data collected from the real continuous operations process of the bio-based product. Empirical results on practical case reveal the proposed framework is well suited with sustainable operations in practice, and that effective control on the flow rate of raw materials and the by-products can maximize the output of desired products, while minimizing the negative impact on workers and the environment.

The remainder of the paper is organized as follows. Section 2 reviews the extant literature regarding operations dynamics. Section 3 concerns the unified framework of sustainable operations dynamics and its operations control systems. Section 4 provides case study on sustainable operations of a bio-based product to verify the framework proposed in Section 3. Section 5 reports the empirical studies of the operations dynamics and the operations control tactics of the bio-based product under various operations strategies. Finally, Section 6 concludes the study and discusses future extensions.

LITERATURE REVIEW

Research on operations economics can be classified into two categories in the literature: one with system dynamics based operations modeling and simulation, and the other regarding the development of dynamical system based on nonlinear differential equations.

System dynamics has extensively applied to sustainable operations in the literature. Bockermann et al. (2005) developed two models based on system systems and economics to evaluate different sustainability strategies and concluded that it needs to make every effort on economic, environmental, social and labor policies to achieve sustainable manufacturing. Stave (2010) used participatory system dynamics modeling as a decision support tool for sustainable environmental management, which captures dynamic connections between social and

ecological systems, integrates stakeholder deliberation with scientific analysis, incorporates diverse stakeholder knowledge, and fosters relationships among stakeholders that can accommodate changing in- formation and changing social and environmental conditions. Zhang et al. (2013) presented a conceptual model that utilizes systems dynamics for sustainable manufacturing assessment to interpret the complex interplaying factors at the operational and enterprise levels. Feng and Fan (2014) developed simulation model based on system dynamics simulating the policy of cross- training and considered the effect of worker learning and forgetting and the heterogeneity within worker pool. Their experiments identified the best way that optimized operations line under different cross-training tactics, worker management policies and worker team structures. By system dynamics and case study methods, Shamsuddoha (2015) studied sustainable manufacturing in the poultry livestock sector to solve existing problems to gain economic, social and environmental benefits. They found that integration of the supply chain was able to bring economic, social and environmental sustainability along with a structured operations process.

A significant amount of research has studied the applications of nonlinear dynamics theory to operations dynamics in the literature. Prior research can be found in Radons et al. (2004). Marca et al. (2010) studied continuum models of operations systems and their prototypical control problems driven by hyperbolic partial differential equation, which was used as a constraint of a nonlinear optimization problem. They showed numerical results on optimal start rate for both constant and varying demand and discussed the influence of the nonlinearity of the cycle time on the limits of the reactivity of the operations system. Armbruster and Uzsoy (2012) considered continuous- time operations system and discussed several implementation schemes from discrete-event simulation. In addition, they examined two alternative approaches: discrete-time linear programming modeling based on nonlinear clearing functions, and systems of coupled partial differential equations re- lying on transport phenomena. Yang et al. (2013) proposed a data-driven continuous fluid flow approach for modeling aggregated assembly line dynamics in terms of the principles of nonlinear dynamics theory. They solved this model using real-world data by Matlab and found that this model is of potential use and can provide deeper insights into the dynamics of complex manufacturing systems. Wang and Gunasekaran (2015) developed a mathematical model based on nonlinear dynamic system to describe the dynamics of the impact of supply chains on environment while achieving sustainable supply chains. They proved the existence and uniqueness of its solutions, analyzed its equilibrium and stability, and conducted performance and sensitivity analysis. Tan (2015) considered continuous material flow operations systems and optimal operations flow control problems with unreliable station and deterministic demand. He developed a mixed-integer linear programming formulation for performance evaluation and optimization and showed its validity for continuous material operations systems.

In general, current literature lacks research on a unified framework for sustainable operations dynamics, particularly for operations dynamics of sustainable continuous process. Hence this paper will serve this purpose and, most importantly, explore dynamic behavior of sustainable continuous process and optimal operations strategies to achieve operations sustainability.

SUSTAINABLE PRODUCTION DYNAMICS AND CONTROL

This section presents a comprehensive framework for modeling the sustainable operations dynamics and its optimal operations control systems that seek to maximize the output of desired products and/or economic returns at the least environmental and social impacts.

Dynamics model

Operations dynamics is governed by complex, inherent interdependence of inputs and outputs and various interacting operations processes.

Sustainable repetitive manufacturing systems associated with assembly lines are often modeled in an aggregate fashion. However, modern manufacturing system is a huge network consisting of many operations and storage facilities. Raw materials, parts, or subassemblies flow into operations systems and produce finished products through a sequence of operations in different facilities. Such manufacturing systems manifest nonlinear dynamics and the internal flows are explicitly formulated as continuous-flow operations, in terms of nonlinear dynamics theory as studied by (Sharifnia, 1994), Scholz- Reiter et al. (2002) and Radons et al. (2004). This is because continuous-flow models are simple and computationally advantageous in a decentralized fashion (Sharifnia, 1994). On the other hand, continuous process plays a vital role in sustainable operations such as in bio-based operations and in pharmaceutical industry. The continuous process in sustainable operations consists of water tanks and pipes as well as product and by-product flows, where entities including materials, desired products, and by-products flow through a system of tanks connected by pipes. Valves controls the flow rates of entities, and the time spent in each tank is dependent on the rates of influx and outflow. The quantities of inputs and products in each tank change continuously over time. Figure 1 illustrates the continuous process of sustainable operations below.
Throughout the entire transformation, however, various processes as well as different inputs and outputs interact dynamically, which shows nonlinear correlation.

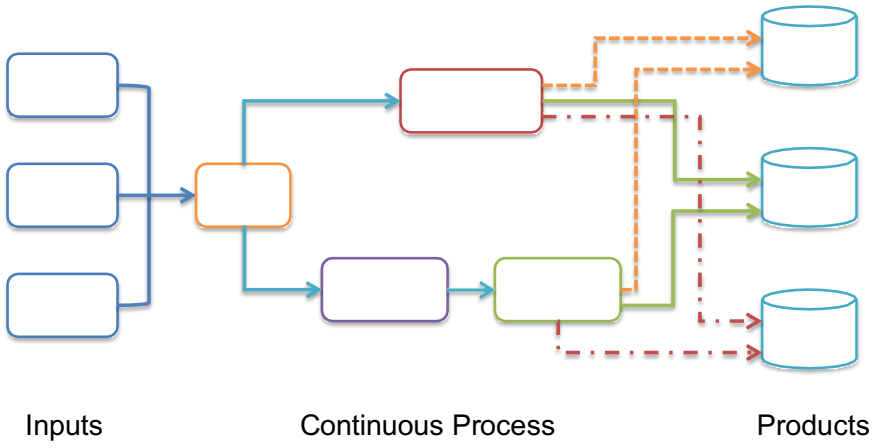

Figure 1: Continuous process in sustainable operations

To develop efficient and effective operations strategies, we present an integral framework of dynamic model of sustainable operations in the following.

$$\dot{\boldsymbol{x}}(\boldsymbol{t}) = \boldsymbol{f}\big(\boldsymbol{x}(\boldsymbol{t}), \boldsymbol{u}(\boldsymbol{t})\big), \forall\, \boldsymbol{t} \in (\boldsymbol{0}, \boldsymbol{T}), \boldsymbol{x}(\boldsymbol{0}) = \boldsymbol{x_0} \quad (1)$$

where $\boldsymbol{x}(\boldsymbol{t})$ denotes the quantities and/or concentrations of all inputs and/or products at time *t*, called system state. $\boldsymbol{x_0}$ refers to the initial inputs of sustainable operations process, including required raw materials, parts, or sub-assemblies for sustainable operations. We can partially achieve effective control on sustainable operations by adjusting $\boldsymbol{x_0}$. $\dot{\boldsymbol{x}}(\boldsymbol{t})$ is the operations rate or the change of quantities of inputs and/or products, which is concurrently affected by the

quantities and/or concentrations of all entities being produced and/or being consumed in the operations systems, as well as the quantities and/or concentrations of raw materials, parts or components entering operations systems. $\boldsymbol{f(x)}$ is a nonlinear vector field and describes dynamic correlations between different inputs and products. $\boldsymbol{u(t)}$denotes time-varying operations control strategies, measures and gives feedback on sustainable operations performance in real time, thus fulfilling optimal performance management. In the case of industrial chemicals operations, effectively controlling substrate concentration can shorten reaction time, increase the output of desired products, and mitigate the impacts of by-products. $\boldsymbol{T} \in (\boldsymbol{0}, \infty)$ denotes the time at which dynamic systems reach steady state. Furthermore, we introduce notations to facilitate our analysis and simulation as follows. Let $\boldsymbol{U_{ad}}$ be the set of admission operations control strategies and then it follows that $\boldsymbol{u(t)} \in \boldsymbol{U_{ad}}, \forall\, \boldsymbol{t} \in [\boldsymbol{0}, \boldsymbol{T}]$. Given any $\boldsymbol{u(t)}$, let $\boldsymbol{W}$ denote the state space of studied dynamic systems, i.e., $\boldsymbol{W} = \{\boldsymbol{x(t)} \in \boldsymbol{R^n} | \dot{\boldsymbol{x}}(\boldsymbol{t}) = \boldsymbol{f}\big(\boldsymbol{x(t)}, \boldsymbol{u(t)}\big), \forall \boldsymbol{t} \in [\boldsymbol{0}, \boldsymbol{T}]\}$.

Operations control

This subsection presents a framework of operations control on sustainable operations systems that attempts to seek compromise between economic benefits, and social and environmental concerns.

Sustainable operations process not only produces desired products, but also generates toxic by-products. Desired products bring in revenues to organizations, while by-products are harmful to workers and the environment. Sustainable operations place a strong emphasis on economic, social and environmental aspects, so it is essential to achieve effective operations control on sustainable operations. Hence, we develop a multiple objective optimal operation control model to find the best operations strategies with the objectives of maximizing the output of desired products and, at the same time, minimizing the social and environmental impacts of by-products.

Let $\boldsymbol{G_n}$ denote Hessian matrix, $\boldsymbol{n} = \boldsymbol{1, 2, \cdots, N}$, and $\boldsymbol{x(T, u)}$ be the quantities and/or concentrations of final products in operations systems at time $\boldsymbol{T}$, i.e., the final products' quantities and/or concentrations when dynamic systems reach steady states. Using multiple objective optimization techniques, the sustainable operations control systems (P) can be formulated in the following.

$$\textbf{max} \quad \boldsymbol{J_1(u) = x(T,u)^T G_1 x(T,u)/T^2} \tag{2}$$

$$\textbf{max} \quad \boldsymbol{J_n(u) = x(T,u)^T G_n x(T,u)\ /T^2, n = 1, 2, \cdots, N} \tag{3}$$

$$\textit{s.t.}\ \boldsymbol{x} \in \boldsymbol{W}, \tag{4}$$

$$\boldsymbol{u} \in \boldsymbol{U_{ad}}, \tag{5}$$

$$\boldsymbol{x(0) = x_0}. \tag{6}$$

The first objective (2) is to maximize the amount of desired product, while the second (3) is to minimize the use of resources and the output of by-products as toxic by-products have harmful impacts on workers and the environment. Constraint (4) ensures that sustainable operations process satisfies the dynamics characteristics described by dynamic systems (1). Constraint (5) states that control variables $\boldsymbol{u(t)}$ vary in the admission operations control set, $\boldsymbol{U_{ad}}$. Constraint (6) implies the inputs of resources for sustainable operations processes. Throughout the remaining parts, we shall denote the operations control problem as (*P*).

To solve (*P*), we introduce a weighing factor *λ* indicating operations managers' preference, thus converting (*P*) into a single objective problem. Let $\boldsymbol{\lambda_n} \geq \boldsymbol{0}$ denote weights satisfying $\sum_{\boldsymbol{n=1}}^{\boldsymbol{N}} \boldsymbol{\lambda_n} = \boldsymbol{1}, \boldsymbol{n} = \boldsymbol{1, 2, \ldots, N}$, and, by weighing (2) and (3), (*P*) can be written below.

(*SP*) $\max\ J(u) = \lambda_1 J_1(u) - \sum_{n=1}^{N} \lambda_n J_n(u)$ (7)
s.t. (4), (5), and (6). (8)

(SP) attempts to find a comprise among economic, environmental, and social concerns and allows for the importance of different impacts that operations managers perceive. For instance, when three entities are involved in the operations, suppose that λ_1 takes the value of greater than $\frac{1}{3}$, which means that operations managers see economic benefits as more important than environmental and social impacts. Hence, these operations control models offer operations managers a decision-making tool to evaluate different scenarios (e.g., government regulations, corporate policies, operations strategies) and their impacts on overall operations performance.

CASE STUDY: CONTINUOUS PROCESS OF 1,3-PD SUSTAINABLE OPERATIONS

This section introduces a case study on the sustainable operations of 1,3-propanediol(1,3-PD) and presents its operations dynamics and optimal operations control models. The bio-based 1,3-PD is a high-performance, sustainable building block material and replaces petroleum-derived materials. 1,3-PD has been adopted by leading manufacturers in a variety of consumer and industrial markets, since it not only provides unique performance advantages, but can also reduce environmental footprint and harms to workers' health and safety (Molel et al., 2015).

1,3-PD operations dynamics

The sustainable continuous process of 1,3-PD starts with the flow of substrate (e.g., glycerol) into the reactor at a certain rate, and, over a period of time, some products (e.g., 1,3-PD, acid, and ethanol) flow out of the reactor at the same rate, while keeping the entire volume of reactor constant (Wang et al., 2007). For the purpose of modeling 1,3-PD operations dynamics, we assume that substrate perfectly intermixes and inputs and outputs are uniformly distributed in the reactor. Furthermore, during the reaction process, substrate flowing into the reactor only includes glycerol and products flow out at the dilution rate *D* (Wang et al., 2008).

Let $\boldsymbol{f(x)} = (\boldsymbol{f_1(x), f_2(x), f_3(x), f_4(x), f_5(x)})$, $\boldsymbol{x_1(t), x_2(t), x_3(t), x_4(t), x_5(t)}$, be biomass, glycerol, 1,3-PD, acetate and ethanol concentrations at time *t* in reactor, respectively, *D* be the dilution rate, and C_0 denote the feeding glycerol concentration. Hence, continuous process dynamics for producing 1,3-PD can be formulated in the following.

$$\boldsymbol{f_1(x) = (\mu(x) - D)x_1}, \quad (9)$$
$$\boldsymbol{f_2(x) = D(C_0 - x_2) - q_2(x)x_1}, \quad (10)$$
$$\boldsymbol{f_3(x) = q_3(x)x_1 - Dx_3}, \quad (11)$$
$$\boldsymbol{f_4(x) = q_4(x)x_1 - Dx_4}, \quad (12)$$
$$\boldsymbol{f_5(x) = q_5(x)x_1 - Dx_5}, \quad (13)$$

where $\boldsymbol{\mu}$ denotes the specific growth rate of cells, $\boldsymbol{q_2}$ refers to specific consumption rate of substrate, and $\boldsymbol{q_i, i = 3,4,5}$, represent specific formation rate of 1,3-PD, acid, and ethanol, respectively, which are expressed by the following equations on the basis of previous work (Wang et al., 2009).

$$\boldsymbol{\mu = \mu_m \frac{x_2(t)}{x_2(t)+k_s} \prod_{i=2}^{5} (1 - \frac{x_i(t)}{x_i^*})} \quad (14)$$

$$\boldsymbol{q_2 = m_2 + \frac{\mu}{Y_2} + \triangle_2 \frac{x_2(t)}{x_2(t)+k_2}} \quad (15)$$

$$q_i = m_i + \mu Y_i + \Delta_i \frac{x_2(t)}{x_2(t)+k_i}, i = 3,4 \quad (16)$$

$$q_5 = q_2\left(\frac{b_1}{Dx_2(t)+c_1} + \frac{b_2}{Dx_2(t)+c_2}\right) \quad (17)$$

In Equation (14), $\mu_m = 0.67g/h$ denotes the maximum specific growth rate of cells under anaerobic conditions when temperature is 37°C and $pH = 7.0$; $k_s = 0.28$ is Monod saturation constant; and $x_1^* = 10g/L, x_2^* = 2039mmol/L, x_3^* = 939.5mmol/L,\ x_4^* = 1026mmol/L$ and $x_5^* = 360.9mmol/L$ represent the critical concentrations of biomass, glycerol, 1,3-PD, acetate and ethanol. In Equations (15) - (17), $m_i, Y_i, \Delta_i, k_i, i = 2,3,4$, and $b_1 = 0.025,\ b_2 = 0.06,\ c_1 = 5.18, b_2 = 50.45$ are model parameters, whose values are identified through experiments and listed in Table 1 from the previous work (Wang et al., 2007).

Table 1: The values of the parameters in Equations (15) and (16)

Parameters	m_2	m_3	m_4	Y_2	Y_3	Y_4	Δ_2	Δ_3	Δ_4	k_2	k_3
Values	2.20	-2.69	-0.97	0.0082	67.69	33.07	28.58	26.59	5.74	11.43	15.50

Control problem

1, 3-PD is the desired product, while acid and ethanol are both by- products that are hazardous to the environment and workers and also inhibit the output of 1,3-PD. To improve the output of 1,3-PD and reduce the impact of harmful by-products, we present an operations control model for sustainable operations of 1,3-PD. Specifically, the operations control model uses the productivity of 1,3-PD as cost functional, and utilizes the output concentrations of acetate and ethanol as the objectives for social and environmental concerns, based on 1,3-PD's continuous operations dynamics (9)- (13). Let $W = \{x \in R^5 \mid x\ satisfies\ (9), (10), (11), (12), and\ (13)\}$ and $U_{ad} = \{u \in R \mid u(t) \in [0.01, 0.3],\ \forall t \in [0, T]\}$. Then operations control model for 1,3-PD's sustainable operations is formulated below.

(P_1) $\quad \max \quad J_1(u) = x_3(T,u),$
$\min \quad J_2(u) = x_4(T,u),$
$\min \quad J_3(u) = x_5(T,u),$

$s.t \quad x \in W, u \in U_{ad}.$

where the first objective J_1 attempts to maximize the output of 1,3-PD, and the second and the third are to minimize the output of by-products, acid and ethanol. By introducing the management's preference, $\lambda_n, n = 1,2,3$, the corresponding weighted sum problem can be written as follows.

(P_2) $\quad max\ J(u) = \lambda_1/J_1(u) - \lambda_2 J_2(u) - \lambda_3 J_3(u)$
$s.t \quad x \in W, u \in U_{ad}.$

Where $\sum_{n=1}^{3} \lambda_n = 1$.

EMPIRICAL STUDY

This section continues with the above-mentioned case study with the focus on evaluating the performance of the proposed operations dynamic model and identifying the optimal operations control strategies for 1,3-PD sustainable operations.

Performance analysis

We shall validate the proposed dynamic model of 1,3-PD in comparison with experimental data, and analyze the impacts of dilute rate and the concentrations of biomass and substrate on operations dynamics.

Validation of dynamics model

Given experimental data, the dynamic model (9) - (13) is validated through solving the system of differential equations with $x_{01} = 0.115g$, $x_{02} = 495mmol/L$, $D = 0.1L/h$, and $T = 100$ hours as shown in Figure 2. The blue solid lines denote simulated results based on dynamics model, while green dots represent experimental data.

Figure 2 compares the concentration variations of biomass, substrate, 1,3-PD, acetate, and ethanol between simulated results and experimental data over a period of 100 hours in the reactor. The first thing to note is that simulated results on the concentrations of substrate and 1,3-PD fit better with experimental data than those with biomass, acetate, and ethanol throughout the whole time frame. To begin with, concentration variations of biomass, 1,3-PD, acetate, and ethanol follow a fairly similar pattern over the period. The general trend is that their concentrations grow rapidly in the initial stage of reaction, reach a peak, and then decline to constant, which implies that dynamics system reaches steady states. In contrast, substrate's concentration experiences a downward trend, starting at 495*mmol/L*, drop- ping to approximately 50*mmol/L*, and then rising to steady states around 90*mmol/L*. It can be seen that this dynamic model is well established as simulated results show such much similar trend as experimental data do in terms of concentration variations of biomass, substrate, 1,3-PD, acetate, and ethanol.

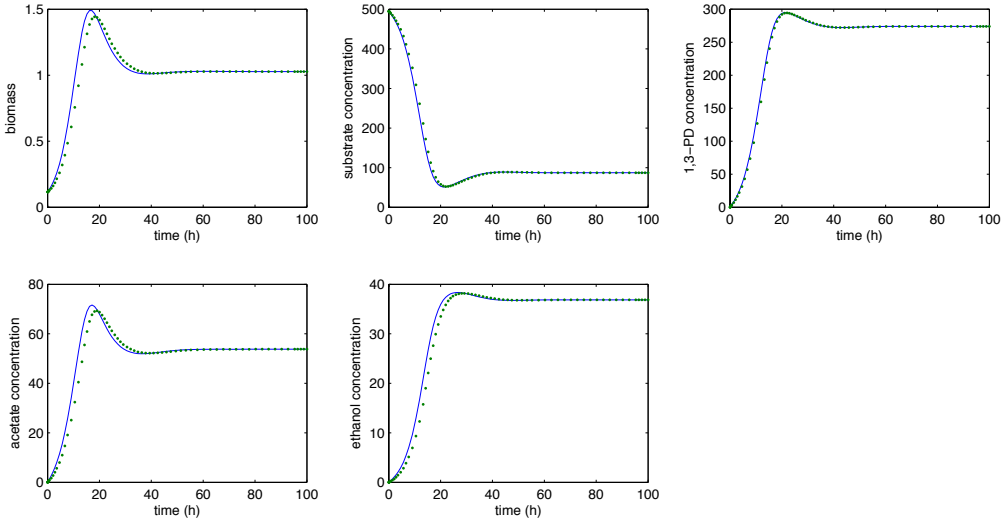

Figure 2: Comparison between simulated results and experimental data over the period of 100 hours

Impact of initial biomass on dynamics

To evaluate the impact of initial biomass on operations dynamics, we set x_{02} = 495*mmol/L*, D = 0.1*l/h*, and T = 100 and solve the dynamic model (9) - (13) when x_1 = 0.115*g,* 0.3*g,* 0.5*g,* 0.7*g*, respectively. The simulated results are shown in Figure 3, where blue solid lines, green dots, red cross, and light blue dash lines denote concentration variations of biomass, substrate, 1,3-PD, acetate, and ethanol, respectively, corresponding to different initial biomass concentrations. Specifically, Figure 3 illustrates the concentration variations of biomass, substrate, 1,3-PD, acetate, and ethanol over the period of 100 hours when initial biomass concentration increases from 0.115 to 0.7. Overall, with different initial biomass concentrations, the concentrations of biomass, 1,3-PD, acetate, and ethanol rise more sharply, while substrate's concentration declines more steeply over the period. Furthermore, the growth in initial biomass concentration also results in the increase in the highest concentrations of biomass, 1,3-PD, acetate, and ethanol. For example, the concentrations of biomass, 1,3-PD, acetate, and ethanol reach peak at approximately 1.45*g*, 295*mmol/L*, 70*mmol/L*, 48*mmol/L*, respectively, with x_{01} = 0.115*g*; they peak at around 1.85*g*, 300*mmol/L*, 73*mmol/L*, 40*mmol/L*, with x_1 = 0.7*g*. Hence it can be seen that initial biomass concentration has a huge impact on biomass concentration over the period. It is apparent that excess biomass needs to consume more substrate to meet its growth needs, which explains the reason why substrate concentration drops steeply when initial biomass concentration varies. Although the concentrations of 1,3-PD, acetate, and ethanol follow very similar patterns, increasing initial biomass concentration has a slight impact on the highest concentrations of 1,3-PD, acetate, and ethanol over the period. Similarly, the increase in initial biomass concentration has a small impact on the lowest concentration of substrate, starting at nearly 50*mmol/L* when x_{01} = 0.115*g* and ending at almost 40*mmol/L* when x_1 = 0.7*g*. In conclusion, the increase in initial biomass concentration has slight impact on the highest concentrations of 1,3-PD, acetate, and ethanol, and the lowest concentration of substrate, while it significantly affects the rate of change of biomass, substrate, 1,3-PD, acetate, and ethanol over the period in the reactor.

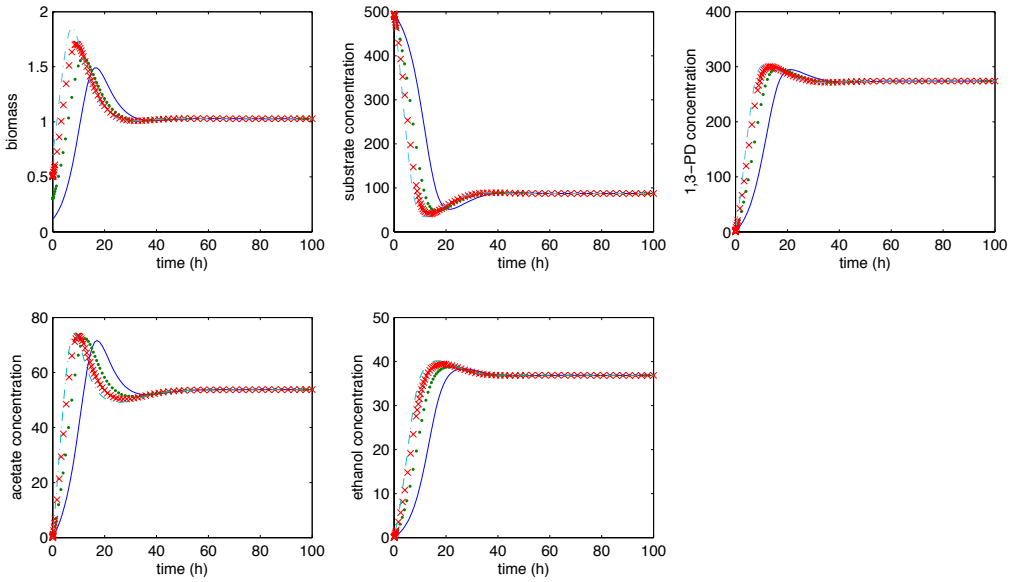

Figure 3: Concentration variations of biomass, substrate, and 1,3-PD over the period of 100 hours with x_1 = 0.115, 0.3, 0.5, 0.7

Impact of initial substrate concentration on dynamics

Since substrate serves as the basis of biomass growth, the impact of initial substrate concentration on operations dynamics is analyzed, when it takes the value of 495*mmol/L,* 600*mmol/L,* 800*mmol/L,* 1000*mmol/L*, respectively. Here, the respective initial biomass concentration and dilute rate are set to x_{01} = 0.115*g* and D = 0.1*L/h*. Figure 4 shows the changes on the concentrations of biomass, substrate, 1,3-PD, acetate, and ethanol when initial substrate concentration rises. Blue solid lines, green stars, red cross, and light blue dashed lines denote the impacts of initial substrate concentration, x_{02} = 495*mmol/L,* 600*mmol/L,* 800*mmol/L,* 1000*mmol/L*.

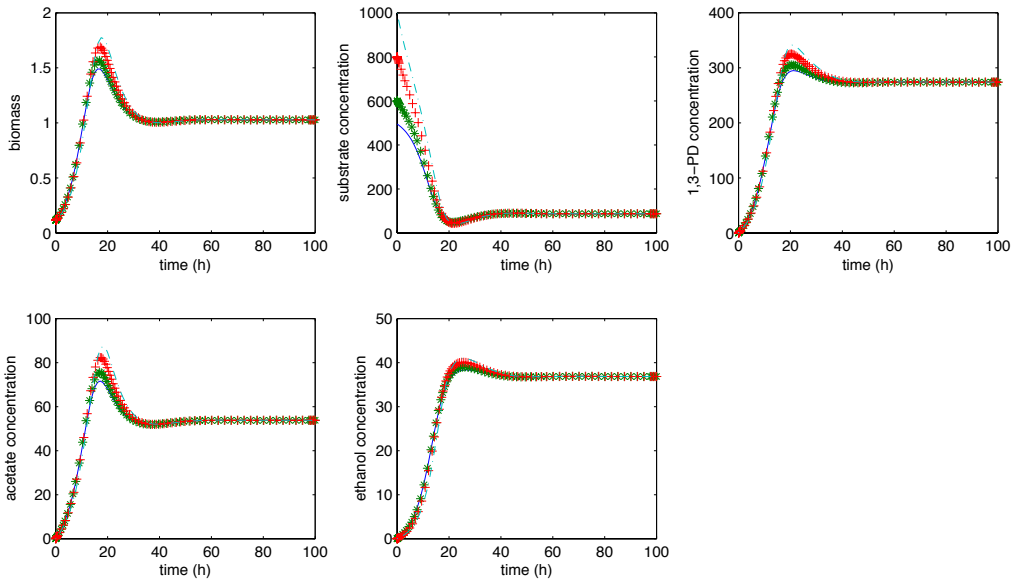

Figure 4: Concentration variations of biomass, substrate, and 1,3-PD over the period of 100 hours with x_2 = 495, 600, 800, 1000

Overall, increasing initial substrate concentration has the significant impact on the maximum concentrations of biomass, 1,3-PD, and acetate, while it has the small impact on the lowest concentration of substrate and the highest concentration of ethanol. The increase in substrate's concentration in the reactor provides more substances for biomass to grow, so the highest biomass con- centration reaches up to 1.8*g* when x_{02} = 1000*mmol/L*, compared to under 1.5*g* when x_{02} = 495*mmol/L*. Accordingly, 1,3-PD concentration increases from 300*mmol/L* to roughly 340*mmol/L*. Furthermore, it is observed that the increase in the initial substrate concentration does not impact the rate of concentration changes throughout the period. Hence we can conclude that initial substrate concentration has little impact on the concentrations of biomass, 1,3-PD, acetate, and ethanol during the period in the reactor.

Impact of dilute rate on dynamics

We consider the following initial concentrations for biomass and substrate, $x_{01} = 0.115g$ and $x_{02} = 495mmol/L$ and aim to examine the impact of dilute rate on operations dynamics. Figure 6 demonstrates such impacts of dilute rate, D, specifically, on the concentrations of biomass, substrate, 1,3-PD, acetate, and ethanol over the period of 100 hours. Blue solid lines, green stars, red crosses, and light blue dashed lines represent the impact of different di- lute rates, where $D = 0.1L/h$, $015L/h$, $0.2L/h$, $0.25L/h$, $0.3L/h$. In general, dilute rates have huge impacts on the rate of concentration changes, maximum concentrations of biomass, 1,3-PD. acetate, and ethanol, as well as the lowest substrate concentration. When dilute rate starts with $D = 0.1L/h$, the concentrations of biomass, 1,3-PD, acetate, and ethanol grow dramatically up to the maximum, whereas substrate concentration drops rapidly to the minimum. As dilute rate moves up towards $0.3mmol/L$, the maximum concentrations of biomass, 1,3-PD, acetate and ethanol fall substantially and the growing rate of their concentrations also deceases. In the mean- while, substrate concentration drops very slowly and reaches steady state at around $300mmol/L$ when $D = 0.3L/h$, compared to steady-state concentration of $50mmol/L$ when $D = 0.1L/h$. In addition, it is important to note that dilute rate has considerable impact on the time when dynamic system reaches steady state. The system reaches steady state at approximately $20h$ when $D = 0.1L/h$, while it starts to enter steady state at around $40h$ *given* $D = 0.3L/h$. It follows that dilute rates have huge impact on the dynamics of 1,3-PD's sustainable operations, so it is necessary to control dilute rate in order to achieve the tradeoff between social, environmental concerns, and economic benefits.

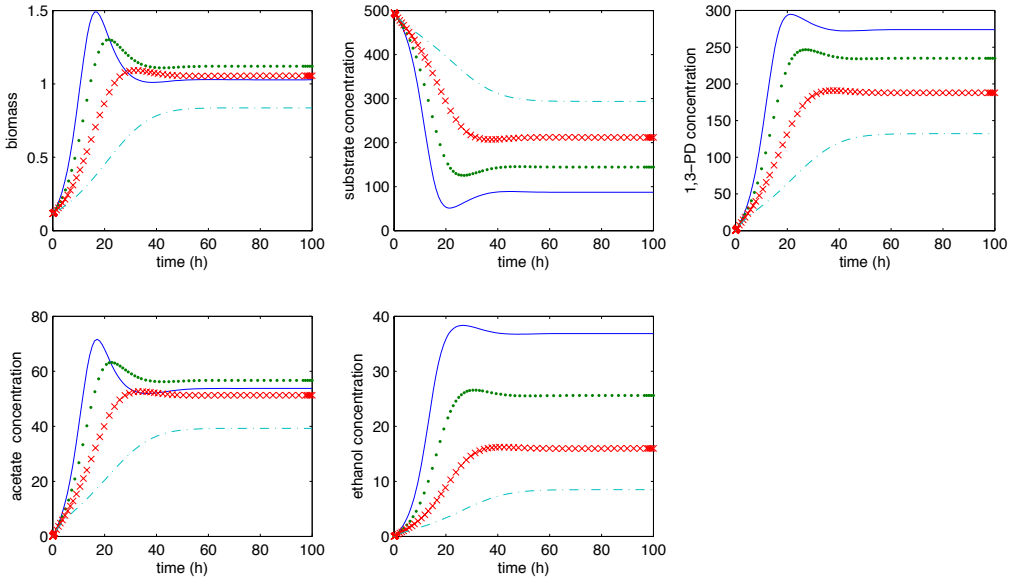

Figure 5: Concentration variations of biomass, substrate, and 1,3-PD over the period of 100 hours with $D = 0.1L/h$, $0.15L/h$, $0.2L/h$, $0.25L/h$, $0.3L/h$

Optimal operations control strategies

From the above analysis on Figure 6, it can be seen that substrate's dilute rate has the significant impact on the concentrations of biomass, substrate, 1,3-PD's, and by-products. This subsection concerns controlling the flow rate of substrate into reactor so optimally as to find a tradeoff between maximizing the output of 1,3-PD and minimizing adverse impact of acetate

and ethanol on workers and the environment. In this case study, we choose x_0 = (0.115*g/L,* 495*mmol/L,* 0*,* 0*,* 0)^T as the initial concentrations for biomass and substrate, respectively. Using hybrid particle swarm optimization algorithm presented by Wang et al. (2009), we obtain an optimal operations control policy for (P_1), D^* = 0.06*L/h*. Figure 1 gives steady-state concentrations of 1,3-PD, acetate, and ethanol as dilute rate, *D*, varies from 0.01*L/h* to 0.3*L/h*, where blue dot sign denotes the variation on steady-state concentration of 1,3-PD over *D*, red cross sign represents the change on steady-state concentration of acetate over *D*, and pink plus sign shows the trend of steady-state concentration of ethanol over *D*. The maximum of 1,3-PD obtained by (P_2) is 293.99*mmol/L*, while the minimums of acetate and ethanol are 41.93*mmol/L* and 47.35*mmol/L*, respectively.

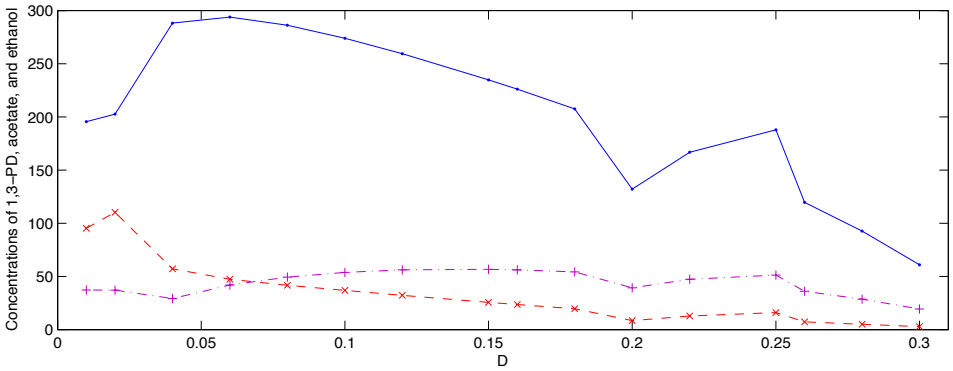

Figure 6: Steady-state concentrations of 1,3-PD, acetate, and ethanol as *D* varies between 0.01*L/h* and 0.3*L/h*

CONCLUSION AND FUTURE EXTENSIONS

Although sustainable operations have received growing interest in industries and academia, research in the literature has not fully investigated the dynamics and operations control of its continuous process. Since inputs, desired products, and by-products interact in operations process, sustain- able continuous operations presents dynamics characteristics. This study aims to achieve efficient and effective operations management on sustainable operations by studying its dynamics and operations control. This paper presented a comprehensive framework for operations dynamics of sustainable continuous process, based on nonlinear dynamical systems. Also, we offer an operations control model, taking into account economic, environmental, and social impacts. To solve this control model, we developed a compromising model by introducing weighing factors to different impacts. It attempted to find trade-offs that can minimize environmental and social impacts while maximizing economic benefits. Then a real case confirmed the proposed dynamics and control models and tested the impacts of inputs on operations dynamics. Simulated results showed the appropriateness and robustness of the proposed dynamics and operations control systems. Our research on real case found that initial inputs and materials flowing into operations systems significantly affect the dynamics of sustainable operations. Hence, control- ling initial inputs and the flow rate of materials in operations process enables us to optimize sustainable operations performance.

There are three major extensions for this research. One is on the design of effective algorithms for solving operation control problems. A good algorithm can help operations controllers to quickly find the best operations strategies in response to unexpected changes that occur in operations process. The other is to extend the results developed in this paper to design

robust, adaptive sustainable operations systems in the big data context. Operations controllers adjust the flow rate of materials by analyzing real-time data from sensors, thereby directing dynamics systems towards optimal sustainable operations. Also another possible extension is to develop a probability model that captures random behavior and nonlinear dynamics for both repetitive and continuous processes. Moreover, developing stochastic operations control models manages dynamic, stochastic operations processes, thus optimizing sustainability performance.

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DECISION SCIENCES INSTITUTE
Teaching case: Forecasting and production planning using Decision Science

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ABSTRACT

Supply chain management is essential to company success and customer satisfaction. In this case study, we use the historical data to forecast the demand for each client and develop an optimisation model to plan for the production such that total cost which includes shipping cost, holding cost and production cost will be minimised. Developing a spreadsheet model here helps the company to determine the best production plan to meet the demand subjected to operational constraints.

KEYWORDS: Keywords: forecasting, inventory management, shipping cost, production planning, spreadsheet modelling, optimization.

1 INTRODUCTION

Advance Cable Manufacturing Sdn. Bhd. is a privately held, employee stock ownership company with a rich history dating back to 1904. The company started off as a steel foundry in the earlier part of century producing cast iron and other metal products. As the economy modernises, the company diversifies its product base to include different types of metal related products such as wires. The wire products became a profitable line and soon displaces other products which are manufactured in more cost-efficient locations.

2 BACKGROUND

Cable manufacturers in Southeast Asia have recently faced stiff competition from goods produced in China and Germany. Even with the various transportation cost and tariffs, China-produced cables are much cheaper than their Southeast Asian counterparts because of inexpensive labour and factory operation. Germany dominates the high-end cable manufacturing market with competitive pricing due to the EU free trade zones or speciality cables. As Advance Cable Manufacturing Sdn. Bhd. produces both cheaper and more specialised wires, it comes under stiff competition from both global players regarding quality and cost.

Advance Cable Manufacturing Sdn. Bhd. has been able to maintain its market presence in the face of low cost and speciality foreign competition primarily because of its reputation in the cable market. Be it working with customer supplied specification or catering to a unique requirement, Advance Cable Manufacturing Sdn. Bhd. design teams develop innovative, one-of-a-kind wire and cable solutions to solve its client business problems. On-site manufacturing processes include wire drawing, plating, braiding, cabling and extrusion services. And, since all the proprietary equipment and tooling is designed and built in-house, the company has complete control while also offering flexibility when needed. Through vertical integration of manufacturing processes, the customers' design-to-market curve is the shortest in the industry.

3 BUSINESS SETUP

Advance Cable Manufacturing Sdn. Bhd. serves 8 major clients (clients 1, 2, 3, 4, 5, 7, 8, and 9) and each customer has its distribution network in different countries. The clients are consumer electronics and industrial goods manufacturers. In each country, the sales volume comprises of sales in different products lines such as Goods, Appliances and Industry, Desktop, Lamp and Smartphone. Below is the detailed sales volume composition which is broken down into constituent products for each customer in each country.

Clients		**Products**				
	Country	**Goods**	**Appliances and Industry**	**Desktop**	**Lamp**	**Smartphone**
1	Greater China	1%	36%	20%	31%	13%
2	Greater China	11%	11%	20%	26%	32%
	India	15%	24%	26%	28%	6%
	Japan	25%	28%	37%	7%	3%
	Korea	22%	30%	18%	0%	29%
	SEA	3%	27%	28%	12%	30%
3	Greater China	14%	18%	19%	32%	18%
	Japan	15%	24%	27%	22%	11%
	SEA	16%	14%	13%	39%	19%
4	Greater China	30%	30%	14%	23%	3%
	India	47%	18%	24%	10%	1%
	Japan	31%	7%	34%	7%	21%
	Korea	6%	20%	23%	24%	27%
5	Japan	9%	15%	29%	31%	16%
7	Greater China	27%	4%	27%	17%	25%
	India	28%	21%	5%	34%	12%

8	Greater China	29%	18%	14%	33%	6%
	India	37%	21%	15%	13%	14%
	Korea	44%	6%	5%	12%	33%
	SEA	27%	13%	2%	29%	29%
9	Greater China	12%	19%	33%	21%	15%
	India	12%	38%	27%	12%	11%
	Japan	1%	16%	35%	29%	19%

Table 1: Sales Volume Composition by Products for Each Customer in Each Country

To simplify the process of manufacturing, storage and shipping, Advance Cable Manufacturing Sdn. Bhd. produces the components for each particular product line which then gets assembled at the destination by the customers according to their design specifications. This specific process reduces the cost of manufacturing while extending the product flexibility for customers.

Table 2 below shows the breakdown of the components required for different products, also known as the bill of materials (BOM). From Table 2, we can see that for each unit of Desktop, you will need 3 of component 1, 1 component 5 and 2 component 6. Each unit of Smartphone will require 1 unit of component 1 and 2 unit of component 2. The same logic applies to the other products.

	Components			
Products	**1**	**2**	**5**	**6**
Goods	1	2	1	0
Appliances and Industry	0	2	1	1
Desktop	3	0	1	2
Lamp	1	4	0	2
Smartphone	1	2	0	0

Table 2: Bill of Materials for Each Product

Advance Cable Manufacturing Sdn. Bhd. has 4 core production facilities (**P1, P4, P5 and P7**) in different parts of Malaysia whose sole focus is manufacturing and quality testing. Production plant **P1** is located in Alor Seta, **P4** is located in Miri, **P5** is located in Kuala Terengganu and **P7** is located in Kota Kinabalu. As an ISO9001:2008 certified company, the company has more than 600 employees operating three shifts, five days a week.

The production plants operate state-of-the-art machines which produce the wire components efficiently. Due to some production limits, it is not uncommon for the production plants to transship the components among themselves to meet customer's demand. The company has a strict policy where only the same component that is produced by two plants can be

transshipped. This is due to storage facilities required to ensure the quality of the components is maintained as inventory. The transhipment between any 2 plants will take around 1 month. Production of the components also takes 1 month. The various production plants have different production volume limits and unit production costs as well. Table 3 and 4 below are the detailed breakdowns of the production volume limit and cost of production.

Plant	P1		P4	P5		P7
Components	5	6	2	5	6	1
201201	12348441	12691851	25040292	55469840	59291481	40670920
201202	12348441	12691851	12520146	55469840	59291481	40670920
201203	13801624	12224245	26025869	52378450	57722070	11640533
201204	13801624	12224245	12520146	52378450	57722070	11640533
201205	12500859	13596740	26097599	53320712	50135596	16736375
201206	12500859	13596740	12520146	53320712	50135596	16736375
201207	0	0	26025869	56137849	58423970	74945609
201208	12500859	13596740	12520146	56137849	58423970	74945609
201209	0	0	26025869	60139296	53345707	47188773
201210	12500859	13596740	12520146	60139296	53345707	47188773
201211	0	0	26025869	54389995	61297377	29435217
201212	12500859	13596740	12520146	54389995	61297377	29435217

Table 3: Production Volume Limits (Per Unit of Item) for 2012 at Different Plants

Plant Location	P1	P4	P5	P7
201201	$2.98	$4.99	$2.33	$2.87
201202	$1.05	$4.25	$1.79	$4.37
201203	$3.37	$4.18	$3.17	$4.87
201204	$1.91	$4.02	$4.40	$2.87
201205	$3.85	$1.98	$3.76	$1.02
201206	$4.26	$2.11	$4.08	$2.78
201207	$3.70	$2.72	$1.41	$2.83
201208	$4.70	$2.70	$1.40	$2.52
201209	$3.93	$4.72	$2.13	$4.72
201210	$1.33	$3.04	$1.85	$4.36
201211	$2.16	$4.93	$2.62	$2.04
201212	$3.58	$1.56	$2.85	$4.25

Table 4: Unit Production Costs for 2012 at Different Plants

The production plants P1 and P5 produce the same components, and as a result, should there be any shortfall, the components can be transshipped between the plants before getting shipped to the countries that they each serve. Below is the breakdown of the transhipment volume limits and unit costs of transhipment between the 2 plants.

Production Plant Transshipment	P1		P5	
Component Supplies	**5**	**6**	**5**	**6**
201201	$3.51	$1.85	$1.31	$1.74
201202	$3.44	$4.23	$4.77	$2.01
201203	$4.86	$1.36	$1.64	$2.25
201204	$3.33	$4.12	$4.41	$4.49
201205	$4.41	$3.89	$4.91	$2.00
201206	$3.31	$4.46	$3.13	$2.68
201207	$3.42	$1.90	$3.16	$1.81
201208	$1.92	$1.17	$1.07	$2.86
201209	$2.07	$1.21	$4.92	$3.00
201210	$2.7	$3.13	$1.07	$3.24
201211	$4.98	$4.42	$1.68	$4.54
201212	$3.38	$3.85	$1.29	$2.08

Table 5: Unit Transshipment Costs for Each Component for 2012 out from Each Plant

Production Plant Transshipment	P1		P5	
Component Supplies	**5**	**6**	**5**	**6**
201201	2100000	1300000	2500000	4500000
201202	0	1100000	2500000	1100000
201203	0	0	2500000	1100000
201204	0	0	2500000	1100000
201205	0	0	3500000	1100000
201206	0	0	3500000	4500000
201207	0	0	3500000	4500000
201208	0	0	4500000	4500000
201209	0	0	4500000	4500000
201210	0	0	4500000	4500000
201211	0	0	4500000	4500000
201212	0	0	0	0

Table 6: Transshipment Volume Limits for 2012 out from Each Plant

The various production plants produce various components that can only be shipped to specified countries as a result of shipping route and speed of delivery. The approach is also controlled by the customers who prefer shipping from specific locations as the customers are paying for the shipping cost if they are shipping from those ports. Such arrangements are

primarily due to the shippers available in each area and the ease of passing through the custom. Table 7 below is the breakdown of the distribution. For example, Plant P1 will supply component 5 to Greater China and India, while Plant P5 will supply component 5 to Korea, SEA and Japan.

Production Plant	Component Supplies	Country
P1	5	Greater China
		India
	6	Greater China
		India
		Korea
P4	2	Greater China
		India
		Japan
		Korea
		SEA
P5	5	Korea
		SEA
		Japan
	6	SEA
		Japan
P7	1	Greater China
		India
		Japan
		Korea
		SEA

Table 7: Production Plant, Component Supplies and Country Mapping

Given the need to handle intermittent demands, the various production plants have different inventory storage limits and different cost for storing their inventory. The cost of inventory fluctuates as a result of local electricity and maintenance fees as the components are held in specialised warehouses. The tropical heat and humidity in the region can cause serious damage to the components through mildew and rust. The special facility maintains constant and optimal storage conditions for these components. Table 8 and 9 below showcase the breakdown of the inventory volume limits and unit inventory holding costs for the next 12 months in 2012 at the different production plant.

Plant Location	P1	P4	P5	P7
201201	1421140	4263420	1470016	1541585
201202	1421140	4263420	1470016	1541585
201203	1744869	5234607	1650877	1744492

201204	1744869	5234607	1650877	1744492
201205	1744745	5234235	1624015	1780055
201206	1744745	5234235	1624015	1780055
201207	1791077	5373231	1270015	1664717
201208	1791077	5373231	1270015	1664717
201209	1463540	4390620	1479964	1471949
201210	1463540	4390620	1479964	1471949
201211	1651848	4955544	1557211	1454079
201212	1651848	4955544	1557211	1454079

Table 8: Inventory Volume Limits for 2012 at Different Plants

Plant Location	P1	P4	P5	P7
201201	$0.50	$0.40	$0.30	$0.10
201202	$0.40	$0.10	$0.30	$0.20
201203	$0.50	$0.10	$0.10	$0.20
201204	$0.20	$0.10	$0.30	$0.50
201205	$0.20	$0.40	$0.20	$0.30
201206	$0.10	$0.50	$0.10	$0.10
201207	$0.50	$0.20	$0.50	$0.30
201208	$0.20	$0.50	$0.20	$0.30
201209	$0.30	$0.10	$0.20	$0.20
201210	$0.50	$0.50	$0.50	$0.40
201211	$0.50	$0.10	$0.20	$0.10
201212	$0.20	$0.30	$0.10	$0.20

Table 9: Unit Inventory Holding Costs for 2012 at Different Plants

The supply chain process flow is a complex one. Figure 1 depicts how the different plants produce the components, and each component is used in different products, and the different products are consumed in different countries, which are markets for the different customers.

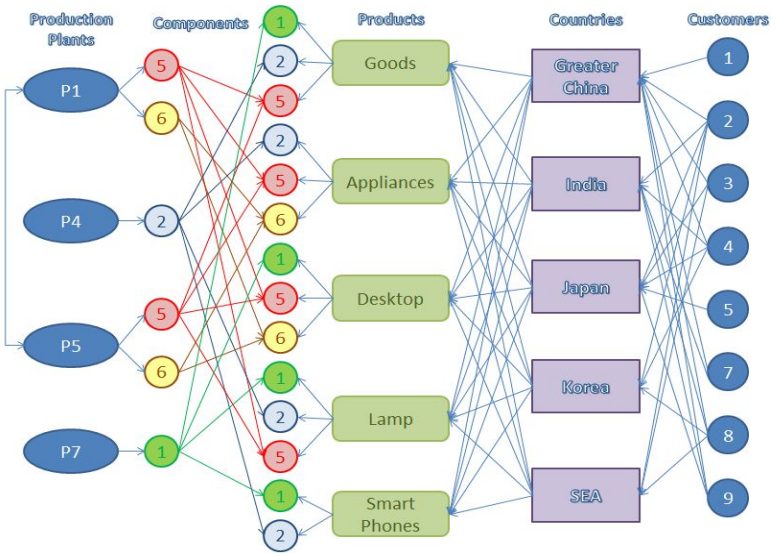

Figure 1 – Supply Chain Network

4 THE BUSINESS PROBLEM

In light of recent competitive developments, the executive management team in Advance Cable Manufacturing Sdn. Bhd. have placed greater emphasis on managing their production planning and inventory performance. The purpose and shift in focus are primarily driven by the need to reduce cost and efficient delivery of goods to market. To achieve the goals, the team would like to begin by producing a comprehensive supply chain plan for the next 12 months based on their demand forecasts, production capacity, shipping capacity and expected costs. The plan is supported by data and decision science models which guides the management's decision-making process.

Advance Cable Manufacturing Sdn. Bhd. invites you, the decision science expert, to assist the executive management team by producing the necessary supply chain plans for the next 12 months based on the past 2 years' monthly sales volume. The plan has to be supported and driven by data. The plan has to be compelling with innovative approaches providing sound projections for 2012. Due to the lack of experience in the area of decision science, the methodology provided requires clear and simple explanations to ensure the management team's understanding. Clear references to other case studies and implementations are encouraged especially when they provide clear benefits for the plan.

As a decision science expert, you are excited about the opportunity was given to solve the real-world business problem. However, you are also sceptical about solving it within the short time frame given as it covers the whole process of forecasting, production planning and inventory controls. You are optimistic that if you can talk to the people on the ground and analyse the data, it shouldn't be any different from other projects that you have undertaken before. With these ideas in mind, you now have the confidence to take up the challenges and the journey has just begun.

DECISION SCIENCES INSTITUTE
Teaching case: Forecasting and production planning using Decision Science

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Teaching Guide

SYNOPSIS OF THE CASE

The case study requires the application of forecasting models, inventory management and assignment approaches to solving the case. Due to the complexities involved, it will be difficult for the undergraduates for any decision science subjects to tackle the problem in a single setting. It is recommended that the instructor using the case study to break the case across multiple lessons and solving a specific aspect of the problem in each class. Graduate students will be well suited to tackle the case due to advanced knowledge and practitioner experience in decision science subjects.

TARGET GROUP

Undergraduate or graduate students pursuing a degree in any decision science subjects. Students must have prior experience with Excel, R or any forecasting software. It is imperative that the students have exposure to forecasting techniques, mixed-integer linear programming or integer programming. Students should have some basic understanding of the manufacturing industry, shipping industry, logistics and lean manufacturing. In the case of undergraduate coursework, we recommend the case study to be used in level 3000 or 4000 modules.

PEDAGOGICAL OBJECTIVES

This case study's main objectives are to help students in the following:

- Understand the management's perspective and the business environment that can affect the approach to solve the problem using decision science.
- Discuss the problem statement and identify relevant inputs and required outputs
- Learn to build models to tackle business problems with minimal prior industry knowledge
- To inculcate an appreciation of forecasting techniques and how the forecasts have an impact on the subsequent business decisions and the knock-on effects on supply chain

planning.
- To appreciate the relationship between production assignment problems, inventory holding issues and delivery logistics problem.
- Develop an appreciation for the complexities of supply chain issues in real life.
- Develop the skills and confidence to apply forecasting and optimisation techniques to solve a business problem
- Analyze and solve real-world business problems using the Excel optimisation tools.

CASE ANALYSIS

The analysis of the problem in this case study starts with an understanding of the problem and making appropriate assumptions. After initial "brainstorming", students should be able to list the key inputs of the models and the necessary outputs at each stage of the plan that acts as the inputs to the next model.

The instructor should begin the case by introducing the following concepts to the students:

- Manufacturing business models
- Difficulties in securing raw material supplies
- Logistics of manufacturing industry
- Managing inventory in manufacturing
- The management of cost in manufacturing

There are 3 main discussion questions.
1. How should we tackle the problem?
2. What are the techniques that we can use to solve the problem?
3. Are there other business considerations?

Specific topics discussion questions.

Forecasting

- What are the popular techniques for forecasting?
- Do you foresee issues with the small amount of data for forecasting?
- Given the need to present the forecasts to senior management who are more comfortable with Excel spreadsheets, do you think using a simpler model that is available in Excel spreadsheet will be more readily accepted?
- Do you think advanced forecasting techniques such as neural network will work well in this case?
- Would Croston's method work as well in this case?
- What are the suitable measures to determine the best forecasting model?

Inventory Management

- How do you relate the inventory holding costs to the concept of lean manufacturing?
- Do you think that holding inventories in cheaper countries will facilitate lean manufacturing?
- What would be the best inventory holding condition and does that affect your shipping and manufacturing model?

Manufacturing Assignment

- Besides Mixed Integer Linear Programming (**MILP**), what other assignment techniques can be applied?

Logistics and Shipping

- If there are intermediate shipping locations which can store the inventories at a very cheap rate, how does that affect the shipping problem?

Main objectives of this case require the students to make bold assumptions, explore uncertainty and model ambiguous and ill-defined business problem. The model can help students to deal with reality and uncertainties of real business and develop the managerial judgment to develop an optimal solution.

DECISION SCIENCES INSTITUTE
Teaching case: Forecasting and production planning using Decision Science

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Forecasting Problem Teaching Guide

Forecasting Model

Before we begin to perform forecasting, the preceding discussion should list all the necessary business constraints and information. The main data that we will be using to build our forecasting model is the sales training data sheet. The data contains the previous order volume from the various customers needed in the specific region. The data contains many zeroes as the order volume from various clients are inconsistent which is a major problem in real-world forecasting situation.

At this point, it may not be clear to students why the zeroes are a major obstacle to forecasting. It is important for the instructor to highlight the excessive zeroes are an indication of a type of phenomenon called **intermittent demand** problem. To tackle these problems, the students will need to learn Croston's method. However, in the interest of time and simplicity, those demand data with excessive zeroes will be forecasted using the mean value of actual demand (non-zero data points). In the case of a client who has not ordered in years, we may assume that there will be no future orders.

We will demonstrate an approach to solve the forecasting problem in R using auto.arima function below. Before the students begin this exercise, they have to make a copy of the file on their own Google drive.

```
#########################################################################
#####Step by step guide to solving the forecasting section of the problem.
#########################################################################
if(!"googlesheets" %in% rownames(installed.packages()) | !"forecast" %in%
rownames(installed.packages())){
  install.packages(c("googlesheets","forecast"))
}
###Loading the necessary library
library(googlesheets)
library(forecast)
#########################################################################
```

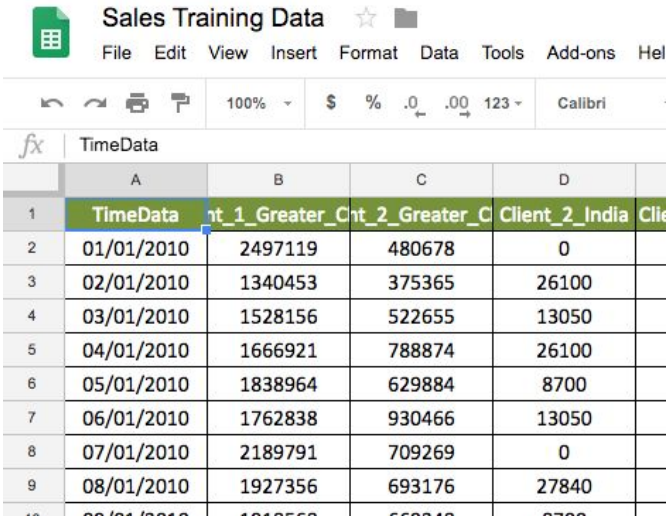
Snippet 1: R packages checking and installation

Before we begin the process of forecasting, we must first install the relevant packages in the R software that will enable us to perform the necessary tasks. To perform automated forecasting, we will need the R package "forecast" which contains the auto.arima function that does automated time series modelling. By using this approach, the instructor can progress faster without having to go through the details of ARIMA forecasting. To enable access to the data that is stored on Google drive, we will be using the "googlesheets" R package to retrieve and return data to Google Sheets.

```
###Importing the data for forecasting
##This function requires you to authenticate with Google Sheets in order
##to list the various sheets available for you to analyse.
gs_ls()
#The data that we will be interested in is the Sales Training data
sales.train.data <- gs_title("Sales Training Data")
#To get the right data, we can use the list worksheets function to review
#the sheets available within each workbook.
gs_ws_ls(sales.train.data)
#There are 2 sheets: "Sales Training Data" and "Test Data"
#The Sales Data is in "Sales Training Data" sheet and we are reading that.
sales.train.data.model <- gs_read(ss=sales.train.data, ws = "Sales Training
Data")
# Converting the data into a proper data.frame
sales.train.data.model <- as.data.frame(sales.train.data.model)
#The test Data is in "Sales Test Data" sheet and we are reading that.
sales.test.data.model <- gs_read(ss=sales.train.data, ws = "Test Data")
#Converting the data into a proper data.frame
sales.test.data.model <- as.data.frame(sales.test.data.model)
#Create the forecast dataset
sales.forecast.data.model<-sales.test.data.model
##############################################################################
```

Snippet 2: Data extraction from Google Sheet

Once the packages are installed, we can then begin the process of extracting the relevant information from the sales data that is stored on Google drive as a Google sheet. Below is a screenshot of the Google sheet containing the sales information.



	A	B	C	D
1	TimeData	nt_1_Greater_C	nt_2_Greater_C	Client_2_India
2	01/01/2010	2497119	480678	0
3	02/01/2010	1340453	375365	26100
4	03/01/2010	1528156	522655	13050
5	04/01/2010	1666921	788874	26100
6	05/01/2010	1838964	629884	8700
7	06/01/2010	1762838	930466	13050
8	07/01/2010	2189791	709269	0
9	08/01/2010	1927356	693176	27840

Figure 2: Sales training data in Google sheet on Google drive

We will first connect to Google drive using the R package and list the files. The file should be named “Sales Training Data”. There are two sheets, the first one is the training data while the second one is the test data (Actual data). After connecting to the sheets, we will convert the information in Google sheet into R data frames which will be used for building forecasting models.

```
#At this point, depending on the approach taken by the instructor, the
#material presented here can vary due to the forecasting approach. In
#this particular case, we will be using auto.arima approach solve the
#problem.

#This step extracts all the clients and regions combination from the data
listofregionsclients<-names(sales.train.data.model)[2:ncol(sales.train.data.mod
el)]

#We will iterate through the regions and use the automated forecasting
#approach to predict the model.
#Depending on the skill levels of the students, you can choose to run
#Seasonal models and non seasonal models too

for (i in 1:length(listofregionsclients)){
  ##Giving you an indication of the process
  print(i)
  ###Preparing the data in the appropriate time series structure
  model.data.train.sample<-ts(sales.train.data.model[listofregionsclients[i]],
  start=c(2010,1),frequency=12)
  ###The ARIMA model is selected with both seasonal differencing and first
  order differencing
  model.Arima <- auto.arima(model.data.train.sample,d=1,D=1)
  ###Forecasting the future
  model.result<-forecast(model.Arima,h=12)
  ###Storing the results
```

```
  sales.forecast.data.model[listofregionsclients[i]]<-as.numeric(model.result$
  mean)
}

###Uploading the data for review
sales.train.data %>% gs_ws_new(ws_title = "forecast results", input =
sales.forecast.data.model,trim = TRUE, verbose = FALSE)
##############################################################################
```

Snippet 3: Data preparation and automated forecasting.

Once the data has been offloaded into R as dataframes, we will then proceed to build the forecasting model. It is important that the instructor explains the choice of approach and model. In this particular case where ARIMA is used, there are two strong reasons to support its adoption.

The first reason is the ease of understanding. It is recognised that there are more powerful models such as neural networks or X-11 are available for use. However, the management team is new to the approach and is unlikely to be quantitatively oriented nor technically skilled to comprehend these models. Through ARIMA models, most of the models can be simplified in autoregression terms or moving average terms. The simplicity will likely to ease the discomfort of the management.

The second issue that will likely to escape the students' thought process is the problem of implementation. Again, the auto.arima function provides a simpler and faster approach to update the forecasting model as compared to other approaches. Re-running more advanced models such as neural network or Deep learning will likely to consume more time and resources. Updating those models will also involve a degree of human interaction which can be avoided in the case of auto.arima.

Once the models have been built and forecasts are generated, we will push the data back into the Google sheet on a new sheet. The Google sheet provides us with the ability to examine the forecasts in greater details. Students are reminded to understand the model assumptions such that a forecast is based on historical trend and not drastically change over time. A good forecasting model is important but we also need to be aware that we could never develop a 100% accurate forecast model.

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Optimisation Problem Teaching Guide

Optimisation Model

Before the instructor proceeds with the optimisation model, it is important to discuss the forecasts and the actual results to understand the gaps. At this point in time, it is good for the instructor to point out that customers can actually return goods due to a lack of demand or as a result of contractual terms. This is reflected by the negative number in the demand table. Due to a large number of constraints present in the optimisation problem, most versions of Excel solvers will not be able to tackle the problem. We recommend the use of LibreOffice solver add-on or the use of Google sheet solvers in the event that the instructor will like the student the problem without exploiting the underlying data structure simplification process. At the later stage of the problem formulation, we will exploit the structure of the problem to render it solvable using Excel Solver.

As we start the optimisation process, it is important for us to identify the various inputs and outputs required by the model. There are several dimensions to this problem. To simplify the process for the students, we will describe the variables in greater details and how they are relevant to the problem.

Unlike most of the formulation where they first start with the inputs or outputs, we will begin with the critical dimensions that form the subscripts of the key variables. It is important to define time. The time period as represented by t in this problem is on a monthly basis and all production or transhipment will take a month to complete. There are four plants around the region and they are represented as p. The components are represented as c. The final goods/materials are represented by m

Variable	**Symbol**
Time	t
Plant	p
Component	c
Materials	m

Geography	g
Client	l
Component-Material Ratio	r

Table 10: Dimension variables and the respective symbols

The output variables will be the demand and cost of production which includes manufacturing cost, storage cost and transhipment cost. The output variables are important as they form the target objective and constraints that have to be achieved. In most optimisation problems, the cost variables will form the objective function.

Input Parameter	**Symbol**
Production Cost	E
Transhipment Cost	F
Inventory Cost	G

Table 11: Output variables and the respective symbols

The input variables for this problem are the amount of component to be produced, the amount of components to hold in order to meet the demand and transhipment among the plants. The decision variables will be the solution to the supply chain problem as they will provide the required solution.

Decision Variable	**Symbol**
Production	A
Inventory	B
Demand	D
Transhipment In	I
Transhipment Out	O

Table 12: Input variables and the respective symbols

The limit parameters are the constraints or limits of reality that has to be achieved.

Input Parameter on Limit	**Symbol**
Production Limit	L

Transhipment Limit	Q
Inventory Limit	W

Table 13: Limit variables and the respective symbols

The first step to solve the problem is to identify the number of components required by the clients in various regions. To compute this, we must first formulate the breakdown of the materials into the components. Mathematically, this can be formulated as the following.

$$D_{c,t,g,l} = \sum_{m} r_{m,c} D_{m,t,g,l} \quad \text{- (1)}$$

Equation 1 represents the breakdown of the demand for goods for a specific client in a geography for a time period into the demand for the component. Once we have the demand for the components, we will need to evaluate the production of components to meet the demand. In this formulation, we have to identify a number of items that will have an impact on the business problem. To meet the demand, it is possible to produce more and then hold on to the excess as inventory that can be used for the next period. When it is not possible to achieve that, the problem can be solved through transhipment of goods from other production facilities. At this point, students should be probed with regards to oversupplies at the plants to meet the future demand, what do we do with the produced goods? Concepts of inventory management, warehouse capacity and holding cost will be discussed. Taking those into consideration, the formulation is as below.

$$A_{c,t,g,p} + B_{c,t-1,g,l} - B_{c,t,g,p} + I_{c,t,g,p} - O_{c,t,g,p} = D_{c,t,g,l} \quad \text{- (2)}$$

Equation 2 represents the production of components to meet of the demand for goods for a specific client in a geography for a time period. Given that we have the production constraints, we now need to set the limits of the constraints.

$$\sum_{c}\sum_{g} A_{c,t,g,p} \le L_{t,p} \quad \text{- (3)}$$

$$\sum_{c}\sum_{g} \left(B_{c,t,g,p} - B_{c,t-1,g,p} \right) \le W_{t,p} \quad \text{- (4)}$$

$$\sum_{c}\sum_{g} \left(I_{c,t,g,p} + O_{c,t,g,p} \right) \le Q_{t,p} \quad \text{- (5)}$$

Equations 3, 4 and 5 represents the various production limits, transhipment limits and inventory holding limits respectively. On top of the constraints, we will also need to establish some relationships between the transhipment variables. Given that the transhipments can only occur between specific plants, we need to set up specific relationship equations.

$$I_{c,t,g,p} = O_{c,t-1,g,p} \quad \text{- (6)}$$

$A_{c,t,g,p} \ge 0$ and are integers - (7)

$$B_{c,t,g,p} \geq 0 \quad \text{and are integers} \quad \text{- (8)}$$

$$I_{c,t,g,p} \geq 0 \quad \text{and are integers} \quad \text{- (9)}$$

$$O_{c,t,g,p} \geq 0 \quad \text{and are integers} \quad \text{- (10)}$$

Equation 6 forces the model to only consider valid transhipment relationships as described in the business case. Equations 7, 8, 9 and 10 forces the values to be positive integer values. Once we have all the constraints, we can now set up the objective function which will guide the optimisation process.

$$Cost = min\ w.r.t \sum_c \sum_t \sum_g \sum_p \left(E_{c,t,g,p} A_{c,t,g,p} + G_{c,t,g,p} B_{c,t,g,p} + F_{c,t,g,p} I_{c,t,g,p} \right) \quad \text{- (11)}$$

At this point in time, it will be useful for the instructor to highlight an interesting observation with regard to the kind of component that can be produced. Component 5 and 6 are only produced at Plant P1 and P5. Component 1 and 2 are only produced at specific plants that can be shipped to all markets. By exploiting this unique property, the solution to this problem can be assembled by solving three simpler problems.

1. Component 1 supply chain optimisation
2. Component 2 supply chain optimisation
3. Components 5 and 6 supply chain optimisation

Instructors are advised to utilise this opportunity to explain to students the importance of exploiting business problem and data structure to simplify the optimisation formulation process. At this juncture, it is important to impress upon the students the advantages of problem simplification and how it can reduce the resource needed to solve the problem. Instructors who would like to demonstrate the difference can request the students to attempt both approaches to solving the problem. Most students will encounter difficulties with Excel's inbuilt solver to solve the problem.

Students are required to follow the steps and compute all the components required for all the customers in various location. The Instructor may use the Excel solution workbooks to guide the students.

REFERENCES

Bryan, Jennifer and Zhao, Joanna, 2017. Package 'googlesheets'. Cran R Project Package. 2018.

Hyndman, R.J. and Khandakar, Y., 2007. *Automatic time series for forecasting: the forecast package for R* (No. 6/07). Monash University, Department of Econometrics and Business Statistics.

Data Links

DSI Case Study Data
(https://drive.google.com/open?id=1wTs8umN1MDqbOzxpaHDtkYBVObz1kkgr)

Sales Forecast Training Data
(https://drive.google.com/open?id=1NLCpBxWm40x1sdsF5xF_fdEElHKxRaFt)

Excel Solution Templates Links

P1 and P5 Solution Templates
(https://drive.google.com/open?id=1vR8z_HnMaNO_FNwG3aWTurB26pgwy7bh)

P4 Solution Templates
(https://drive.google.com/open?id=1nmfFiA5APvnB6LEmAm0s-DTabqgaC8pu)

P7 Solution Templates
(https://drive.google.com/open?id=1kpgPAOV1zfc4YI-GbRx4fMNJjQFPN2Zm)

R Solution Code Links

R Solution Sample Code
(https://drive.google.com/open?id=1PEFHh_yB6730SsisZPiuuXQ2wGKaCdNv)

DECISION SCIENCES INSTITUTE
Teaching manpower planning using spreadsheet

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ABSTRACT

Manpower planning is central to most business because human resources are scarce and expensive. We wrote our consultancy project into a case study for classroom teaching, in order to bring some realism into the classroom. It is important for students to learn problem solving and analytical skillsets in a real-world context. Using the case, we show how students can analyze historical data to derive insights and construct a useful basic model developed from scratch, and thereafter, enhancing it to include more complexities. The model thus produced can directly applied to improve staff productivity.

KEYWORDS:—manpower planning, Utilisation, Sensitivity analysis, Linear relationship, Optimal resource

INTRODUCTION

Our client ABC is a service company whose customers would submit their applications online before a deadline for some premium services. The company would only shortlist certain applicants according to their business rules as their services were always oversubscribed. Customers would be notified via email if they were chosen. They would also be given an appointment date to come and meet with the customer service officer (CSO) and select from some premium services (S1, S2 and S3). If the customer could not attend the scheduled appointment, they would reschedule with the company to the next available timeslot. Figure 1 shows the business process of servicing the customer.

Figure 1: Business process of servicing the customer

Our problem will focus on stage 3 and 4 of the business process.

Stage 3: (Manpower planning) The manager needs to determine how many appointments a CSO can clear per month and how long will it take to service all the shortlisted applicants. The current process has the manager doing this assignment based on his "gut" feelings and personal experience. The current practice is for each customer to be given X minutes at the counter regardless of the service that they will choose and each CSO is assigned Y customers based on their utilization rate and daily working hour. Staff utilization rate is defined as the total amount of time spent to service the customer divided by the total capacity. Some CSOs complain that they are unable to service all the customers within the working hour and they are working overtime without pay. The workload distribution among staff is also uneven even though the manager thinks that it is a fair assignment as every staff is given the same number of customers to serve.

Stage 4: (Service customers) On the appointment date, there are instances where the shortlisted applicants do not show up (No show). In this case, the company loses its revenue and wastes its manpower resources as the CSO has already been allocated. On the other hand, if the customer shows up, the CSO opens the appointment file and registers the start time of appointment. The CSO services the customer based on their selection of services type (S1, S2 or S3). Once the service is done, end of service time is recorded and they proceed to the serve the next customers in line. The company also collects service time statistics and customer's feedback through survey at the end of stage 4.

Recently, there have been numerous complaints by the customers that the lead time from shortlisting to seeing the CSO is very long; in some cases, the appointment date is scheduled more than 30 days after shortlisting. The service level agreement (SLA) states that the company will serve all the customers within 30 days from shortlisting; otherwise there is a service failure on their part and the company's reputation can be jeopardized. The management of the company is interested to know whether or not the complaints are legitimate, and if so what do they need to do provide better service to the customers.

Manpower planning goes beyond day to day scheduling and operation. It also involves macro level planning (timeframes from 3-6 months) such as budgeting for new hire and headcounts. New staff needs training to become proficient thus management need to know well ahead of time how many more staff will be required to meet the SLA.

Time has changed, and customer centricity should be in the heard of organization culture. Customer expects high quality and customized/personalized service from the company to stay loyal. There are a lot of data being collected within the company. The data ranges from customers' demographics to the appointment details. It is vital for the company to embark on data analytics and provide valuable insights into service performance related to SLA and staff utilization rate.

This case study's main objectives are to help students in the following:

- Explain the importance of managing people within the organization

- Analyze the past historical data to get insights about the current situation
- Explain the importance of macro level manpower planning within the organization
- Develop the manpower planning model from scratch and enhance it to solve company manpower issues

- Illustrate the importance of manpower planning to fulfill customers need
- Implement sensitivity analysis on a spreadsheet model to emulate various business scenarios

(Dantzig, 1954) first introduced Integer programming (IP) model to solve the shift scheduling problem at the toll booths. IP assumes that all the decision variables are only take integer values. The second variation is where all the decision variables are binary (either 0 or 1), then it is called binary integer model. The third type is a mixed integer programming model (MIP) where there is a mixed of integers and non-integers value which are stated in (Anderson, Sweeney, Williams, & Martin, 2012).

Generally, most scheduling problems are NP-hard which means that we are not able to find the solution within polynomial-time. However, due to the business requirement to get the solutions within a short time frame, these problems are solved using business rules, logic or heuristics approach. The following researchers have worked on various versions of resource scheduling problem in over the years, (Ozcan, 2005), (Cezik, Gunluk and Luss, 2001), and (Bard, Jarrah and deSilva, 1994) solved the employees requirement probmem for each period of the day using IP and the objective is to minimize the manpower cost using forecasted demand for labours. (Al-Yakoob, S.M & Sherali, 2007) used mixed-integer programming model to schedule the employee working multiple shifts and over 86 stations distributed all over Kuwait.

(Barker, 2015) focused on developing real-world optimization model using Spreadsheets. (Ma, Choy and Sen, 2014), solved a similar problem which is related to planning for check-in counter resources at the airport. The authors developed a predictive model using historical data such as airline code, destination, region, day of week, month of they year to determine the forecasted passenger load. Using the forecasted passenger load, the authors developed a simulation model to where it seeks to determine an optimal number of check-in-counters at the airport to service a predicted passenger load within the service level agreements. The study used a six step methodology to solve passenger load and check-in counter requirement problems. The developed simulation model enables the terminal manager to visualize how various input parameters such as passenger loads impact the number of counters required and the resulting service level performance. This methodology can be adapted for the current problem statement, where past historical data can be analyzed and derived the input parameter such as service time and staff utilization rate for the mathematical model.

Macro level human resource planning focus on planning timeframes of 3 months to 6 months rather than daily operation. It is beneficial for organization to forecast the number of skilled

manpower required based on forecasted customer's demand to ensure business-as usual, efficient, smooth operations on a daily basis, by identifying manpower gaps and allowing lead time for training of these skilled labour. It also allows organization to forecast financial requirements such as budgeting for headcount (Prasad, 2012).

We need to build a customized model for manpower planning using spreadsheet as the business problem is quite unique to the organization in this study and they are not willing to purchase any commercial software for this purpose. They are also building up their analytics capability within the organization so they want us to impart and share our knowledge to develop this system. Spreadsheet is chosen as it is cheap and widely available within the organization. It is also easy to use and doesn't require any additional training. Therefore, we will start our discussion with the understanding of the business problem and try to identify any bottleneck from the data. A mathematical model will be built using the input from data to solve the macro level manpower planning issue.

In the next few sections, we analyze the historical data available and aim to derive input parameters for manpower planning. Subsequently, we develop a mathematical model for this purpose and run multiple business scenarios which comprises of changing the number of shortlisted applicants verses number of staff and the staff utilization rate. We share how this course has been delivered to thousands of undergraduate students annually in our university. We also highlight the challenges faced when teaching this kind of course to students and how we are able to adopt it into the successful delivery of the course. Finally, we discuss some learning points from the model and future work with a conclusion.

CASE ANALYSIS

Problem description

Students are asked to identify what is the problem they are trying to solve in this case? Two datasets were given to students which include fifteen months of historical data with tens of thousands of shortlisted applicants' detail. "CustomerDB" includes customer demographic information such as Customer ID, Age Group, Income Level, Gender, etc. The second dataset namely "AppointmentDB" comprises of Customer ID, Shortlisted Date, Staff ID, Date and Time of appointments, Status of appointment (Show, No Show), Type of service chosen (S1, S2, S3) and service start and end time.

We want students to learn how to ask the right questions to answer the business problem. This part is quite hard for them as they have no or litter experiences working in the industry. The discussion focus on customer complaints of service failure; and what they think is the main issue. Most students will say it is due to no enough CSOs to service the customer. How do they know it is the case? They are reminded that any claim needs to be supported by data, and

hopeful they will grow accustomed to this process of data to decision making. Can they build a mathematical model to answer the followings?

a. The first business problem is to derive the amount of time required to service all the shortlisted applicants using a given/fixed number of CSOs available.
b. Is the current strength of CSOs enough to meet the SLA?
c. What will be the optimal numbers of staff required for their daily operation?

Currently, human resource planning is done manually based on the manager's personal experience. Thus, it is difficult to accurately estimate the total amount of time required based on the appointments. The estimate of number of appointment multiply by X minute is a poor estimate of the actual time required. Therefore, this becomes our objective in this study, to gather the right service time and parameter and develop a useful macro level manpower planning tool to assist us in decision-making process. It is important for the company to manage its manpower resource effectively to achieve organizational goals, i.e. optimizing manpower resources and reducing the amount of time required to clear the shortlisted applicants. Understanding the resource utilization also allows the organization to benchmark its productivity rates within the same or across various industries.

Data input and preparation

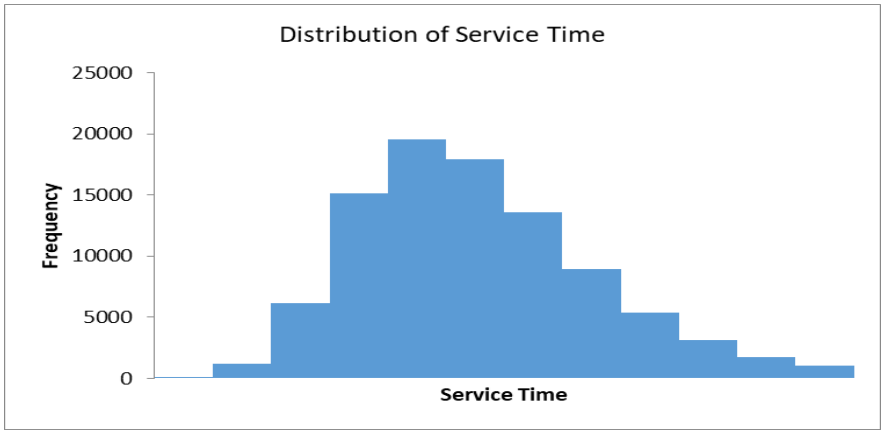
Before creating the spreadsheet model, the preceding open-ended discussion is concluded with the class collectively listing variables relevant to the model. Students need to merge two datasets into one common dataset using Customer ID. Students are required to share interesting insights after analyzing the data.

There is a large disparity in the service time between different age group and various service type. There is a consistent proportion of age group who apply each month and this information is used in our model. Twenty percent (20%) of the applicants who are shortlisted do not show up for the appointment. The company's plan is to develop a data mining model to predict the status of appointment but this is beyond the scope of this case.

From "appointmentDB", we need to derive a new field called service time which is the difference between the service end time and service start time. We can also compute the total time take by each staff to service the customer, hence the average utilization rate of each staff can be computed. Staff utilization rate also varies between 50% to 85%. For simplicity, we take an average utilization rate for all CSOs. Students are asked to explore what other parameters they think management might be interested. Since most customers complained about long lead time, the data can help them to answer what has happened. How many percent % of the shortlisted applicants have a lead time of more than 30 days? We can also compute the lead time from the shortlisted date to the appointment date, the waiting time for each appointment which is the maximum of 0 or (Appointment start time – schedule time).

The customers are grouped into various age groups based on their customer demographic information, A1 represents the young, A2 represents the middle-aged and A3 represents the elderly. 70% of the population belongs to A1, 20% of A2 and the remaining 10% is A3. We have a total of nine categories summarizing the distribution of the service time for each customer age group and service type (A1 S1, A1 S2 … etc). (Figure 2) below is an example of service time for A1 S1. It was observed that the distribution of the service time for all group is normally distributed and we use the mean as the average service time. We also remove the outliers which are +/- 3 times the value of standard deviation.

Figure 2: Distribution of service time for A1 S1



Without loss of generality, we have summarized the proportion of shortlisted appointment by age group (A1, A2, and A3), service type (S1, S2, and S3) and their respective service time in Table 1. A customer, whose age group is A1 and required service S1 will need 0.1 hours which is about 6 minutes. The variation of service time also differ tremendously among various age group for the same service type. Without the support of data analysis, the manager does not realize that it may cause a big issue in the customer waiting time, service quality, and staff productivity. Two staff may be serving the same number of customers each day but their utilization can be very different, e.g. A3 S1 needs 4 times longer than A1 S1.

Table 1: Customers by age group and service time

	Service time	**S1**	**S2**	**S3**
	Total shortlisted applicants	**Hours**	**Hours**	**Hours**
Age Group	A1	0.1	0.15	0.2
	A2	0.3	0.4	0.45
	A3	0.4	0.45	0.5

Table 2 shows the percentage of service selected by each age group**.** For age group A1, the proportion of services required also varies, 20% of A1 selected S1, 30% of A1 chose S2 and the remaining 50% required S3 service.

Table 2: Percentages of service selected by each age group

Service Selected	S1	S2	S3
A1 (70%)	20%	30%	50%
A2 (20%)	30%	30%	40%
A3 (10%)	10%	40%	50%

The working hour per employee is 8 hours daily, and they are multi-tasking. There are 5 staff available. Our model assumes that there are 22 working days in a month as they need to work 5.5 days including a Saturday half day, but they should not be 100% utilized to be realistic thus the model needs to capture this operational constraint. They only spend a proportion of their time to service the customer; because at other times they are also needed to support other business operations like preparing the quote and liaising with various vendors. Staff utilization rate denotes the percentage of time an employee will spend on serving the customers. The following Table 3 shows the input.

Table 3: Staff parameters and past 15 month's shortlisted number of applicants

Staff	5
Working hours	8.0
Utilization rate	60%
Time period (Month)	**Total shortlist applicants**
1	2300
2	1897
3	3254
4	2056
5	1692
6	4586
7	1298
8	3490
9	2876
10	3987
11	3456
12	5348
13	3546
14	5498
15	3450

Business Questions for the case

Question 1:
Assuming that there is a fixed number CSOs available daily, the management would like to know how fast can we service all the customers with the current number of resources? How many man days/man months will be required to service the total number of shortlisted applicants? Run the sensitivity analysis by varying the staff utilization rate from 60%-80. How does it affect the total duration? A service failure occurs when the total duration of service is 10% more than the total man day in a month. How many months does the service failure happen?
If the management would like to service all the shortlisted applicants within the same month, how many employees do they need each month?

Question 2:
If we need to suggest any changes to the plan in future, what is the optimal number of staff the company needs to hire to avoid service failure? ? If we vary the number of shortlisted applicants by +/- 20%, what is the impact on the manpower requirement?

CASES DEVELOPMENT/MODEL BUILDING

Model 1: Manpower planning model

Before we build the first model, we discuss the influence diagram shown in Figure 3, what are the input, output and how they are linked together using influence diagram. We can also visualize the number of shortlisted applicants over 15 months using a bar-chart in Figure 4. We can see that the number of shortlisted applicants over the 15 months fluctuates a lot with the highest number of shortlisted applicants on month 14th with 5498; which is 1.7 times of the average number of shortlisted applicants per month (average = 3249). From this graph, we should already anticipate there will be some resource issues. The macro-level resource planning will look at the overall service quality and failure over a period of 3 months to 1 year.

Figure 3: Influence diagram to compute total man days

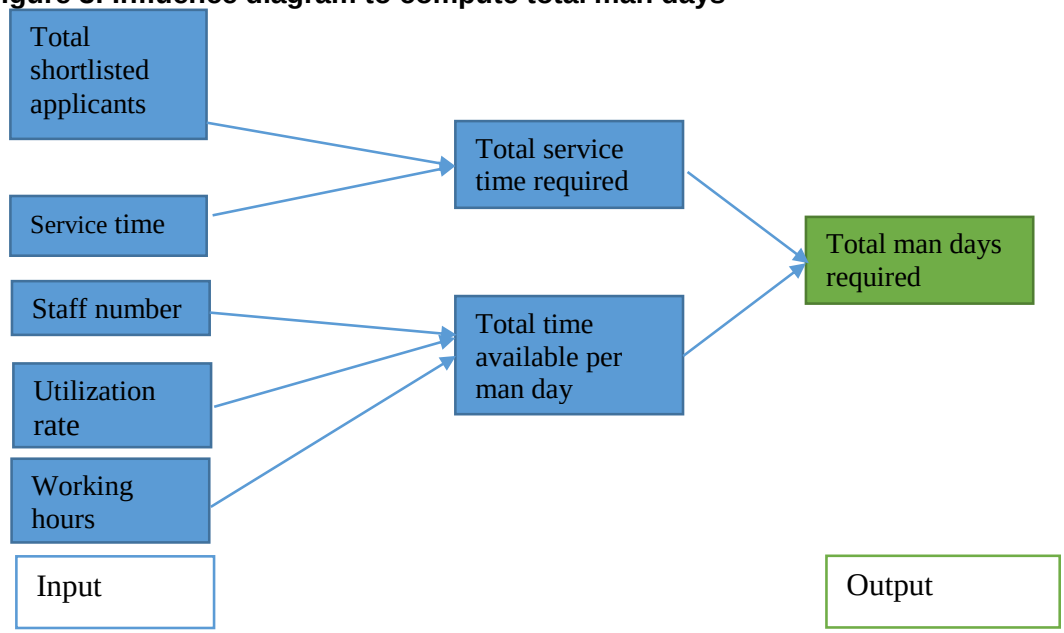
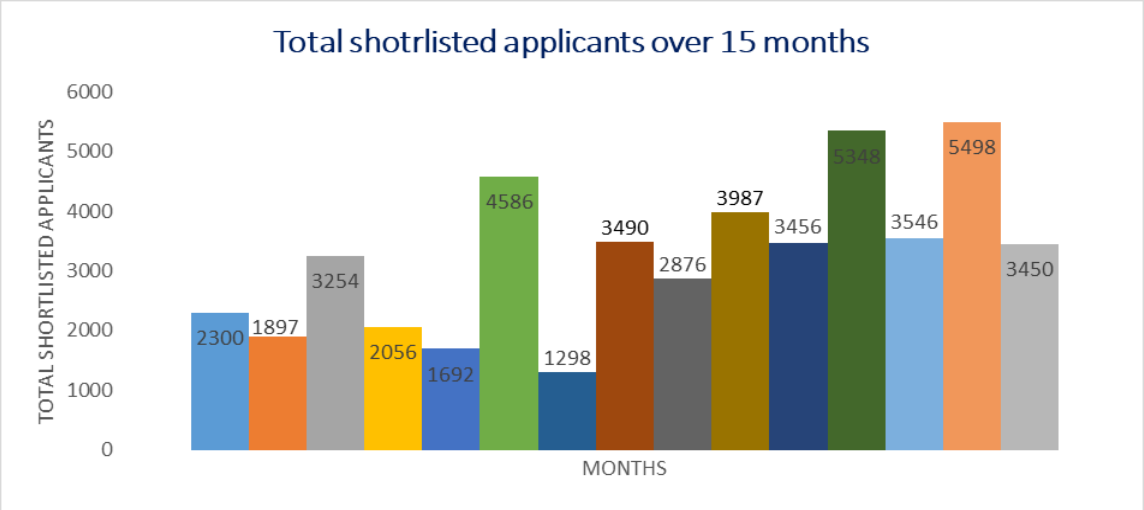


Figure 4: Total shortlisted applicants over time



We need to compute the shortlisted applicants by age group A1, A2 and A3 and compute the total time required for each age (T_A1, T_A2, T_A3) group accordingly to percentages of required service (i.e. various service time S1, S2 and S3). We can sum up T_A1, T_A2 and T_A3 to get the total time required (T_1) to service all the shortlisted applicants. We also need to compute the total available time per day using number of staff, utilization rate and working hours.

Let number of CSO available be C
Total A1 = Total shortlisted applicants * 70%
Total A2 = Total shortlisted applicants * 20%
Total A3 = Total shortlisted applicants * 10%
Total time required by A1 (T_A1) = Total A1 (20% * S1 + 30% * S2 + 50% * S3)
Total time required by A2 (T_A2) = Total A2 (30% * S1 + 30% * S2 + 40% * S3)
Total time required by A3 (T_A3) = Total A3 (10% * S1 + 40% * S2 + 50% * S3)
Total time required (T_1) = T_A1 + T_A2 + T_A3
Total time available per man day (T_2) = C * utilization rate * working hour
Total man days required = Total time required (T_1) / total time available per man day (T_2)
We can easily convert number of man days to man month by dividing it by 22. We can compute if there is a service failure in each month using IF formula. The excel template (
Figure 5) below shows the solution for model 1. The number of months when the service failure happens is actually quite high, which is **2 out of 3** of the total. We also use conditional formatting in Excel to highlight those months which had a service failure (i.e. # of man month > 1.1).

The conclusive remark after developing this model is the percentage of service failure over 15 months is more than 60% and it can help to answer how many man months will be required based on current staff number. The current number of CSOs deployed is not enough to service all the number of shortlisted applicants per month.

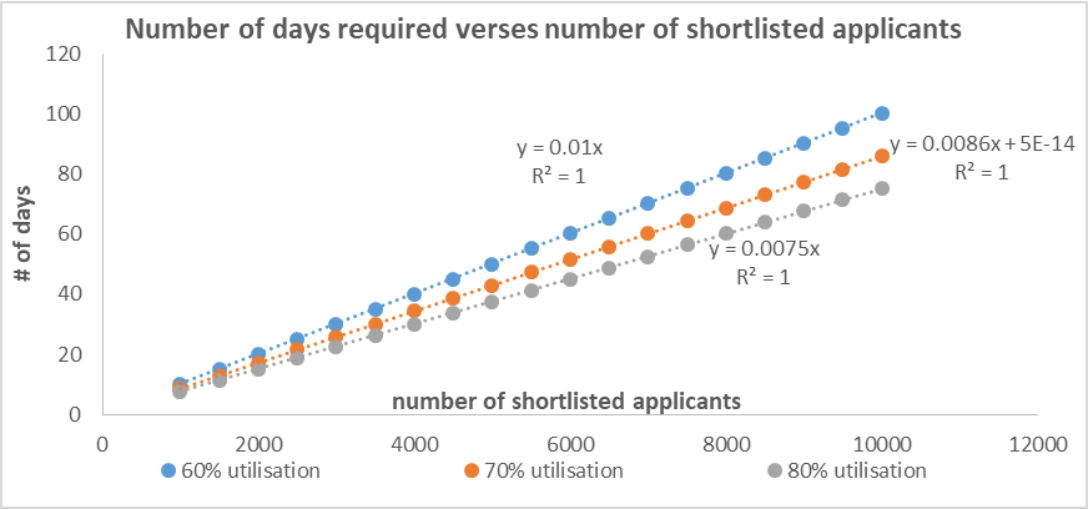
Figure 5: Excel solution for Model 1 - To compute number of man days

		Number of applicants			Total time required					Service failure	1.1	
Time period (Months)	Shortlisted Applicants	Total A1	Total A2	Total A3	T_A1	T_A2	T_A3	Total time required (T_1)	# of days	Convert to month	Service Failure	Number of staff required
1	2300	1610	460	230	265.7	179.4	108.1	553.2	23.05	1.05	N	6
2	1897	1328	379	190	219.1	148.0	89.2	456.2	19.01	0.86	N	5
3	3254	2278	651	325	375.8	253.8	152.9	782.6	32.61	1.48	Y	8
4	2056	1439	411	206	237.5	160.4	96.6	494.5	20.60	0.94	N	5
5	1692	1184	338	169	195.4	132.0	79.5	406.9	16.96	0.77	N	4
6	4586	3210	917	459	529.7	357.7	215.5	1102.9	45.96	2.09	Y	11
7	1298	909	260	130	149.9	101.2	61.0	312.2	13.01	0.59	N	3
8	3490	2443	698	349	403.1	272.2	164.0	839.3	34.97	1.59	Y	8
9	2876	2013	575	288	332.2	224.3	135.2	691.7	28.82	1.31	Y	7
10	3987	2791	797	399	460.5	311.0	187.4	958.9	39.95	1.82	Y	10
11	3456	2419	691	346	399.2	269.6	162.4	831.2	34.63	1.57	Y	8
12	5348	3744	1070	535	617.7	417.1	251.4	1286.2	53.59	2.44	Y	13
13	3546	2482	709	355	409.6	276.6	166.7	852.8	35.53	1.62	Y	9
14	5498	3849	1100	550	635.0	428.8	258.4	1322.3	55.09	2.50	Y	13
15	3450	2415	690	345	398.5	269.1	162.2	829.7	34.57	1.57	Y	8

We can run sensitivity analysis by changing the staff utilization rate between 60% - 80%, which will affect the total available time per day and we can plot the graph to show the relationship between the total shortlisted applicant and the number # of man days required. As we have expected, if we increase the utilization rate of the staff, then the total number of man days to

clear the number of shortlisted applicants will be reduced. We can find the relationship between the number of shortlisted applicants and the number of man days required by using the **TRENDLINE** function in Excel. It is a linear relationship and the equation of the lines vary for different utilization rate is shown in Figure 6. This equation is used in the tool given to the manager to answer his manpower planning queries and what-ifs.

Figure 6: Sensitivity analysis by changing staff utilization rate



If we want to know, how many staff will be required to service all the number of shortlisted applicants within a month using the basic model 1, we can re-compute the number of staff required using formula below. Since the number of staff can only be integer value, we will round it up with zero decimal place using the **ROUNDUP** function in Excel.
Number of CSOs required = total time required (T_A1) / (22 * working hour * utilisation)

Figure 7: Number of staff required based on number of shortlisted applicants

Time period (Months)	Shortlisted Applicants	Number of staff required
1	2300	6
2	1897	5
3	3254	8
4	2056	5
5	1692	4
6	4586	11
7	1298	3
8	3490	8
9	2876	7
10	3987	10
11	3456	8
12	5348	13
13	3546	9
14	5498	13
15	3450	8
Average	3249	8

Figure 7 shows the number of staff required to service all the number of shortlisted applicants within a month. We ask students how they are going to help the organization to solve the manpower challenge. Some students suggested that they can hire part-time additional staff to fill up the resource requirement. Others mentioned that the company can pay the staff overtime to work extra hours. In any of those case, it is not going to solve the problem as there are limited talent and limited time that one can work within a stipulated time. However, there are also some operational constraints based on the real-business scenario, such as all the staff need to be full-time employees of the organization (i.e. security control) to service the customers. The new staff needs to undergo special on-the-job for at least 1 months and understudy with mentors before they can officially become CSOs to serve the customers effectively. The answer provided by the model cannot be used blindly as there are manpower budgets constraint. If we hire 13 staff to meet the peak at months 12th and 14th, there will be an additional overhead on the company operational expenses. Furthermore at other times, these staff will be idle and unproductive. From this point onwards, we discuss about how to utilize the human resources effectively and efficiently in an organization by finding out the optimal number of resource required with some recommendation for process changes. This leads us to the development of model 2.

Model 2: What-if Analysis

We have recommended that the company provide an online booking system so that the customers can choose the appointment after being shortlisted. In order to obtain the optimal number of staff required to service all the number of shortlisted applicants, we have suggested the company to have steady number of shortlisted applicants by opening a fixed number of booking each month via online portal. Customers are able to see the available number of booking next month after they are shortlisted and book online. If all the bookings are filled up, the company won't be opening up any new slots for the month, and the unfulfilled customers need to submit the application again. This will ensure that all customers are served within a month. If the human resource requirement is steady then they don't need to pay overtime charge which is 1.5 times the normal pay. It will be a win-win situation for the customers and the company.

Let us now use the same data and test our new approach. We need a model to find out the optimal number of staff required. Firstly, we get the average number of shortlisted applicants per month using the historical data, which is 3249, and we use the average number of shortlisted applicants per month and fixed utilization rate of 60% as an initial starting point. Then we use this simulated number of shortlisted applicants and compute the total time required and total staff required. To answer the question on “If we vary the number of shortlisted applicants by +/-20%, what is the impact on the manpower requirement?”

Sensitivity analysis is the one of most valuable concepts used in the dynamic business-environment studies. We limit this analysis to the impact of changes in the uncontrollable variable values to the business objective. In the case, given the unknown number of shortlisted

applicants or staff utilization rate, students need to explore how the optimal number of staff will be affected by varying different input values and illustrate the solutions in the table. We have added % of variation to get the new number of shortlisted applicants and the output that we need to compute is the total number of staff required. This computation is very similar to what we have found earlier. Using the total staff required, we can use the 2D **DATA-TABLE** function in Excel where the row input cell is the utilization rate and the column input cell is the number of shortlisted applicants' percent % variation. The output of the table is (Total staff required) in the table. The sample Figure **8** below shows the model 2 solution.

Figure 8: Excel solution for Model 2 – Optimal staff required

Model 2

Number of shortlisted applicants	3300	
% variation	0%	
New shortlisted applicants	3300	
Time required for A1	381.15	
Time required for A2	257.4	
Time required for A3	155.1	Demand
Total Time required	793.65	
total staff requierd	8	

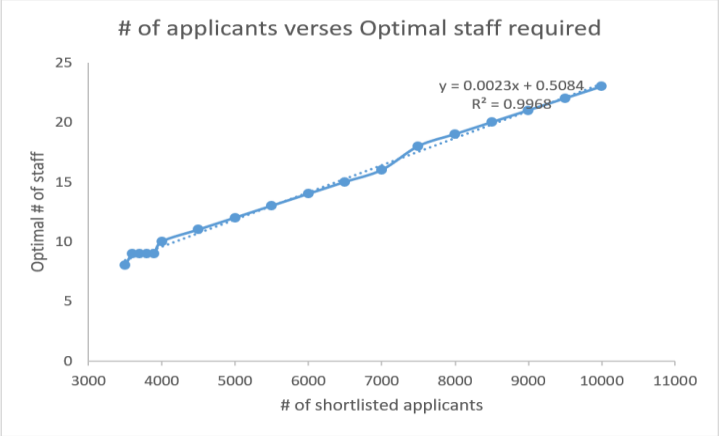
Sensitivity analysis by changing number of shortlisted applicants and utilization

	Utilization rate				
8	40%	50%	60%	70%	80%
-10%	11	9	7	6	6
-20%	10	8	7	6	5
-30%	8	7	6	5	4
-40%	7	6	5	4	4
-50%	6	5	4	4	3
0%	12	10	8	7	6
10%	13	10	9	8	7
20%	14	11	10	8	7
30%	15	12	10	9	8
40%	16	13	11	10	8
50%	17	14	12	10	9

Next, we can run the sensitivity analysis by varying the number of shortlisted applicants between 3500 and 10000 and find the optimal number of staff required. We can easily build the table using Excel **DATA-TABLE**. This table will give the company very useful information about the staff requirement verses the number of shortlisted applicants they can serve in a month. Based on the human resource budget, the manager can accept more number of shortlisted applicants while meeting the SLA. **TRENDLINE** is also added to the graph to give the relationship between the number of shortlisted applicants and optimal number of staff required per month. R2 value is 0.9968 which shows that this is a good fit to use for business. The result and graph for this analysis is shown in **Figure 9**. However, the model only serves as a decision support tool for the company's management, and it is up their discretion to make decision on the ground and manage trade-offs. Students are asked to explore what will be the next step for the company and the discussion ends here.

Figure 9: Number of shortlisted applicants verses optimal number of staff

# of shortlisted applicants	8.00
3500	8
3600	9
3700	9
3800	9
3900	9
4000	10
4500	11
5000	12
5500	13
6000	14
6500	15
7000	16
7500	18
8000	19
8500	20
9000	21
9500	22
10000	23



CHALLENGES IN CLASS

After teaching this course, here are some of the challenges we face in conducting the class.

- Student find it challenging to follow the concepts
- Student do not have past experiences of solving problem
- Student has no prior Spreadsheet Excel skill
- Student lack developed analytics skills

DISCUSSION AND CONCLUSION

Most students begin the case with little knowledge of the "world of business", except possibly through the eyes of current news in newspapers and television. The purpose of bringing students through such an exercise is to show them how to build exploratory model using spreadsheet as a simple tool. They also learn and practice features of spreadsheet that are relevant to the exercise. Most importantly, the case and all business case studies in general, help students acquire real-world experience in the classroom. It also shows how a spreadsheet model that can be built in about an hour and a half can be of practical use in the real world. It is good to start building the basic model in Excel from scratch and progress to advanced modeling techniques. For the first few lessons in the course, they find it hard to deal with the ambiguity, and to get started without much information being given. But after a few lessons, they learn to appreciate the power of the spreadsheet as a problem discovery and framing mechanism, and they can work towards creating models in which the inputs can be changed as easily and frequently as they want with the output still computed correctly.

We find it useful and beneficial if the students help each other during the class exercise as they can learn from each other. The instructor as a result becomes more available to other students who need deeper guidance. Towards the end of the session, the instructor can illustrate the workings and explain various correct and erroneous approaches to solve the problem and why one option is better than the others.

In summary, the case reinforces the following skills:

a. Analyze the historical data and get the generalized data summary for future use
b. Make assumption and build models for ill-defined real-world business problems
c. As opposed to making decisions based on "gut" feeling, models with valid assumptions are robust and start with simple model that can be enhanced for more complex business scenario
d. We must be able to suggest challenges to the business if it will improve the overall customer experiences and staff satisfaction

The results from the students' feedback shows that students find problem solving skills very important to real-world. This is also a transferrable skill to solve various problems. Excel is a good exploratory tool and it is useful to build the dynamic model using most parameters as an input and reference. Students are also reminded to make certain assumption to build the model and validate the results with users. They can also use Excel to run various scenarios and making decision based on scientific approach especially in today digital world.

On the whole, the problem-solving approach using Excel holds several advantages over existing lecture-based study. Compared to the lecture-based teaching, it has a very visual nature, is fun to play with, allows for collaborative learning, and provides immediate feedback to students about the key concepts that are to be taught. They can visualise the numbers using various graphs and charts, and they can modify the model accordingly if business environment changes. This case is intended for both undergraduate and graduate student levels; to determine the macro-level manpower planning for an organization. Spreadsheets are demonstrably useful, and students are encouraged to continue to hone their "business modeling with spreadsheet" skills.

LEARNING POINT FROM THE CONSULTANTCY PROJECT

Our journey continues. The whole workbook which includes model 1 and 2 has been given to the company. The manager uses it to solve manpower planning issue and improves the manager's productivity because the planning time has been greatly reduced from days to minutes. CSOs are happier as there is a more balanced workload distribution based on average service time by age group and service, rather than based on a fixed X minute per customer and total of Y appointments per day.

As an extension for this use case, we have also developed a predictive model to determine the appointment status (Show, No Show) with 85% accuracy rate. Subsequently, we use the predictive result and the output from macro-level planning (i.e. the number of staff required) and solve the staff scheduling problem. We are able to allocate each predicted "Show" appointments to staff subjected to working hour limit.

Manpower planning and staff scheduling are common issues in many other industries such as F&B, education, medical, service and others. We can use the same approach discussed here to

solve their respective manpower problem. Certain industries may operate round the clock, and some employees are bound by the union rule, which can then be calibrated into the model to adopt to various businesses' needs. From the above, we foresee that other manpower planning applications can be developed using our approach.

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DECISION SCIENCES INSTITUTE
Teaching Warehousing with Excel

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ABSTRACT

This presentation highlights and illustrates several specific ways of using Excel to teach a warehouse management class in an online environment. Excel is well suited for warehouse layout drawings to scale and programmable exercises. Excel can be efficiently used in combination with the course delivery software to guide students through exercises and provide a tool to check intermediate and final answers. Finally, certain simple but often overlooked functions, like the rounding family of functions, can be taught as an auxiliary learning objective.

KEYWORDS: Excel, Warehousing, Teaching methods, Experiential learning

INTRODUCTION

Few colleges and universities offer formal classes in warehouse management as part of their supply chain curriculum, but those that do face a substantial challenge: there is no college level textbook of warehousing. Instead, the common practice is to use industry handbooks, such as those written by Richards (2017), Frazelle (2002), and Tompkins & Smith (1998). These books are addressed to practitioners and do not include problems or exercises, so instructors have to come up with their own.

This is where Excel comes in handy. Excel is a widely available application, and most students are familiar at least with its basic functions by the time they are ready to take the warehouse management class, so there is no extra expense or training involved.

Excel provides an excellent environment to create exercises in, including complex programmable ones, as well as drawings of warehouse layout for illustrations. It also works very well in tandem with any course delivery software. Additionally, a warehouse management class presents an opportunity for students to build skills using less common but useful functions in Excel.

All of these situations are described in more detail in this teaching brief. The examples are taken from a course taught online and are thus particularly beneficial for this format known to have limited options for student-instructor interaction.

THE ILLUSTRATIVE FUNCTION OF EXCEL

The ratio of length to height of a standard Excel cell is 3:1. This offers a great opportunity to draw a basic warehouse layout to scale by simply using the borders of the cells without any changes to cell sizes. In terms of scale, one cell can be assumed equal to 12 ft by 4 ft. A typical resulting image of a warehouse will have racks with 12-ft. bays and 12-ft. wide aisles commonly used for counterbalance forklift operation. The depth of the selective racks is 4 ft, but with two adjacent rows of racks, the depth could be assumed to be smaller, given the flue space. For a basic warehouse layout design problem, the flue space can be disregarded. Appendix 1 shows

a fragment of a warehouse layout from a problem which asks students to design an optimum layout of an addition to a warehouse, given the existing constraints.

The advantage of warehouse layout drawings in Excel is their simplicity paired with the true-to-life ratio of design element sizes. Creating this kind of drawing in another application, e.g., AutoCAD, would have been more cumbersome without any substantial advantage to the learning process. Students report that they typically find it very helpful when a warehouse layout drawing is supplied as an illustration of a complex problem or case. Besides, due to wide availability of Excel, students can actively participate in the exercise by drawing their own design in problems that call for creativity. Since no special skills beyond the basics are required, students can focus on the content of the exercise and not on how to make a drawing.

COMBINATION OF EXCEL WITH COURSE DELIVERY SOFTWARE

Using Excel in conjunction with course delivery software presents an opportunity to offer additional guidance and feedback to students on complex computational problems. The problem needs to be structured as an Excel spreadsheet. If the calculations require multiple steps, some cells may be designated as checks for intermediate results. The same color can be consistently used throughout the course for easy identification of these cells. Once a student has entered certain data and/or formulas in the input fields, the check cells will display the results. These intermediate results may be entered into the special tool, such as a quiz with a fill-in-the-blank answer format, in the course delivery software, e.g., Brightspace or Blackboard. The student than will see if the answer entered is correct or incorrect and will see any standard feedback that the instructor can program into the tool, e.g., a typical reason for getting an incorrect answer in that calculation. I set the help tool to unlimited attempts and do not make the scores on it count towards the grade for the exercise to encourage students to use the tool without any fear of spoiling their grades. For the help tool to maximize learning, the format should not suggest any specific answer, i.e. it should not be a multiple choice format. A fragment of an Excel exercise with cells marked “HELP TOOL” is shown in Appendix 2.

In the same way, final answer cells can be designated by a certain color, and a quiz can be set up where students will enter their answers. For difficult problems, I recommend two attempts for the final answers quiz. After the first attempt, the students will be able to see their score for each question and read the feedback. If any questions have been answered incorrectly, they have a second chance based on the feedback. Even if the multiple computational steps are consecutive and only one final answer is expected, it is possible to use answers to some of the intermediate steps in the quiz, so that a partial credit can be given to students who completed several steps but have not arrived at the correct final answer, in the same way a partial credit would be given if the whole spreadsheet was submitted for grading.

This system may look complex to program, since it takes two quizzes for one problem with multiple answers. However, once the setup is finished, the instructor’s time is saved, because everything is graded automatically by the course delivery software. This advantage becomes substantial for larger size classes. Besides, compared to the alternative of the students simply submitting their Excel sheets for grading, the use of Excel paired with the course delivery software provides a high level of interaction. This guidance is really appreciated by students. Its additional advantage is its immediate availability to students on their terms compared to a student e-mailing a question or request for help to the instructor and then waiting for a response for an uncertain period of time. The availability of the help tool with unlimited attempts encourages students to experiment and promotes experiential learning. Clearly, this type of

Excel use in tandem with the course delivery software is not specific to warehouse management problems and can be recommended for other classes with computational home assignments.

COMPLEX EXERCISES AND CASES IN EXCEL

In addition to problems requiring straightforward calculations, it is possible to use Excel to develop case-like complex problems that will teach students analytical skills. As an example, my students of the warehouse management class are assigned an optional homework requiring to solve a problem of a potential shortage of space in a warehouse due to a planned change in operations. The warehouses block-stacks pallets three tiers high, and the potential solution is to add a fourth tier. However, there are several constraints that students have to evaluate and overcome (pallet weight limit, building clear height, forklift lift capacity, and others). The constraints are defined by formulas and explained in words. All the constraints translate into five tests that must be satisfied to add a fourth layer. However, when a student changes the number of tiers from three to four, several of the tests turn from the green “pass” to the red “fail.” From that point on, the student starts to investigate which constraints the failed tests will lead to and how to overcome them, e.g. replace the currently used pallets with higher capacity pallets.

The way this exercise appears in Excel is shown in Appendix 3. Unlike using Excel tables to provide data for a case written as text, the whole case is contained in one Excel sheet, and students are expected to solve the case by primarily experimenting with numbers in the sheet and receiving immediate feedback from the five tests contained in the sheet.

Setting up an exercise in a form of a structured case in an Excel spreadsheet promotes experiential learning. It is an exciting exercise for students who love solving puzzles and many students report that they enjoyed working on this exercise. However, due to its difficulty, it is offered as an optional exercise with bonus points only. The example discussed above, while specific to warehousing, illustrates that Excel can successfully be used for complex, case-like problems to develop analytical skills, which is highly appreciated by advanced students in any class.

BUILDING EXCEL SKILLS PER SE

So far we have focused on ideas that do not require additional skills in Excel beyond the basics students are already expected to have. However, there are certain useful functions in Excel that are relatively simple but are commonly overlooked. So why not teach a few of them in a warehousing class?

For example, there is a whole family of rounding functions that allow rounding up, down, to a certain number of digits before or after the decimal point and rounding in special increments. I have built all of them into a warehouse design exercise in a way that teaches the appropriateness of using a particular way of rounding, e.g., length of a rail dock in 75-ft. increments, the length of a typical railcar served by the warehouse.

The learning objective of discovering and using new Excel functions is secondary in this exercise, but because it is well integrated into the fabric of the exercise, the learning becomes very memorable. The key for the instructor is to identify a good opportunity for blending new Excel functions into an exercise. Learning about which Excel functions students are likely to know or unlikely to know from other classes should also help to understand whether the functions used will be complementary to the already existing Excel skills of students or will come as a reinforcement of those they have already learned. This will determine the strategy of

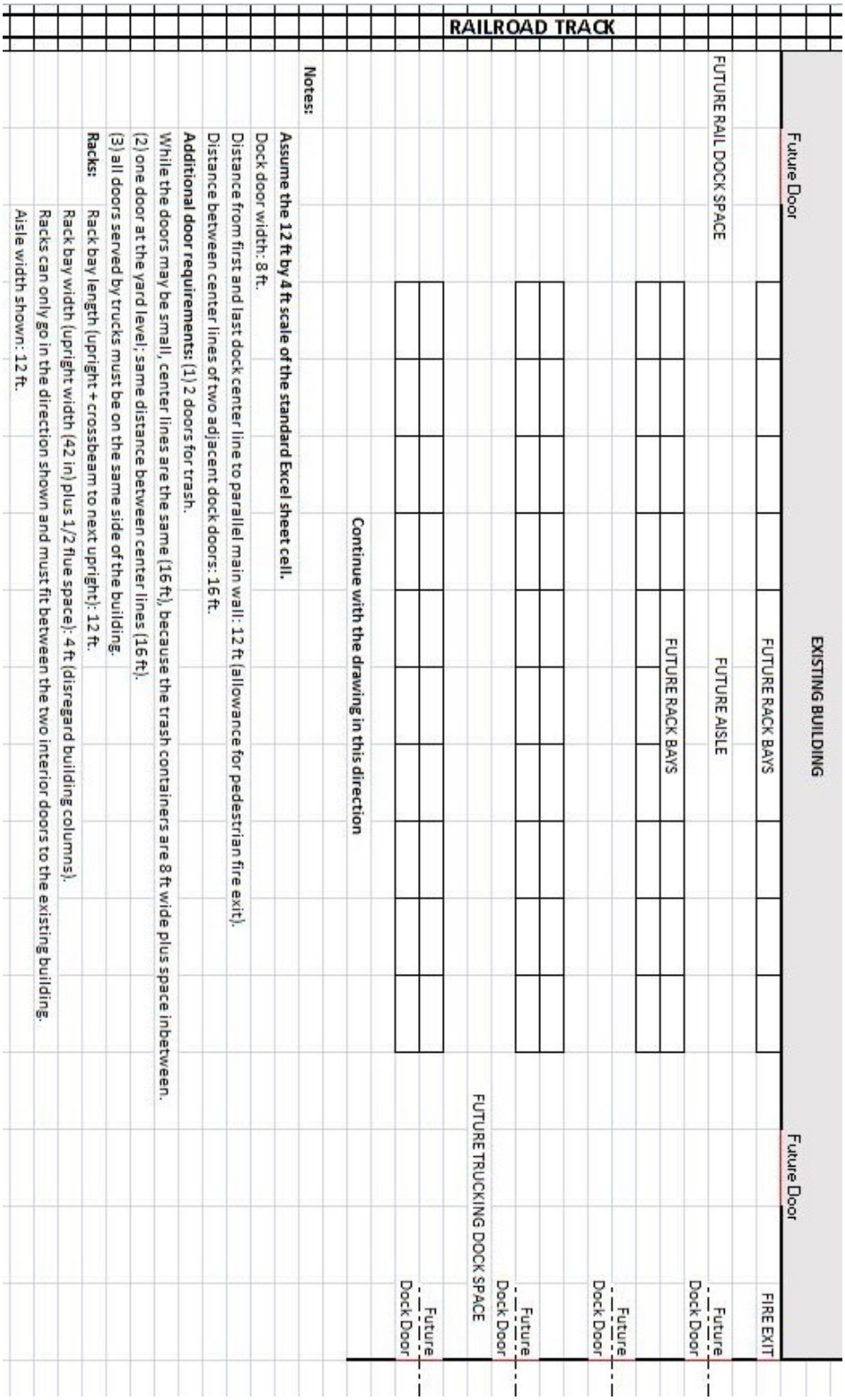
introducing the functions into exercises or problems. For example, the rounding functions of Excel are new to most students, so to help them, I provide a one-page rationale for using each of the rounding functions.

CONCLUSION

Without a warehousing textbook, instructors are left to design their own problems and exercises to teach quantitative aspects of warehouse management. Excel is an ideal tool to use in a warehouse management class to reach four specific objectives:
(1) teach warehouse layouts by providing illustrations and environment for students to easily to modify them or create their own;
(2) develop analytical skills through complex problems and cases set up as Excel spreadsheets with feedback options;
(3) provide convenient feedback and guidance to students by combining Excel based exercises with help tools and quizzes built in the course delivery software; and
(4) integrate some of the new or less known Excel functions into Excel based exercises to provide students with an additional benefit of expanding their Excel skills.

This teaching brief used examples from an online warehouse management class to illustrate the teaching techniques, but these objectives are not limited to a warehouse management class; the approaches and techniques described here can successfully be used in other classes as well.

APPENDIX 1
Warehouse layout illustration



APPENDIX 2
Fragment of an exercise with a help tool

Inbound loads, by truck

Year	Sales forecast, units	Sales growth in units per year, %	Share of containers in all inbound units	Inbound units per container	Inbound containers per year	Working weeks a year	Working days a week	Working days a year	Containers to unload per day (dock throughput)	Time to unload a container, hr	Shifts a day	Working hours per shift
1	600,000	4	0.8	400	HELP TOOL	52	5			4	1	8
2		4	0.6	400			5			4	1	8
3		4	0.4	400			5			4	1	8
4		4	0.2	400			5			4	1	8

Totals

Year	Required outbound doors	Required inbound doors	Trash doors	Yard doors	Subtotal all doors served by trucks	Façade length per door, ft	Façade length based on doors	Fire exits	Façade length for a fire exit, ft	length for all fire exits, ft	Grand total façade length, ft
1						HELP TOOL		HELP TOOL	4		
2											
3											
4											

CALCULATION OF THE REQUIRED LENGTH OF THE BUILDING BASED ON RAIL DOCK LENGTH REQUIRED

Year	Sales forecast, units	Sales growth in units per year, %	boxcars in all inbound units	Inbound units per boxcar	Working weeks a year	Working days a week	Working days a year	Boxcars to unload per day (dock throughput)	of average boxcar, ft	car changes available per day	Total required rail dock length, ft
1	600,000	4	0.2	400					75	2	
2		4								2	
3		4								2	
4		4								2	

APPENDIX 3
Fragment of an Excel spreadsheet-based case

For uniformly distributed loads and heavy duty floor capacity per square inch (otherwise needs to be part of the calculations)

			Lift Truck Load Diagram (from Slide Presentation)						
Pallet	Weight, lbs	60	**Capacity -->**	**lbs**	**lbs**	**lbs**	**lbs**	**lbs**	**lbs**
	Width, in	48	**Lift, in -->** 167	2,600	2,400	2,300	2,200	2,100	2,000	1,900	1,800	1,700
	Depth, in	58	**Lift, in -->** 177	2,400	2,400	2,200	2,100	2,000	1,900	1,800	1,700	1,600	1,500
	Height, in	5	**Lift, in -->** 187	2,200	2,200	2,100	2,000	1,900	1,800	1,700	1,600	1,500	1,400
	Capacity, lbs	3,500	**Load Center, in -->**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**
Load (w/o pallet)	Weight, lbs	950										
	Width, in	48										
	Depth, in	60										
	Height, in	60										
	Wrapped & Strapped (yes/no)	no										
Pallet Entry Type	Width Side (yes/no)	yes										
	Depth Side (yes/no)	no										
Load Overhang Considered	Larger Width, in	48										
	Larger Depth, in	60										
	Actual Load Center	30										
	Lift Truck Table Load Center	30										
Stacking Limit	Mfr. Instructions	5										
	Shipper Instructions	4										
	T to B Compression Computer Calculation	6										
	Practical Assessment of Load Stability	4										
	Most Restrictive Limit	4										
Building Clear Height, in		270										
Lift Truck	Lift, in	184										
	Backrest Height, in	90										
	Extended Height, in	274										
	Effective Lift	180										
	Lift in Lift Truck Load Table	187										
	Min. Safe Pallet Lift, in	6										
	Capacity for Given Load Center at Max. Lift given clear height, lbs	1,900										
	Lift Capacity, tiers	1										
	Safe Lift Capacity, tiers	1										
	Most Restrictive Lift Capacity, tiers	1										

Green and red cells contain formulas!
They are explained below

A tier is defined as a pallet with a load.

ENTER DESIRED TIERS: 3

	Checks:	**Weight**		
	Desired # of tiers vs. the most restrictive stacking limit in E25	Most Restrictive Limit	PASS	**Test #** **1**
	tiers*Loadweight + (tiers - 1)*Palletweight	Pallet Capacity	PASS	**2**
	Checks:	**Height**		
	tiers*(PalletHeight + LoadHeight) + PalletLift	Bldg Clear Height	PASS	**3**
	Sum of heights of tiers on the floor before the top one(s) is added	Lift truck actual extended	PASS	**4**
	Sum of heights of tiers on the floor before the top one(s) is added	Top Pallet(s) Lift (Lift Truck	PASS	**5**

YOUR TASK: Your warehouse receives a lot of this product for storage. The relevant details of the product and pallet it comes on are in columns B through E and the forklift capacity table is in the top box above. You block-stack the product three tiers high. However, a 20 to 25% increase in the amount of this product is required soon without any changes to your storage capacity. So you are thinking if perhaps you could store the product four tiers high that will solve the problem. There are many factors that you need to consider, so you have prepared a helpful table that lists all these factors and provides five weight and height tests for a four-tier storage. All you have to do is enter the number of tiers you want to use in the blue cell in the box above and the table will show if it passes all the five tests. All five tests must be met for you to implement your solution. Unfortunately, some turn from "PASS" to "FAIL" as you replace 3 with 4 in the blue cell. However, your next best solution of storing the extra product in a public warehouse is expensive and inconvenient. So you'd rather spend a little time to figure out what you can change in your operation to accommodate the 4th tier. You are prepared to spend a reasonable amount of effort, time and money, but you cannot change the clear height of the building, any safety standards or the calculation formulas. So is there a solution? Please recommend the best solution in the box below and highlight with color the cells where you have modified the values. Your decision box above should show 4 tiers and all 5 tests should be a "PASS". Submit the modified file with your answers through Assignments by the deadline.
Highlight all the changes you have made in the table with a distinct color.

The purpose of this task is to reinforce the knowledge of the factors that influence stacking decisions and to develop problem-solving skills in a complex multi-factor, multi-relationship situation. Most of the data are realistic, even though some had to be modified to make this an educational activity.

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DECISION SCIENCES INSTITUTE
Text Mining on Consumer Reviews of Internet of Things (IoT) Applications

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ABSTRACT

The aim of this study is to analyze reviews of “Internet of Things (IoT)” related products by using text mining. Apart from sentiment analysis, our anticipated goal is to find out the features of IoT products appeal the most to the consumers. Based on the clustering results, we were able to draw conclusion on common advantages of IoT products and provide suggestions to the technical improvement as well as some useful business strategies from aspects such as private issues that most consumers shared with their concerns.

KEYWORDS: Internet of things, Text mining, User experience

INTRODUCTION

The internet of things, IoT, refers interrelated computing devices capable of transferring data over a network without human-to-human or human-to-computer interaction, which are often equipped with ubiquitous intelligence. IoT is also defined as connecting things by internet based on information sensor equipment to achieve information exchange and remote management. With the rapidly development of Internet of Things technology, the concept of smart home became very popular, but if someone can use the network to break into the security line of smart home products, such as: thermostats, smart TV, camera, etc., they can easily obtain privacy information. In other words, IoT products impose potential security risks. (Bandyopadhyay & Sen 2011) (Suo et al. 2012).

The aim of our study is to select reviews of popular IoT products from Amazon,, perform clustering analysis by using SAS Enterprise miner to find out what features of IoT products

attract consumers, as well as attributes that cause negative opinions. In conclusion, suggestions and prediction of the trend of the development of IoT are provided

LITERATURE REVIEW

The concept of a network of smart devices was discussed as early as 1982, with a modified Coke machine at Carnegie Mellon University becoming the first Internet-connected appliance. (Bandyopadhyay & Sen 2011) (Bonomi et al. 2014) As of 2016, the vision of the Internet of things has evolved due to a convergence of multiple technologies, including ubiquitous wireless communication, real-time analytics, machine learning, commodity sensors, and embedded systems. (Ng & Wakenshaw 2017) However, for the development of IoT, security is a major concern for this young industry. Lack of IoT security expert makes it very difficult to avoid the risks of attack from hackers.

According to conservative estimates, the number of global embedded chips, sensors, radio frequency smart objects have exceeded 1 trillion (Bin et al. 2010). Security and privacy are the key issues for IoT applications. The IoT industry is facing enormous challenges, for example, the privacy problems confused people, the limitation on the platforms, the number of equipment make it hard for upgrade and maintenance, operation based on cloud is neither effective nor reliable. **(**Suo et al. 2012) Even with such huge challenges, IoT products are still appealing to many more consumers because of their convenience to people's daily life.

Prior research (Ng & Wakenshaw 2017) has suggested that consumer experiences with physical products are highly visible in the era of IoT. In this study, we perform analysis on customer reviews of IoT products to gain valuable insight on these products.

DATA COLLECTION

In data preparation phase, we started searching original data from IoT related literatures, IoT products' reviews from Amazon.com, and IoT related social media platform posts. We used data mining software "Octoparse" and a Google Chrome extension tool "Data Miner" to identify potential data for analysis. For the purpose of this study, we decided to use "Data Miner" tool to extract top ten IoT products' reviews from Amazon.com.

We selected ten target products from http://iotlist.co/. Each product has over 1,000 customer reviews. The 10 products we selected were: Apple Watch, Echo Show, CUJO, Echo Dot2, Fat Scale, Fithitsurge, Google Wifi, Nest Cam, Smart Light and Smart Plug. We chose an existed public script to start raw data collection in "Data Miner". After running the data mining code, we downloaded six columns of data of the selected IoT products from their customer reviews: review-title, review-text, verified purchase or not, number of helpful, number of stars, date of review.

Data pre-processing on all the ten product review files was performed after raw data were collected. The reviews that were not verified purchase were filtered and deleted. This is to make sure all reviews we would use for text mining are reliable. The data files are then prepared to use in text mining and clustering analysis.

CLUSTERING ANALYSIS

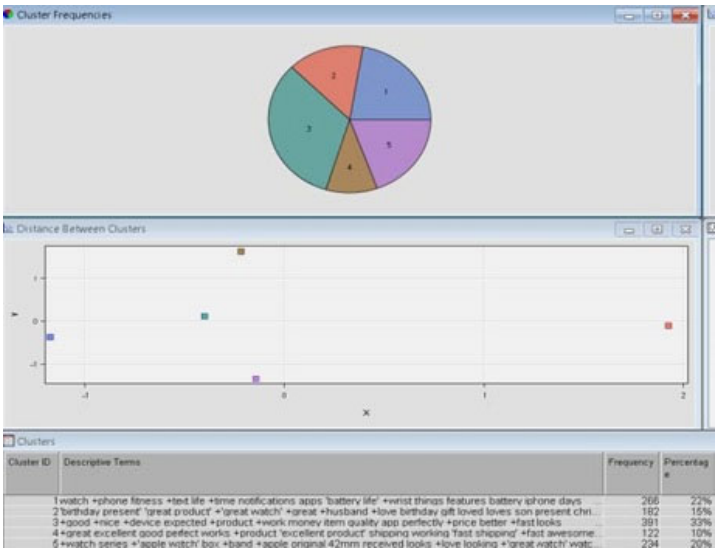
Clustering analysis was conducted using SAS Enterprise Miner. The purpose of clustering analysis is to discover common features, as well as current issues of IoT products from consumers' perspectives. After data preprocessing, the first step is to choose adequate configuration parameters in SAS. Several trials were conducted by adjusting parameters used in SAS Text Mining. Parameters such as term weights, frequency weights, SVD dimensions and resolutions were considered. We found that when the Max SVD Dimension is set as a larger number, or the SVD resolution is set as high, the results tend to be of less clusters. In these cases, some important information may be hidden. When both parameters were set lower, the results will be of more clusters. However, more clusters may not necessarily mean better outcomes. The examination of consumer reviews in each cluster was done manually. We needed to make some decision on the selection between cluster numbers and the accuracy of clusters. Finally, we chose to compromise between more clusters and a higher accuracy, and chose "medium" as SVD resolution, and "medium" as Max SVD Dimension.

In order to better determine the characteristics of each cluster, we set the number of descriptive term as 15; the clustering algorithm as Expectation-Maximization and cluster number as "maximum equals 20". We ran SAS for the first time and analyzed the results. Based on the result, we altered the settings for each product, then repeating this process to obtain ideal results.

The analysis on IoT product Apple Watch

The first product we analyzed was Apple Watch. Figure 1 shows the result of the clustering analysis of the reviews of the Apple Watch sold on Amazon.

Figure 1: Clustering analysis of the reviews of Apple watch



The result has five clusters in total. We summarized the features of each cluster by the descriptive terms for the cluster. We found the first cluster is about the quality and lifetime of this product, according to the key words such as "battery life".

The second cluster is related to considering the product as a gift. By checking the review text, we found many people think Apple Watch is a wonderful choice to give to their friends or relatives as presents.

The third cluster basically focuses on price. We found some people mentioned about the price of Apple Watch, such as “good price”, “worth it”.

We also discovered outliers exist in each cluster. People may not necessarily be talking about exactly the same things as the cluster summarized. Especially in cluster 3, there are some comments like “great”, “excellent”, which may represent some kind of positive sentiment toward the product, but not specifically illustrate any features, such as price.

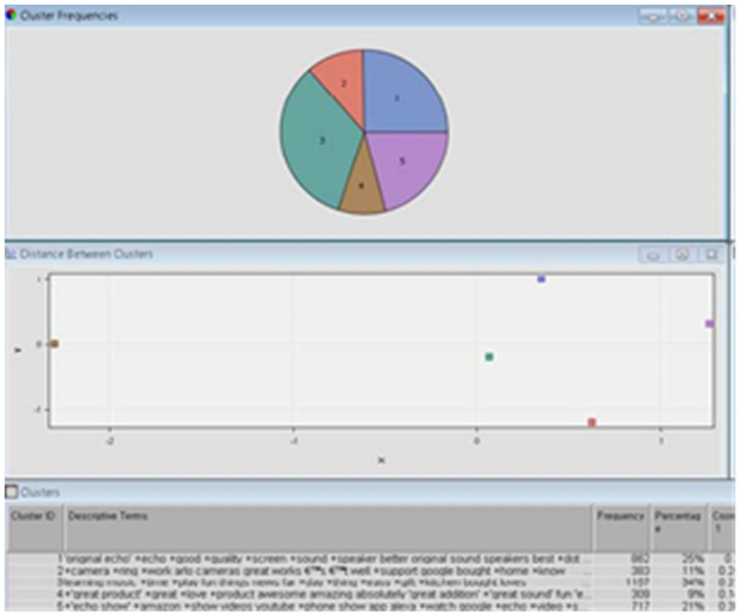
The fourth cluster including information of shipping. People had comments like “fast shipping”, “fast delivery”, etc.

The last cluster talks about the beauty of the products. The exquisite looking is also an attraction to many people.

The analysis on IoT product Echo Show

Second IoT product reviews we analyzed were the comments of Echo Show on Amazon. Clustering analysis similar to Apple Watch is performed and the results are shown in figure 2.

Figure 2: Clustering analysis of the reviews of Echo Dot2



As can be seen from the description of the clusters, Echo Show has great sound, which is a major attraction to people. The second cluster indicates that a good camera is also a huge benefit. Music is the keyword of the third cluster. Obviously, Echo Show plays good music which

people love. From the fourth cluster we know that this product really give lots of fun to customers. The last cluster tells that people care about those videos on flat platforms like Youtube, which provide support for Echo Show that makes it a more competitive product.

The summary of analyses on other IoT products

As mentioned previously, we have conducted clustering analysis for the top 10 products on Amazon, apart from Apple Watch and Echo Show. We also analyzed CUJO, Echo Dot2, Fat Scale, Fithitsurge, Google Wifi, Nest Cam, Smart Light and Smart Plug. Similar text mining analyses are conducted for the reviews of rest of the IoT products. The summaries of clustering results are descried as follows.

For CUJO, there are four clusters about good customer service, good functionalities, convenience to setup and use, as well as the ability of parental control.

As for Echo Dot 2, the key words are price, functionalities, good looking, good quality and enjoyable light or light.

For Fat Scale, people care about price, convenience, sturdy batteries, good for fitness and financial issue.

For Fithisurge, there are a lot more clusters than other products we analyzed. We found clusters for battery, weight tracking, heart rate monitor, warranty policy, nice to wear, good screen and husband love respectively.

The next one is Google Wifi, the important things about the product are signal, connection problem and convenience of setup.

As for Nest cam, stand out points are convenience of installing, good cable, good camera.

The last two products are Smart Light and Smart Plug. For the former one, people focus on connection issue, nice color, convenience of control and good price or quality. For the later one, people focus mainly on link issue, remote control, smart control, lovely turn on as well as convenience of setup.

According to the summary of these products, we are able to find some common features that they share, especially, convenience, fitness as gifts, good functionalities. Besides, we also noticed a small portion of the results is about people's concern, such as privacy issue and security.

CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

Based on clustering analysis, we found common features of IOT products, which people interested in, and features that people concern about. Based on the summary, suggestions can be made for example the company may improve the packaging of IOT products since many have commented on such issue. Others improvements may include: Fixing/reducing technical problems such as poor signals; improving security and privacy issues.

These suggestions are those points summarized from our study that we think IOT products can improve as well as some business tactics which can be useful in improving sales. We think with

the right business strategies and technical improvement, in the future, IOT products will reach a greater success in the market.

There will be more and more intelligent hardware in the future, to connect to the Internet all the time. IoT services and products are promising in the near future across various industries. In the next step, we plan to add and analyze more product reviews to draw comprehensive and interesting conclusions. Also we plan to look into the analysis segments based on various timelines to perform trend analysis as well as to refine the setting of clustering analysis in SAS.

We plan to identify weakness of IoT products. From an academic point of view, adding more literature review as out data resource is also one of our future works. The last thing is to extend our research area to other field like public transportation, supermarket or hospital.

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DECISION SCIENCES INSTITUTE
The Decision Making Process of Productive Capacity in Port Environment

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ABSTRACT

This study aimed to understand how to set up the daily process of decision making related to productive capacity. The research was carried out through six semi-structured interviews. The findings showed that productive capacity decisions are divided into routine and strategic decisions and is guided by rational and intuitive processes.

KEYWORDS: Management decision-making process, Productive capacity, Port environment, Reason, Intuition

INTRODUCTION

The port context has been evidenced as an important link in the intermodal transport chain. Therefore, the need for optimization of port management in order to reduce cost of cargo handling has been increased (Mabrouki, Bentaleb & Mousrij, 2014). To analyze this context, it is necessary to consider that port activities are impacted by many factors, including the dynamics of the world economy, the limitations of port space, cargo handling restrictions, high storage costs, strikes, oversight, inadequate training of personnel, and constant relations and negotiations with public agencies (Lee & Park, 2016; Serra, Martins & Bronzo, 2009; Zampirolli, 2017).

Given this reality, the operation manager in the port context ends up having a fundamental role, since its decisions can impact the productive organizational capacity. However, the current literature on decision making in the port context has been based fundamentally on a more traditional chain. The focus is, for example, on measurement models that seek to identify port strengths and weaknesses in order to provide information that provides optimal strategies to

improve performance (Ha, Yang & Heo, 2017), in specific methodologies for identifying and evaluating (Mabrouki, Bentaleb & Mousrij, 2014) or in the hierarchy of port operations interactions.

In this context, it is possible to realize that what is expected are managers who make decisions based on paradigms grounded on traditional rationality and analytical models of information processing, given a large amount of data and information present in organizations, as well as the advanced technologies that support managerial activities (Agrawal, 2014). Thus, it is believed that the use of formal logic results in the best solution available to any problem faced in any circumstance (Simon, 1947).

However, it must be considered that tool-technology, as well as all information concerning a scenario or a problem situation, will not always be available to the decision maker (Hymowitz, 2001), much less in a complex and specialist context such as the port (Lee & Park, 2016; Serra, Martins & Bronzo, 2009; Zampirolli, 2017). Additionally, the decision can be developed in contexts of multiple actors, organizational and environmental constraints and its potential consequences can be difficult to be evaluated in their totality (Huy, 1999; Weick, 1990).

Thus, it is important to look at other elements that guide the decision-making process, that is, to a more subjective and intuitive nature. The relevance is to understand how they influence, complement and participate in managerial decision making. This can bring relevant contributions to the advancement of emerging approaches in Decision Making, in which such decision drivers find refuge and space (Agor, 1986; Dane & Pratt, 2007; Sayegh, Anthony & Perrewe, 2004).

In this way, the article seeks to fill this gap by explaining how rational and intuitive decision-making are configured in decision-making contexts of productive capacity. Therefore, we try to answer the following research problem: How it is set up the day-to-day decision making process related to productive capacity, given the huge amount of data and information available in organizations?

This study is justified from the following points. First, the reflections here woven walk against the traditional theories speech of Decision Making in management, which consider that the decision based on rational/analytical thinking is what gives greater assertiveness of results at the expense of intuitive decisions (Simon, 1947). Also, we seek to articulate intuition and emotion as critical and influential elements of the decision-making process from emerging approaches to decision making (Carter et al., 2017; Huy 1999; Sayegh, Anthony & Perrewe, 2004).

Second, much of the focus on the development of decision theory so far is related to rational and behavioral aspects of decision making under normal conditions, that is, without the occurrence of atypical events. In this way, it is important to go a step forward on managerial literature, giving attention to the development of theory under decision-making contexts related to risk, uncertainty and time pressure - considered atypical (Sayegh, Anthony & Perrewe, 2004).

Finally, from a practical point of view, this study becomes fundamental in launching a differentiated look at the decision-making process in the port context, usually analyzed in the light of more traditional perspectives, as in the studies of Ha, Yang and Heo (2017), Lee and Choo (2015) and Mabrouki, Bentaleb and Mousrij (2014). The purpose of this work is to contribute to the field by bringing to the fore the use of intuitive aspects as fundamental elements for the decision-making process of port operational managers.

In this sense, the central argument of this study is based on the understanding that there is no "pure" and "ideal" type of decision-making. In fact, what exists are variations of this relationship, that is, rational and intuitive, one being used more clearly, and another depending on the type of configuration of the decision and the type of context in which it is being articulated. Thus, it is assumed that this relationship is inseparable and can make the decision-making process and its results richer and more contributory.

LITERATURE REVIEW

Rational Decision Making

The rational decision-making process is characterized as deliberative, structured and quantitative. Based essentially on logical mental processes, in which decision-making follows an orderly logical sequence, supported by a wide range of statistical tools (operational research and management science) and expert systems technology. The term rational - or logical - is applied to decision making that is consciously analytical. It analyzes problems systematically through the modern arsenal of analytical tools provided by managerial science and operational research (Simon, 1956; 1979; 1987).

Thus, taking as an example the port activity segment, characterized by the high technicity, specialization of the workforce and standardization of activities (Serra, Martins & Bronzo, 2009; Zampirolli, 2017), it is assumed that in this environment configuration of rational decision-making are frequent. Consequently, this context turns an interesting locus of study to understand how managers deal with the amount of data and high technology tools they have at their disposal, as well as with the analytical capabilities of their teams in the configuration of their decision processes (Sincorá, 2016).

Thus, to support the predominantly rational management decision-making process, it is observed in the literature that several researchers have focused on the development of analytical tools for solving problems related to the management of port terminals. Robenek et al (2014) developed an algorithm to optimize the allocation of ships on the berths and the organization of stock in the yards. To address the problems of daily shipyard allocation and crane utilization, Zhen et al (2017) proposed a programming model considering the tidal restrictions and the flow control in the channel. Due to the dynamic nature of the decision problems in a container terminal, Rida (2014) designed an optimal sequence of decisions, based on the Markov Decision Process (MDP) - mathematical model that considers that only part of the situation is under the control of the decision maker - to minimize the total dwell time of ships on the berths.

Zhu et al (2018) developed a computational simulation model to determine the capacity of a coal export terminal regarding to the terminal layout, equipment efficiency, unloading and loading processes, and frequency of ships and trains arriving at the terminal. Legato, Mazza, and Gulli (2014) constructed a simulation and optimization model integrating the tactical and operational levels to support decision-making regarding problems in the allocation of cots. In the same way, Zhen (2015) studied the problems of allocating berths to container ships that periodically dock at a terminal, given the uncertainties that hinders the decision-making process. Also, Pratap et al (2018) analyzed the operation process of a solid bulk terminal and proposed a model of decision support for managers based on rules that aim to minimize the time spent by ships in port.

Intuitive Decision Making

Simultaneously to the rational decision making, it is possible to consider the decision making as intuitive (Simon, 1987). Due to the increasing uncertainty and complexity that managers face in their work environments, it becomes almost impossible to rely solely on a rational decision-making process (Carter et al, 2017), thus opening space for the practice of intuitive decisions.

Also, intuitive processing was reported as effective under conditions of time pressure and uncertainty (Carter et al, 2007; Dane & Pratt, 2007).
Using a unifying concept of intuitive decision-making (Carter et al, 2017), the configuration of this type of decision is processed in two ways: experience and emotion. When based on experience, decision-makers commonly recognize parallels between decisions made in the past with the current one, and so decide accordingly with it. This approach happens because past situations provide suggestions that give "specialized access to information stored in memory", called tacit knowledge (Carter, Kaufmann & Wagner, 2017; Simon 1987).
Emotional processing, based on emotional and affective aspects, happens more often in situations considered uncertain, in which managers experience "intestinal feelings" or "growing excitement in the stomach" so that the propagation of such sensations affect the configuration of decision-making processes. Thus, it is assumed that intuition includes affections or feelings that guide decision-making and action (Agor, 1986; Carter, Kaufmann & Wagner, 2017).

Rational-Intuitive Decisional Processing

The disciplines of psychology and management suggest that intuition can complement rationality as an effective approach to decision making (Carter et al, 2007; Dane & Partt, 2007). Researchers who advocate a dual-process approach – that is, which differentiates a rational system from an intuitive system – assume that these two knowledge systems work together in decision-making. Also, scholars of this thematic present a variety of recommendations on how to use intuitions in combination with more rational decision-making. Simon (1987), for example, asserts that effective managers do not have the luxury of choosing between analysis and intuition – experience involves the use of both types of decision-making. Hodgkinson and Sadler-Smith (2003) argue that the ability to switch between “mental habits” and “active thinking” is the ultimate skill of today's organizations.
Shapiro and Spence (1997), using the same ideas, explain that the ordering of the two types of decision making is also important. They suggest that intuition should be recorded first, followed by a more thorough analytical assessment of the problem. The degree to which rational decision-making must be emphasized, however, must depend on the nature of the task (e.g., structured or unstructured). In contrast, Agor (1986) points out that many managers use intuition after engaging in rational analyzes, to synthesize and integrate the information collected and analyzed.
In 2010, Lejarraga and Gonzalez conducted an experimental research in order to understand how individuals based their decisions on binary choice problems with and without risk prospects. In this way, decisions based on descriptions (rational) and experience-based (intuitive) were analyzed. The results pointed out that depending on how the decision-making scenario presented itself to decision-makers, they had shown themselves to be heavily dependent on experience even when accurate descriptive information was available to them. This trend was marked in decision scenarios with complex descriptions, but, curiously enough, the same pattern was observed for decision scenarios with simple descriptions. This finding revealed that even in the presence of descriptive information about the choice options, individuals still tend to also consider their experience to decide.

METHODOLOGICAL PROCEDURES

Data Collection

This study had as a premise the qualitative research, which aims to interpret how a particular social phenomenon is daily constructed from routines, dilemmas, and problems that permeate the experiences of individuals (Bansal & Corley, 2011). The use of this research perspective is in line with the proposal of this study since it aims to understand how the process of decision-making linked to productive capacity is configured from intuitive, emotional and analytical questions.

More specifically, this study was developed in the port context, considered as an important link in the intermodal transport chain. Within the ports, loading time and production management are relevant aspects, as they influence the economic viability of the terminals (Mabrouki, Bentaleb & Mousrij, 2014). These elements, in turn, are impacted by a series of events that make it complex, such as the dynamics of the world economy, the limitations of port space, cargo handling restrictions, high storage costs, strikes, inadequate training of personnel and constant relations and negotiations with public agencies (Serra, Martins & Bronzo, 2009; Zampirolli, 2017). Given these elements, the manager in the port context ends up having a fundamental role, given that their decisions can impact organizational productive capacity.

Therefore, studying the decision-making of operational managers in the port context becomes crucial, especially based on the idea that decision-making can be characterized in different ways (Simon, 1987), depending on uncertainties and daily events experienced by managers. This discussion represents what Colquitt and George (2011) point out as a starting point in the selection of a topic of study, given that it contributes to the advancement of a great challenge in the port environment, which is the investigation of the dynamics of decisions in this context.

The technique used to collect the data was the interview, which comprises a discursive event in which social occasions can be identified (Spradley, 1979). More specifically, a semi-structured interview script was developed, which allows researchers flexibility in the order and group of questions, even in the face of a previously defined interview schedule.

It was decided to follow the ideas of Spradley (1979) to enable the interview in the elaboration and conduction of the technique. Thus, the initial questions were characterized by the more descriptive aspect, with broader questions aimed at highlighting the daily activities of the interviewees, as well as the history until they became operational managers in the ports where they work. Then, the structural questions were asked to reveal how the interviewees organize their knowledge about the context they are experiencing. The focus was on questions that sought to explore, for example, how respondents make decisions, what types of decision support they receive, and what difficulties and facilities they face in decision-making. Lastly, contrast questions were asked to highlight possible differences or contradictions in the interviewees' speeches. Thus, it was sought to point out to questions about satisfactory and unsatisfactory decisions of managers' daily decision-making process, and to ask when managers felt it was better to make decisions based on reason, intuition or emotion.

The interviews were conducted with six operational managers in October 2017. All of them work in different ports in the Southeast and Northeast of Brazil. For this reason, the interviews were conducted via Internet, through Skype software. Regarding the recording, the voice recorder Almolto Call Recorder was used, which is an extension of Skype that allows to record voice calls. After being recorded, all interviews were transcribed in the Word text editor.

The choice of interviewees was based on the following criteria: 1) to opt for managers operating in the national port segment, considering the particular difficulties faced in the economic viability of activities in the Brazilian port terminals (Lee & Park, 2016; Serra, Martins & Bronzo, 2009; Zampirolli, 2017); 2) opt for managers of operational level, considering that the forms of strategic decision making of these subjects is aligned with the purpose of investigating the decision-making process related to productive capacity. This aspect is considered important for

this article because it seeks to discuss how the decision-making process can provide significant value when integrated at the operational level (Bon & Broersen, 2017).
The choice of research subjects was made possible through a key informant, which is part of the personal network of contacts of the authors of this article. The informant had already worked with the operational managers interviewed, which was crucial to gain access to the field and to develop the interviews. Given this, there was a significant concern on the part of the interviewees to respond in detail to each of the questions.

Data Analysis

Some criteria become important when analyzing data in qualitative research, such as the attribution of meaning, compatibility between theory and what has been observed, generalization capacity, consistency, reproducibility, precision, and verification (Corbin & Strauss, 1990). In seeking to understand how decision-making related to productive capacity is configured in the port context, this study seeks to reveal the criteria mentioned above. For this, content analysis was used as a method of analysis, to make inferences about who, whom, how, with what effect and why an individual says something in a given context (Franco, 2005).
The recording unit adopted in the analysis was a theme type, in which the researcher seeks meanings and meanings in the statements highlighted by the data sources (Franco, 2005). To define the themes, we chose to follow a coding process suggested by Corbin and Strauss (1990), which followed the stages called Open, Axial, and Selective coding. In a complementary way, we considered the authors Glaser and Strauss (2006) and Ryan and Bernard (2003).
Data from the interviews were read from a repetition process (Ryan & Bernard, 2003). Following the orientations of Ryan and Bernard (2003), this initial reading of the data had the objective to find the events, expressions, and ideas that arose with more recurrence. For each moment in which these events were perceived, keywords or phrases were noted.
These annotations were fundamental to begin the process of open codification, which made it possible to start identifying the most recurrent themes in the interviews. Performing the coding process is a fundamental step for data analysis since it transports the researchers and their data to the theory used (Corbin & Strauss, 1990). Thus, some codes have been aligned with the base literature used for the construction of the work (e.g., “tacit knowledge” and "analytical thinking") and others have emerged *a posteriori* (e.g. “decision cost”). In all, 171 codes were found.
Also through the open coding process (Corbin & Strauss, 1990), the codes were compared among themselves to find similarities and differences between them. After this process, codes with similar incidents were grouped into ten blocks (intuition, rationality, decision-making contexts, decision-making cost, analytical skills, professional experience, port operations, decision support, intervening elements and decision-making style) categories and subcategories.
Next, analysis notes (memos) were generated by selecting groupings of codes that had some link between them. With this, the emergence of two main categories could be identified: routine decisions and strategic decisions. Also, we observed the manifestation of two subcategories inherent to the two main categories: decision-making and decision-making. This procedure called memos proves to be significant in the qualitative research scenario because it supports the formulation and revision of theories (Corbin & Strauss, 1990).
Therefore, the next step was to perform the axial coding (Corbin & Strauss, 1990) in an attempt to establish a relationship between the subcategories and their respective categories, and between the categories themselves. The two types of the decision were articulated by two subcategories, classified in the following terms: a) type of context (normal operating situations, under risk/uncertainty and under time pressure); and b) type of decision-making (based on

intuition, reason or both simultaneously). This stage of analysis was fundamental to investigate similarities and differences between subcategories to avoid overlapping as well as to understand what would be verisimilar among the main categories.
The above ideas allowed to proceed to the selective coding stage, which included highlighting the central category, a consequence of the point of interaction between the two thematic categories that emerged from the data. For this, the comparative method proposed by Glaser and Strauss (2006) was adopted. From this method, it is found that, regardless of the type of decision that the operations manager takes, that is, whether routine or strategic, he is always balancing the analytical and intuitive thinking during the configuration of his decision-making process. That is, these thoughts can be understood as decision drivers.
Such a finding has led to the central category, so-called "intuitive-analytical processing," which reveal that there is no "pure" and "ideal" type of decision-making. In fact, what exists are variations of that relationship, one being used more clearly, the other depending on what is being decided. Thus, it supposes that this relationship is inseparable and can make the decision-making process and its results richer and more contributory.

PRESENTATION OF RESULTS

Based on the interviewees' statements, it became possible to characterize part of the port context, as well as to understand how operational managers configure their decisions regarding to productive capacity, which is important for the continuity of operations, adequate customer service and performance satisfactory.
The ports researched are constituted by an infrastructure that includes several services, in which different types of operations are carried out. Among them are the transport and movement of important goods to society. In these operations, the manager must meet certain prerequisites such as compliance with labor safety standards and adherence to environmental laws. In addition, since there is a lot of variability in the port market, not being a fully automated and technology-controlled market, there is still a lot of room for improvement. This situation requires the manager to constantly seek the insertion of new methodologies, especially those that allow the migration from a prevention scenario to a risk management in different types of operation.
In relation to the managers interviewed, they are all from the area of operations, with academic degrees in engineering, computer science, and administration, as well as postgraduate in areas that have given them expertise to the function they hold today. Among their various responsibilities were to supervise teams and projects in development, to check operational results, to coordinate maintenance activities of equipment, to interface with external entities (e.g., navy, maritime pilotage environmental and regulatory agencies, unions, etc), to provide a safe and pleasant environment for the workforce, to meet customer needs, to loading and unloading cargo, schedule ship arrivals and departures, allocate and organize merchandise in the warehouse, and manage the flow of the yard and transport of cargo. Therefore, it can be seen that the body of activities administered by managers is one that directly interferes with the productive capacity of the port.

Port Productive Capacity

The productive capacity of the port is related to the maximum level of value-added activity that a port can carry out in a certain period, under normal operating conditions. Since they do not manufacture products but storage capacity, the operational managers interviewed need to plan

and administer activities that have a direct impact on this capacity, due to the obligation to meet the current and future demand of customers.
In this sense, in managing the productive capacity, managers articulate different types of decisions to allow the continuity and full operation of port operations, especially, assertively using facilities, equipment and labor highly technical and specialized. Such decisions generally refer to activities related to mooring and departure of ships, loading and unloading of goods, maintenance of equipment, yard and warehouse organization, as well as activities inherent in the purchase and rental of machinery, outsourcing of services, permanence and closure of contracts, promotion and dismissal of personnel and relationship developed between the area of operations with internal and external entities to the port.
Thus, in characterizing the day-to-day process of decision-making linked to productive capacity, the existence of two main ways of configuring these decisions, which lie in "routine" and "strategic" decisions, is identified. Such decisions arise from the management of the port productive capacity, having some points of interaction and convergence, however, differentiating themselves through the way in which they are processed and under what conditions they occur.

Routine Decisions

Decisions of productive capacity called “routine” refer to those of the day-to-day operation of the port, so that activities are not interrupted, and there is full continuity, given that port work, happens day and night, every day of the week. The more efficient and effective the performance of the operations as a whole, the better use the operations manager will make of the port capacity, reducing the operating time and, consequently, the dwell time of ships, since it constitutes a critical factor and predictor of performance, as expressed by Interviewee F:

> So, that made us have the performance result impacted because they [the workforce] made ship stoppages, and then, thinking about the ship, it's not a R$ 1.99 business. Each hour of the ship is at least a thousand dollars. A thousand dollars to the exponential of R$ 3,20, this is almost three and two hundred, three and five hundred thousand Reais per hour, not programmed and not justified.

Therefore, routine decisions are linked to the activities of mooring and departure of ships, loading and unloading of goods, maintenance of equipment and, yard and warehouse organization, as reported by one of the interviewees: "(...) every day I always have a decision to make. From a decision, so to say, more operational, which is linked to production. For example, in my area I am responsible for the shipping area, that is, it is the area that is constantly entering and leaving ship, then it is the area that involves the entry and exit of ships (Interviewed C)”. These activities are interconnected, and all are part of the port's business processes, which allow the work to be performed and delivered to the customer.
Also, such decisions are predominantly configured based on rational and analytical decision-making, especially when there is no occurrence of atypical event in operation. Managers generally make massive use of decision support systems, especially those based on information technology (e.g., SGP, OCP, Arena, TAG, Log One, Loud Sister, Navis, Totus, and others). Which extract data and information to guide their decision-making processes. For this, it was observed the need for teams with analytical skills, capable of transforming this data into accessible and applicable knowledge in decision making, since they indicate what is best for the operation regarding productive capacity. Also, the respective decisions have a shorter temporality, that is, take less time to be taken, mainly because routine activities are mostly standardized, precisely to avoid interruption of operations that generate negative impacts on

port operations. The fact that the activities follow a pattern facilitates the agility, precision, and reliability of the decision:

> When I say so, to the maximum I surround myself with data, obviously when they are take-up situations, that's it here and everything else, the decisions are very automatic, because the results are around: 'look, if we do not put a second truck here, maybe we will not achieve the productivity that we are planning and that is necessary to conclude the contract. I'm going in with another truck. Go firm, that's settled. Because we're losing performance, it's not going to cost us anymore. Keep going'. This is a kind of operational decision. Quick and practical within what people are stipulated (Interviewee D).

However, the decision-making reality is also identified in the context of uncertainty, risk and time pressure, considered as unwanted in routine operations. A typical example of occurrence is in Interviewee D's account: "Then the ship is planned to berth at night, then it's late, and then you have to make the decision not to buy labor, reverse plan, change operations drawings and everything else because they are part of the routine line". When decisions need to be configured in abnormal operating conditions, managers end up supporting their decisions in a decision-making process considered intuitive, that is, resort to their tacit knowledge, your experience, the lessons learned, and your feeling/emotion, taking them as drivers of the decision-making process. Also, depending on the complexity of the problem that needs to be addressed, they also rely on the intuition of the work team.

The use of intuitive processing in routine decision-making can also occur when software or IT systems fail, insufficiency and/or lack of data, the emergence of unforeseen situations that compromise the operation - as reported above - and sometimes, as a complement to the rational decision-making process. It is worth emphasizing that when this decision becomes the 'guiding thread' of decision, this more intuitive decision-making process usually emerges more based on the experience of the operations manager or his team. That is, encompassing cognitive elements related to "tacit knowledge", to "memory", to "pattern recognition" and to "parallels".

> So, the system that makes wave measurement for us, in constant high waves, it often has problems, it stops emitting. So they have to have a B plan, and the B Plan is a redundant system that we have, but they do not give all the information. So they have to use the experience of these professionals, which I told you are ship commanders that sailed in all the oceans, use their experience because he looks at the moon and looks at the sea and knows what will happen. It's like a fisherman. So we use the experience of these professionals to make a decision. And many times, in their trajectory, they have made a decision [...] there is one who is sixty years' old who traveled in these oceans with large ships in a much worse condition and without information and technology. So we use this expertise to make decisions (Interviewee E).

Generally, such a decision-making process has a shorter temporality, that is, as the decision-maker triggers recognizable blocks of knowledge stored in his memory, the decision is configured very quickly, almost automatically. Hence the prevalence of its use in situations where time pressure is high, or in conditions where risk and uncertainty are dominant and require responsive responses. However, although managers recognize the use of intuition and its importance in the decision-making context, mainly because port operations are very sensitive to changes in climatic and maritime conditions, it is worth noting the value of pre-planning as a coping strategy for minimization of risk and elimination of uncertainty. This situation occurs from the support of information technology, data and information and people with analytical capabilities, as pointed out by Interviewee A: "I highly value pre-planning, especially when it needs to happen, I try to minimize the risk a lot and eliminate uncertainty with this pre-planning".

Strategic Decisions

Nonetheless, productive capacity decisions are defined here as “strategic”, inherent to decisions that reflect the high impact on the port enterprise in the medium and long-term, mainly regarding performance results. These decisions relate to the purchase and rental of machinery, outsourcing of services, permanence, and termination of contracts, compliance with new regulatory requirements, reorganization of port functions and activities, customer service, contracting, promotion and dismissal of personnel - because the workforce is highly specialized and technical - and a relationship developed between the area of operations with internal entities (other functional areas) and external to the port (Navy, maritime pilotage, environmental and regulatory agencies, unions, etc.).

> So, for example, we are now making an assessment: it has certain service that is done by Vale people, Vale employees, but we are doing some internal analysis that, in the long run, this type of service becomes more expensive if I keep doing it with self-employees. If I outsource this service, I start to do this service with these outsourcers, in the early years this seems to cost more, but over time this cost will decrease, and the company will save money in the long term, i.e. based on that analysis, in this evaluation, everything would take that our decision will be to stop doing this service with Vale itself, and to start hiring someone to do it. In the long run, this gets cheaper.

In strategic decisions of productive capacity, decision making is configured from both rational and intuitive processing. What defines which type of processing is dominant is the matter upon which it is being decided. Decisions involving the purchase and rental of machinery, outsourcing of services, permanence and termination of contracts, compliance with norms and laws, as well as the reorganization of port functions and activities, for example, is the pre-eminent presence of rational processing, in the analysis of data and information coming from both information systems, staff, functional areas and company meetings. The analytical behavior of the manager gains evidence, since he carries out studies and deep investigations in line with the great planning and, assessments before decision-making.

Also, they tend to surround themselves with data and facts, when they have the time to think and decide. The predominance of rational processing mainly occurs because of the high financial impact that such decisions have on the business and the need to develop feasibility and risk analyzes, as well as the preparation of plans to prove to its peers and superiors the consistency and robustness of the decision that was chosen to pursue. This reality can be verified in the following section:

> (...) This was a fact that happened, (...), we had to invest in records of trucks through optical reading, which is an item called OCR here, an acronym. This is a decision that requires investment, so besides the investment, it's a legal service, that alone sells itself: 'Oh, I need to take legal action.' Just to keep a structure of this I needed to redesign my current operations designer. Who made this? The technical level. What did I do? Based on the technical drawing, I took the technical solution and the regulation solution with three or four investment options for decision making together with my top manager (...) (Interviewee F).

However, decisions that include customer service, recruitment, promotion and dismissal of personnel, as well as the relationship between the area of operations with internal and external entities to the port, are based primarily on elements of the intuitive decision-making process. These decisions include the use of the “feeling”, “impression”, and “affection”, denoting intuitive processing based on emotion. Recurrently, the use of a "relational" or "affective intuition" their decision making, need to articulate interpersonal relationships with the actors involved in different moments of the decision process.

> [...] but when the decision is linked to the human assets of the companies, which are the collaborators, the employees, then the emotion bias it enters. For example, if the person failed, I should train or punish. Training would be interesting to me. Punish, another possible way. But you eventually put your emotion there and say, 'I will not punish because I do not know, I think I'm going to shake him, the emotion of him being beaten'. So, there's no way you do not use the emotion; I'd say you even use it when you do not have it (Interviewee E).

Also, the use of intuition can emerge when the decision maker needs to deliberate on a strategic issue in a short period, in which the pressure of the time itself can cause risks to the maintenance of the installed productive capacity. From behavioral point of view, it is seen that time pressure tends to make the operations manager make decisions based on intuitive elements. Also, they select riskier ways of acting when they think that the expected consequences of their decisions may be positives, while the same time pressure can drive them to make less risky decisions by understanding that the expected outcome tends to be negative.

DISCUSSION OF RESULTS

The research findings show that the daily decision-making process linked to productive capacity is based on routine and strategic decisions, which are driven by rational and intuitive processing, in which operations managers use analytical and intuitive elements to outline their decision-making processes.

Decisions that were taken primarily by a more rational orientation, characteristically demonstrated that they were delineated in a deliberative, structured and quantitative way. Based essentially on logical mental processes, in which decision-making followed an orderly logical sequence (Simon, 1987), supported by a wide range of technological tools operated by individuals with analytical capabilities necessary to apply the knowledge generated from treatment of data and facts in the daily decision processes (Sincorá, 2016).

At the same time, decisions that received more intuitive contours presented themselves in two ways: one based on the experience of the manager and his team and another based on the manager's emotional and emotional elements. The most intuitive decision-making was routinely employed in atypical situations in which 'stress phenomena' were configured, such as time pressure, risk, and uncertainty (Carter et al, 2007, Sayegh, Anthony & Perrewe, 2004), induced by climate and maritime changes. In this research, the presence of such contextual variables led the manager to direct his or her decisions based on experience, accessing information stored in memory, represented by frozen analyzes habits and the ability to respond quickly through recognition.

On the other hand, the face-to-face interactions and interpersonal relationships developed by the operational manager with internal and external entities to the port during the design of the decision-making process worked as a 'trigger' for a more 'relational' and 'affective' intuition emerge motivating the manager to decide based on emotion. Simon (1987) points out that intuition based on emotion is very different from intuition motivated by experience (training and tacit knowledge). The behavior of the manager motivated by the emotion is a response to more primitive and instinctive impulses, being able to generate satisfactory results or not, like any other decision contour.

Although it was possible to identify decision-making processes that are relatively rational or more intuitive in both routine decisions and strategic decisions, there is a common presence of both rationality and intuition as drivers of the decision process. In this way, it can be affirmed that there is no "pure" and "ideal" type of decision making that is more adequate. In fact, what

exists are variations of this relationship, that is, rational and intuitive. One being more clearly used, and another depending on the type of decision-making (whether routine or strategic) and the type of context in which (e.g., under pressure of time, risk, or uncertainty), as corroborated in the studies of Agor (1986) and Shapiro and Spence (1997).

Thus, it is assumed that this relationship is inseparable and the combination of these can make the decision-making process and its results richer and contribute to the maintenance of productive capacity. This is consistent with the assumptions of Simon (1987), which states that the manager's experience involves the use of both types (rational and intuitive) in decision-making. In addition, Hodgkinson and Sadler-Smith (2003) argue that the maximum ability of the current organizations is in their individuals to be able to alternate between “mental habits” and “active thinking” in the construction of their decision processes.

From the speeches of operational managers, it is understood that one of the challenges experienced by them in their decision-making realities is in the balance of this configuration, even though it is something subtle and difficult to recognize on their part. They labeled themselves as “essentially analytical and rational” because they understand that more intuitive decision-making does not result in the best available solution to any business problem they face in terms of productive capacity and because they believe that it is not suitable for a context characterized by high technical, specialization of labor and standardization of activities (Serra, Martins & Bronzo, 2009; Zampirolli, 2017), as is the port. However, it was detected that managers, in their routine work, are at all times employing intuitive aspects in the delineation of their decision-making processes, whether as drivers or complements of analytical and rational processing.

Thus, decisions made through "rational-intuitive" processing are those that can provide adequate conditions for managers to make both routines and strategic decisions in their complex decision-making realities. What explain this affirmation is that the combination of analysis data and facts that run on software and IT systems and interpreted by capable employees, together with the use of expertise, the feeling and experiences of the managers, can provide a breeding ground for different possibilities for decision-making settings to be articulated intelligently by the professionals interviewed, with a view to improving their managerial decision-making related to productive capacity.

CONCLUSIONS

The main objective of this research was to understand how it is set up the day-to-day decision making process related to productive capacity, given the huge amount of data and information available in organizations. Based on the proposal, six semi-structured interviews were conducted with operational managers from the port area, distributed by six Brazilian coastal ports. Based on the data, it was possible to show among the findings of the research that the daily decision-making process linked to productive capacity is based on routine and strategic decisions and is guided by rational and intuitive processes.

Nevertheless, it was identified that although the port productive capacity decisions are divided into routine and strategic, it is verified that in both there is the presence of both rationality and intuition as “triggers” of the decision. In general, there is a relationship of interaction and complementarity between these processes, demonstrating that in the investigated decision-making reality interviewed managers combine in different ways “mental habits” (intuitive load) and “active thinking” (rational load). The construction of these decisions is considered as a maximum capacity in terms of decision making in today's corporations, especially for the possibility of making the decision-making process richer and more contributory.

Among the contributions of the study is the development of the proposal within a locus that is little investigated. It is not vast in the national scientific literature, studies that are dedicated to investigating the Brazilian port reality. In this way, with the realization of the research, it became possible to characterize part of the port environment, as well as to understand how the operational managers configure their productive capacity decisions, which in turn, are important for the continuity of operations, customer service and reach of results. Also, the segment investigated has social relevance, given that among its main functionalities is the transport and movement of goods necessary to society.

Theoretically, this article allows us to advance in the discussion of how the interrelationship between rational and intuitive decision-making in normal working contexts and under the influence of "stressor" variables - time pressure, risks, and uncertainties. Although many provocative ideas about the interaction between rational and intuitive decision making have been suggested in the literature, empirical and qualitative research in the field, particularly in the field of management, remains insufficient.

Therefore, the results of this research provide significant evidence of relevant associations between rational and intuitive decision-making process. However, limitations of the study can be woven, such as the failure to satisfactorily fill one of the articulated gap, related to the non-vigilance of the Decision Making literature for the development of theories under decision-making contexts related to risk, uncertainty and time pressure. Although they have been shown in the results, the contribution to this aspect still lacks more robust investigations.

For future research, it is possible to delve deeper into the discussion about how the decision-making process, in fact, is specifically delineated under crisis contexts, time pressure, risks, and uncertainties, especially in different decision-making realities. Also, it is recommended to analyze how the decision-making configuration (rational and/or intuitive) determines the result of the decisions taken, considering the influence of the analytical capabilities and the manager's experience.

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DECISION SCIENCES INSTITUTE
The development of the individual analytical orientation construct and measures

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ABSTRACT

Many organizations are attempting to implement business analytics solutions without addressing the issue of individual end user abilities and capabilities. We use previous structures of other orientation types to build and test the construct of Individual Analytics Orientation and its relationship with decision quality in both performance results and cognitive dissonance. University students from France, USA, Brazil and Slovenia are used to develop and test the measures and examine the relationship to decision quality. The results provide three independent constructs, a set of validated measures to use in further research and statistical validation of the relationship to decision performance.

KEYWORDS: Business analytics, analytical orientation, decision quality

INTRODUCTION

Many organizations are attempting to implement business analytics solutions without addressing the issue of end user abilities and capabilities. Analytics have the potential to transform the way organizations make decisions (Sharma, Reynolds, Scheepers, Seddon, & Shanks, 2010) but the implementation of analytics is a challenging initiative (Lukman, Hackney, Popovič, Jaklič, & Irani, 2011).

The complexity of businesses today means that a company needs to perform a considerable analysis of data gathered in vast quantities on a regular basis (Azvine, Nauck, & Ho, 2003). This makes it necessary to start using advanced analytics to analyze structured and unstructured data from both within organizations and from its environment. Analytics are not the technology in and of itself, but a group of tools used by people with skills and motivation to acquire information, analyze it and predict the outcomes of problem solutions (Bose, 2009).

Organizations are getting very interested in how to exploit analytics in decisions and how analytics can be used to leverage process improvement. The objective on exploiting analytics is to make the decision making process faster, more reliable, more consistent, and more aligned with the strategy and operations of the companies.

The available literature largely focuses on anecdotal case studies (DAVENPORT, 2006), statistical analysis of the impact of analytics (Trkman, McCormack, de Oliveira, Ladeira, & Oliveira, 2010) and the hype in the professional press. This is clearly important, especially in the initial, exploratory phase of the research of the impact of analytics. However, it gives little guidance about the factors that lead to the outcome of analytics implementation; a change in decision-making and consequently performance.

Davenport (DAVENPORT, 2006) mentioned “Analytical Skills” as the first action step for organizations to obtain analytical competition. He used the expression “Begin to build analytical skills”, which means that it’s often difficult to find individuals with some important requisites like quantitative and business skills. He has also mentioned that organizations should start looking for these requisites as soon as possible, and hire them in sufficient volume to create “critical mass”. How do you recognize these factors in individuals and recruit them to be analytical users?

A Gartner report (Tohamy, 2017) recommends that companies should train internal resources who lack formal data scientist training but exhibit a strong affinity for advanced analytics. One early and critical task for supply chain analytical leaders is to inventory their organization's current analytical talent. Tohamy (2017) recommends that they cast a wide net for these resources. In an age where technology is ubiquitous in our daily lives, many supply chain professionals have both the analytical proficiency and affinity to become effective analytical team members. Research shows that fewer than 20% of supply chain managers say they have excellent knowledge relative to supply chain analytics, while more than 45% say they have at most basic knowledge of this subject matter but suspect big differences among companies depending on the level of talent to manage these programs.

We propose that individual analytical orientation, or what you think about the topic of analytics, is an important concept that may be able to answer this question. Considering the high level of smart phone and computer use, if you are analytically oriented you will have developed analytical capabilities and you will value data and computing as a key part of your decision-making process.

The paper presents a construct and measure development effort that resulted in a validated set of construct and measures to be used in accomplishing this and can be used in future research.

The structure of the paper is as follows. First, the construct of individual analytical orientation (IAO) is developed. Then the measures are developed, tested and examined. The main findings and further research topics are set out at the end.

LITERATURE REVIEW

Davenport et al (2007) describe Analytics as the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive decisions and actions.

Davenport (2007) also mentions that a good analyst must have the ability to express complex ideas in simple terms and have the relationship skills to interact well with decision makers. Another example of an analytical profile was: “people with expertise in math, statistics and data

analysis who can also speak the language of business and help market their work internally and sometimes externally."

From a historical perspective, Briceland (1981) stated that Analytical skill is the ability to visualize, articulate, and solve both complex and uncomplicated problems and concepts and make decisions that are based on available information. These skills include demonstration of the ability to apply logical thinking, gathering and analyzing information, designing and testing solutions to problems, and formulating plans.

Others define Analytical skills as a manager's ability to use logical and scientific approaches to analyze problems and confront the business or to identify business opportunities (Goodman, Ladzani, Bates, de Vries, & Botha, 2005).

Considering that analytical skills are related to individual abilities, we understood it would be also relevant to explore the orientation of such individuals to properly use their skills/capabilities.

Organizational orientation can be understood as a set of socially complex thinking and learning processes that are unique, difficult for competitors to imitate, and resound internally throughout the organization (Barney, 1986; Hult, Ketchen, Adams, & Mena, 2008). In this sense, organizational orientation can be considered as strategic capabilities that are intangible and grows from complex cognitive behaviors that builds the basis for organizational strategic goals (Barney, 1986; RUSSO & FOUTS, 1997).

Managers who recognize the value in organizational orientations will develop them with the intent to positively impact firm performance (Mello & Stank, 2005; Noble, Sinha, & Kumar, 2002). Recognizing the need for analytics orientation and developing this is a critical focus of today's manager.

If you are analytically oriented then you should develop your individual analytical capabilities. Analytical capabilities may be conceptualized as an organizations ability to consolidate, analyze, and leverage its information resources to support its decision-making activities, enabled through cross-functional integration of processes and operations, people, and managerial capabilities (Plakoyiannaki & Tzokas, 2002).

Holsapple, Lee-Post, and Pakath (2014) offer that analytical capabilities are competencies possessed by an organization and its processors. Such capabilities determine what can be done in the way of evidence-based problem recognition and solving. It is suggested that analytical capabilities for managing evidence, using models, and logical reasoning can include: i) the use of techniques that are quantitative, qualitative, and combinations; ii) the use of statistical techniques; the use of systematic reasoning; iii) to work effectively with models that are: Descriptive/Explanatory, Predictive, or Prescriptive; and iv) to work effectively with evidence (e.g., databases, click-streams, documents, sensors, maps).

Most of the previous research e.g. (Holsapple et al., 2014; Mello & Stank, 2005; Noble et al., 2002) either explicitly or implicitly study analytical orientation/capabilities at the organizational level. We argue that, while important, this is insufficient. Everyone, regardless of their role in the organization, possesses a certain level of tool expertise and data processing capabilities which influences how he or she is inclined to use available data and information when making

decisions. The definition and measurement of Individual Analytical Orientation and Capabilities is therefore an important first step in the examination Organizational Analytical Orientation.

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THEORETICAL DEVELOPMENT/MODEL

This descriptive-conclusive investigated the relationships among variables and constructs of a conceptual model based on a quantitative effort relying on a typical structured process of investigation and data analysis. An initial phase was conducted in December 2017 using a group of (137), BS, MsC and PhD in Business Management candidates to assess adjustments to the data collection tool and group the measures into factors. The initial questions tested were developed through literature reviews and interviews and are self-assessment measures using a five point Likert scale. Factor analysis was used to group the measures into preliminary constructs.

The final data collection was executed in February 2018 at a triple-crown accredited business school in Slovenia. First year undergraduate business students were asked to fill out the survey before the start of the first computer lab of the Introduction to information systems course. The survey was translated into the Slovenian language by one of the researchers. The students completed the survey online using the school's computer to access the survey. Instructors were present to help with any technical problems. This assured the maximum participation of the students and avoided the non-response bias. Given the fact that we wanted to generalize our findings to the general non-specialist population of business users, the use of the student sample is justifiable (see (Compeau, Marcolin, Kelley, & Higgins, 2012)). After analyzing absent data and outliers, the final sample was collected and was composed of three hundred and seventy-one cases (371).

The final research model is based on three independent and two dependent constructs. The independent constructs are:
TTC – Tools and Techniques Capabilities (how capable are you with analytical tools)
IAO – Individual Analytical Orientation (how you use analytical data and models in making decisions)
DPC – Data Processing Capabilities (how you use data, critical reasoning and facts in making decisions)

The dependent constructs are:
HP – Hangover (regret about your decisions)
GP – Good Performance (self-reported decision performance)

Data Analysis – Construct Validation

We built the research model from theory then assessed the measurement models (reliability and validity) and the structural models (hypotheses). The common method bias in order to assure robust findings was also investigated. Figure 1 shows the model examined.

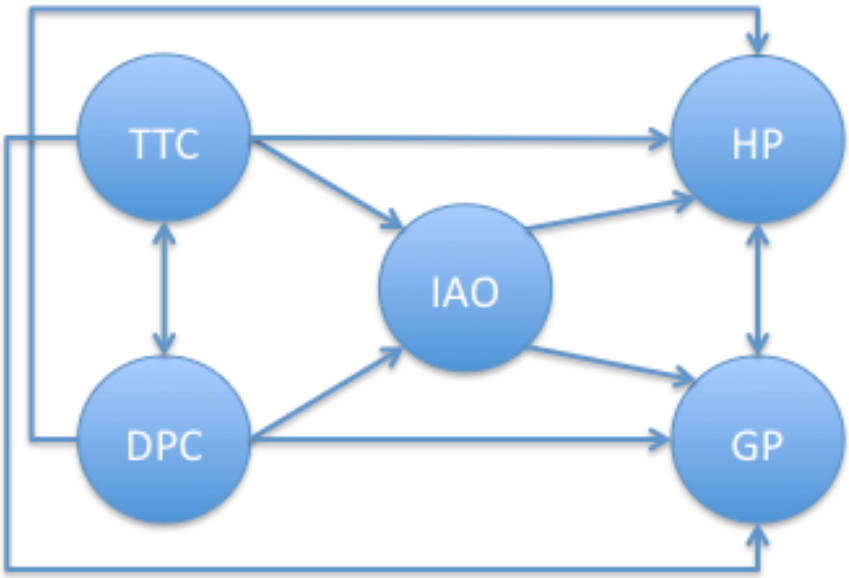


Figure 1: Theoretical Model

To analyze the results we used covariance-based structural equation modeling (CB-SEM) which assesses a new theoretical model (Fornell & Larcker, 1981; Gerbing & Anderson, 1988). Analyses were performed using lavaan: An R Package for Structural Equation Modeling (Rosseel, 2012).

Further, aiming to investigate the suggested relationships, the research model was tested. The goodness of fit of the model was determined using the ratio of chi-square to degrees of freedom (χ^2/df), the Comparative Fit Index (CFI), the Root Mean Square Error of Approximation (RMSEA) (Browne & Cudeck, 1992; Rosseel, 2012, 2014).

SEM comprised two components, which need to be tested separately: the measurement model (relationships between the concepts and their measurement indicators) and the structural model (relationships between all constructs).

Assessing the measurement model

We first assessed the measurement models with a confirmatory factor analysis, using maximum likelihood estimation with the lavaan. To access discriminant validity we used Heterotrait-monotrait (HTMT) ratio of correlation.

HTMT values close to 1, indicates a lack of discriminant validity. Using the HTMT as a criterion involves comparing it to a threshold. If the value of the HTMT is higher than .85 one can conclude that there is a lack of discriminant validity (Kline, 2011). Fornell and Larcker criterion and the assessment of the cross-loadings are inadequately sensitive to detect discriminant validity when compared with Heterotrait-monotrait (HTMT) criterion (Ab Hamid, Sami, & Mohmad Sidek, 2017; Henseler, Ringle, & Sarstedt, 2015). Thus, the use of HTMT criterion should be adopted for this purpose so that the interpretation of the causal effect in the modeling analysis is not misleading.

	HP	GP	IAO	TTC	DPC

HP	1				
GP	0.826	1			
IAO	0.123	0.573	1		
TTC	0.134	0.166	0.181	1	
DPC	0.352	0.443	0.302	0.325	1

Table 1: Heterotrait-monotrait (HTMT) ratio of correlation

As expected, the indicators all showed significant positive factor loadings, with standardized coefficients ranging from .143 to .739 (see Appendix). There were also significant positive correlations amongst latent factors with Good Performance (GP) and negative with Hangover Performance (HP) (see Table 2).

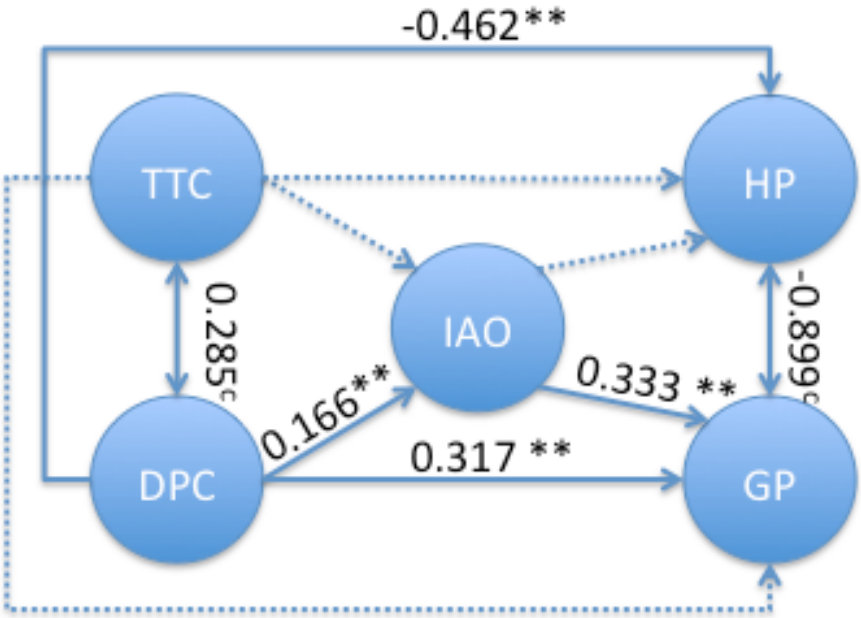
	HP	GP	IAO	TTC	DPC
HP	1				
GP	-0.844	1			
IAO	0	0.352	1		
TTC	0.034	0.077	0.126	1	
DPC	-0.37	0.329	0.185	0.285	1

Table 2: Correlations between latent variables

Converging normally after the 35th interaction, the model, shown revealed an adequate/close fit of the data, χ^2 = 530.027, df= 179, χ^2/df = 2.961, *p-value* = 0.000, CFI = 0.799, RMSEA = 0.073 [.066;.080], TLI = .764.

The CFA results indicated that the reflective items capture the underlying latent variables well and suggested a satisfactory level of convergent validity and internal consistency. Without exception, each item loaded on its hypothesized factor with a significant loading (all loadings significant at p<.001), thus supporting convergent validity.

To gauge the extent to which common method variance CMV might pose a problem, we compared our base CFA model with an extended CFA model which includes a single latent method factor that is uncorrelated with all other latent variables and that loads equally on all items (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). The results showed that the original model fits the data better than the model with a single latent factor. To compare both models in terms of their difference, we applied a chi-squared difference test that revealed a significant chi-squared difference ($\Delta\chi2$=712.29, p-value < 2.2e-16), suggesting that CMV is unlikely to introduce a substantial bias.



** p-value < 0.05
c covariance p-value < 0.05

Figure 2: Model Results

To test the hypotheses, regression equations were formulated and the respective betas were tested.

HP = -0.462 * DPC + Error

Data Processing Capabilities (DPC) was proven to be significant in explaining Hangover since more DPC would mean lower Hangovers. Individual Analytical Orientation (IAO) and Tools and Techniques Capabilities (TTC) were not significant to explain Hangover Performance (HP)

GP = 0.333 * IAO + 0.317 * DPC + Error

Individual Analytical Orientation (IAO) and Data Processing Capabilities (DPC) demonstrated a positive and significant relationship with Good Performance (GP) and Tools and Techniques Capabilities (TTC) were not significantly related with GP.

Individual Analytical Orientation (IAO) showed a significant and positive relationship with Data Processing Capabilities (DPC) but not significant with Tools and Techniques Capabilities (TTC). Despite of the fact of TTC showed no significant impact with other constructs of the structural model, a significant and positive covariance was shown between TTC and DPC. Additionally, a strong negative and significant relationship between HP and GP was identified. This result shows evidences that Hangover is higher when bad performance results are generated and vice-versa.

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RESULTS AND CONCLUSIONS

From this research, there appears to be validated constructs and measures for Individual Analytical Orientation and Capabilities with significant relationships to self-reported decision performance. The use of Data, Fact Based Decisions and the use of models and tools are all shown to be valid measures with relationships to Individual Analytical Orientation and Decision Performance. The capabilities that are validated in this research can be used to test the organizational readiness for analytics. This will identify what individual analytical capabilities are present or need to be improved to successfully implement an project of analytics. Hangover, or decision regret, was influenced by Data Processing Capabilities and negative Decision Performance. This makes sense. When you have less Data Processing Capabilities your Decision Performance generally decreases and you doubt your decisions (hangover). The use of data and models is a learned behavior driven by need or requirements. The importance of Individual Analytical Orientation became clear in this research with its relationship to Decision Performance but how do you develop this in individuals? This is a good area of future research with a research question of: How are Individual Analytical Orientation and Capabilities measured and influenced within an organization?

This was an investigative study and just the first step. Further research must be done on the organizational level to further validate these constructs and measures.

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APPENDIX

Questionnaire

q1	I think that data is very important to my life.
q2	I make important decisions by analyzing data.
q3	I use analytical model (simple or complex) when making important decisions.
q5	I make fact based important decisions.
q6	I often use a Map App on my phone, iPad or computer.
q7	I often use "user reviews" (I.e. Yelp, etc.) when making an important decision.
q8	I usually search for data when considering an important decision
q9	I generally make good important decisions.
q10	I often must reverse course on an important decision because I was wrong
q11	I have confidence in my important decisions.
q12	I am often concerned about my important decisions (hang over) after they are made.
q13	If you were required, how easy it would be to: Find the right data to support your important decisions
q14	If you were required, how easy it would be to: Prepare the right data to support your important decisions
q15	If you were required, how easy it would be to: Exploit the right data to support your important decisions
q16	If you were required, how easy it would be to: Use tools (Ex: Excel, Power BI, Tableau) to describe what is happening
q17	If you were required, how easy it would be to: Use tools (Ex: Excel, Power BI, Tableu) to predict what is going to happen
q18	If you were required, how easy it would be to: Use tools (Ex: Excel, Power BI, Tableu) to prescribe what should be done
q19	If you were required, how easy it would be to: Make use of critical reasoning when making important decisions
q20	If you were required, how easy it would be to: Use evidences/facts to recognize problems
q21	If you were required, how easy it would be to: Use modeling techniques (i.e. Excel templates, etc.) to represent problems
q22	If you were required, how easy it would be to: Use modeling techniques (i.e. Excel templates, etc.) to solve problems
q23	What is your degree preference?

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Statistical Results

lavaan (0.5-23.1097) converged normally after 35 iterations

Number of observations	371
Estimator	ML
Minimum Function Test Statistic	530.027
Degrees of freedom	179
P-value (Chi-square)	0.000
P-value (Bollen-Stine Bootstrap)	0.000

Model test baseline model:

Minimum Function Test Statistic	1953.014
Degrees of freedom	210
P-value	0.000

User model versus baseline model:

Comparative Fit Index (CFI)	0.799
Tucker-Lewis Index (TLI)	0.764

Loglikelihood and Information Criteria:

Loglikelihood user model (H0)	-8881.478
Loglikelihood unrestricted model (H1)	-8616.464
Number of free parameters	73
Akaike (AIC)	17908.955
Bayesian (BIC)	18194.838
Sample-size adjusted Bayesian (BIC)	17963.232

Root Mean Square Error of Approximation:

RMSEA	0.073
90 Percent Confidence Interval	0.066 0.080
P-value RMSEA <= 0.05	0.000

Standardized Root Mean Square Residual:

SRMR	0.067

Parameter Estimates:

Information	Expected
Standard Errors	Standard

Latent Variables:

	Estimate	Std.Err	z-value	P(>|z|)
HP =~				
q12	0.729	0.081	9.023	0.000
q10	0.312	0.047	6.696	0.000
GP =~				
q11	0.528	0.046	11.444	0.000
q9	0.391	0.039	10.109	0.000
q5	0.143	0.038	3.743	0.000
IAO =~				
q2	0.397	0.044	9.031	0.000
q3	0.386	0.052	7.361	0.000
q8	0.395	0.040	9.861	0.000
q7	0.335	0.071	4.692	0.000
q1	0.290	0.038	7.660	0.000
q6	0.239	0.051	4.658	0.000
TTC =~				
q16	0.664	0.046	14.381	0.000
q17	0.739	0.041	17.845	0.000
q18	0.717	0.041	17.570	0.000
q21	0.495	0.045	10.944	0.000
q22	0.441	0.043	10.184	0.000
DPC =~				
q15	0.499	0.045	11.094	0.000
q19	0.388	0.051	7.543	0.000
q20	0.349	0.044	7.849	0.000
q13	0.569	0.044	12.840	0.000
q14	0.534	0.046	11.703	0.000

Regressions:

	Estimate	Std.Err	z-value	P(>|z|)
HP ~				
IAO	0.064	0.089	0.717	0.473
DPC	-0.462	0.105	-4.386	0.000
TTC	0.161	0.084	1.917	0.055
GP ~				
IAO	0.333	0.094	3.547	0.000
DPC	0.317	0.093	3.422	0.001
TTC	-0.047	0.081	-0.580	0.562
IAO ~				
DPC	0.166	0.082	2.015	0.044
TTC	0.081	0.076	1.078	0.281

Covariances:

	Estimate	Std.Err	z-value	P(>|z|)
TTC ~~				
DPC	0.285	0.062	4.620	0.000
.HP ~~				
.GP	-0.899	0.096	-9.340	0.000

Intercepts:

	Estimate	Std.Err	z-value	P(>|z|)
.q12	2.968	0.054	54.939	0.000
.q10	2.806	0.044	63.586	0.000
.q11	3.879	0.042	93.366	0.000
.q9	3.698	0.038	97.953	0.000
.q5	4.000	0.037	108.232	0.000
.q2	4.078	0.038	108.422	0.000
.q3	3.132	0.045	69.877	0.000
.q8	4.111	0.034	120.386	0.000
.q7	3.167	0.060	52.672	0.000
.q1	4.140	0.032	127.685	0.000
.q6	4.342	0.043	100.389	0.000
.q16	3.067	0.049	62.146	0.000
.q17	2.749	0.047	58.920	0.000
.q18	2.860	0.046	62.443	0.000
.q21	2.992	0.046	65.297	0.000
.q22	2.889	0.043	66.679	0.000
.q15	3.097	0.042	73.182	0.000
.q19	3.291	0.047	70.664	0.000
.q20	3.388	0.040	83.967	0.000
.q13	3.040	0.042	71.861	0.000
.q14	2.836	0.043	65.626	0.000
.HP	0.000			
.GP	0.000			
.IAO	0.000			
TTC	0.000			
DPC	0.000			

Variances:

	Estimate	Std.Err	z-value	P(>|z|)
.q12	0.449	0.104	4.311	0.000
.q10	0.606	0.048	12.610	0.000
.q11	0.293	0.040	7.271	0.000
.q9	0.339	0.031	10.805	0.000
.q5	0.481	0.036	13.371	0.000
.q2	0.361	0.035	10.333	0.000
.q3	0.590	0.050	11.741	0.000
.q8	0.270	0.029	9.271	0.000
.q7	1.224	0.095	12.948	0.000
.q1	0.302	0.026	11.542	0.000
.q6	0.634	0.049	12.958	0.000
.q16	0.463	0.041	11.328	0.000
.q17	0.262	0.031	8.464	0.000
.q18	0.265	0.030	8.781	0.000
.q21	0.533	0.043	12.538	0.000
.q22	0.502	0.040	12.713	0.000
.q15	0.416	0.039	10.752	0.000
.q19	0.654	0.052	12.540	0.000

.q20	0.482	0.039	12.436	0.000
.q13	0.341	0.038	9.058	0.000
.q14	0.407	0.040	10.245	0.000
.HP	1.000			
.GP	1.000			
.IAO	1.000			
TTC	1.000			
DPC	1.000			

DECISION SCIENCES INSTITUTE

The Effect of Jumbling Multiple-Choice Questions on Exam Scores

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ABSTRACT

Instructors may wish to administer multiple-choice examinations where the questions do not appear in the same order for all students. Against this, orderings of questions inconsistent with their order in the published bank (which generally follows the text content) may be disconcerting to students. Accordingly, the different orderings may serve to (dis)advantage students taking an exam with one ordering of the questions over students taking an exam having a different ordering of the same questions. The present research investigates the effect on exam scores of three different question ordering strategies.

KEY WORDS: Multiple-choice questions, Ordering questions on exams

Full text and references available upon request.

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The Effects of Man-Made Supply Chain Disruptions on Employee Job Satisfaction, Job Engagement, and Employee Productivity

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ABSTRACT

The effects of a supply chain disruption on employees' job satisfaction and job engagement has not been given serious treatment in the operations management (OM) literature (Kleindorfer & Saad, 2005; Schmidt 2015). Other researchers in the organization behavior (OB) literature (Chen, Ployhart, Thomas, Anderson & Bliese, 2011; Judge, Heller & Mount, 2002; Judge & Kammeyer-Mueller, 2012; Riketta, 2008 among others) have investigated employee job attitudes in relations to supply chain disruptions or in general. However, despite this overwhelming body of work in OB and some discussion in OM, we still have a very limited understanding of the effects of supply chain disruptions on employees' psyche and firm performance.

KEYWORDS: supply chain disruptions; job satisfaction; job engagement; firm performance

INTRODUCTION

Employee engagement may seem like a frill in a downturn economy. But it can make a big difference in a company's survival. Gallup estimates the cost of America's(employees'?) disengagement crisis at a staggering $300 billion in lost productivity annually. When people don't care about their jobs or their employers, they don't show up consistently, they (either?) produce less, or their work quality suffers.

Amabile and Kramer (2011)

Supply chain disruptions, whether natural or man-made create operational and performance risk for the focal companies and their suppliers and can reduce shareholder value (Hendricks and Singhal, 2008). However, the question of how employees' attitudes, namely job engagement, job satisfaction change following disruptions remains an [un]der-researched phenomena. Moreover, subsequent to a man-made supply chain disruption, does the impact of the disruption

negatively affect employees' job attitudes and firm performance? Further, does the degree to which an individual identifies with an organization moderate the effects of a supply chain disruption on employee job satisfaction and job engagement? In this study, we assert that firms are better able to respond and recover from a disruption if they have engaged and satisfied employees. However, little attention has been devoted to understanding the impact of disruptions on employee outcomes. The extant operations management (OM) literature is replete with discussions about natural disaster disruptions and there is growing interest in man-made disruptions and their effects on companies' supply chains (Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007; Kleindorfer & Saad, 2005; Schmidt 2015; Qi, Shen & Snyder, 2010; Van Wassenhove, 2006). In the majority of these studies, the firm, the supply chain, the supply chain partner or the shareholder is usually the unit of analysis. In this paper, we focus on the individual employee. Few OM studies, for example Haynie, Flynn & Mauldin, (2017); Jiang, Baker & Frazier (2009); Kolay, Lemmon, & Tashjian (2016) and Wangel (2012) have sought to understand the impact of companies' decisions on employees' job attitudes. Given the costs of a responding to and recovering from a disruption, we need a better understanding of the effects on disruptions on employees as firms seek to maintain resilience.

Organizational behavior researchers have devoted considerable discussion to the impact of employees' job attitudes on firm performance (Chen, Ployhart, Thomas, Anderson & Bliese, 2011; Ellinger, Ellinger & Keller, 2003; Judge, Heller & Mount, 2002; Judge & Kammeyer-Mueller, 2012; Riketta, 2008; Schneider, Hanges, Smith & Salvaggio, 2003). We still have a very limited understanding of the effects of man-made supply chain disruptions on employee outcomes, i.e. their job attitudes and performance. Given that disruptions are ubiquitous in the supply chain, the impact of this phenomena on employees' level of engagement and job satisfaction has important implications for scholars as well as practitioners (de Menezes, 2012; Sydow & Frenkel, 2013).

The current research applies contingency theory and social exchange theory (SET) to (state purpose of study in direct manner here) Past research has utilized SET to examine the buyer-supplier relationship, (Tanskanen 2015), organizational commitment, (van Kippenberg and Sleebos, 2006), and job embeddedness, (Hom et al., 2009). To the best of the authors' knowledge, SET has not been applied to discussions of job satisfaction and job engagement with respect to man-made supply disruptions. Specifically, we investigate two types of man-made supply chain disruptions: supply chain partner insolvency (SCPI) and labor disputes (LABDIS) and examine how these types of disruptions affect the job attitudes of those involved in that supply chain network and their subsequent job performance. Supply chain partner insolvency is regarded as a type of man-made supply chain disruption which interrupts or barges on operations at both the focal company and its buyer or buyers. Labor disputes are regarded as a type of man-made disruption that can occur at the focal firm or at any node in the supply chain network which can have a significant negative impact on firms' operations.

This study departs from previous discussions on job attitudes in the OM literature (see Jiang, Baker & Frazier, 2009; Agarwal & Gupta, 2018; Haynie, Flynn & Mauldin, 2017) to provide insight into the process through which employees' job satisfaction and job engagement affect their productivity. Job satisfaction is directly linked to productivity as well as to personal well-being (Aziri, 2011). Employee job satisfaction is related to employee job engagement in that both constructs describe the emotional experiences that employees derive from their jobs (Locke, 1976; Sari & Judge, 2004). Specifically, employee job satisfaction describes the pleasurable or positive emotional state resulting from the appraisal of the employee's job or job experiences (Sari & Judge, 2004) cited in Judge (1976). We explore these constructs in in an OM context under the conditions of a man-made supply chain disruption. Companies suffering the effects of a supply chain disruption want to minimize the impact on their ongoing operations. Employees are affected by these exogenous shocks to the company's operations. To the best of our knowledge, the degree to which these employees are affected through their level of job

engagement and job satisfaction has not been addressed in the literature. We address these issues in this study. Applying the foregoing theoretical framework, we address the following research questions:

RQ1. Do man-made supply chain disruptions directly or indirectly affect employees' work attitudes, specifically, job engagement and job satisfaction?

RQ2. Does the change in employees' job attitudes as a result of the disruption affect their productivity?

This study contributes to our understanding of man-made supply chain disruptions and the impact on employees' job attitudes. We utilize an integrated theoretical framework - combining Contingency and Social Exchange theories to gain a new perspective on this phenomenon. Man-made disruptions have not been explored to any degree in the OM literature relative to job attitudes. We extend the discussion by Haynie et al (2017) who focused on job engagement and its impact on employee task performance to highlight the impact of man-made disruptions in the supply chain. This study also has implications for practitioners seeking to understand how to maintain and improve employees' morale after the firm has experienced, either directly or indirectly, a man-made supply chain disruption.

The rest of the paper is outlined as follows: Section II provides the literature review, Section III provides theoretical framework and propositions; Section IV provides the discussion and implication; Section V provides limitations and future research directions; and Section VI concludes the discussion.

LITERATURE REVIEW

The supply chain is an interconnected network of interested parties where the decisions and strategies of one organization can influence the outcomes in other organizations along the supply chain (Wright & Kaine, 2015). That interconnectedness poses several kinds of risks for members of the supply chain. In their study, Jiang et al. (2009) discuss the operational risks posed by labor disputes, while Kolay et al. (2016) focus on the contagion effect distressed firms can have on the economic health of their rivals, suppliers, and creditors. Wengel (2012) suggests that one can assess the overall financial health of a business based on the demeanor of the employees. This suggest that companies' operations success or failure can have an impact on employees' affective states. This study investigates the impact of a disruption on the dyadic relationship between employees of the focal company or companies in the extended supply chain. Table 1 (see below) lists some of the various types of supply chain disruptions. These disruptions are not the only risks to the ongoing operations of an entity. In addition to exogenous shocks, research has indicated that certain management processes, e.g. Just-in-Time (J-I-T), Lean, and TQM (Total Quality Management) can have an impact on employees' job satisfaction, job engagement, and job embeddedness (de Menezes, 2010; Hom et al., 2009; Parker, 2003).

Other research had investigated the effects of other job characteristics on employee and firm performance. Lee et al. (2004) in their study noted that job turnover has been a major research topic in organizational studies for more than 50 years. In the current work, we highlight an area that has gone under-research during the same time frame – the effect of a supply chain disruption of employee's level of job satisfaction and job engagement on employee productivity and firm performance. Does a disruption create uncertainty among workers of the focal firm or an affected firm in the supply chain? And what can firms do to mitigate the effects on employees' job attitudes? Further, can firms predict a disruption and also work to mitigate its effects or prevent its occurrence? The level of satisfaction or engagement may be affected by other factors discussed in the literature, e.g. turnover intentions, level of commitment, etc. (Judge et al., 2012). Despite the extensive coverage in the literature, we do not understand the relationship between certain job attitudes and man-made supply chain disruptions and its attended effects on employee performance.

There is considerable discussion in extant literature on job engagement (Basit, 2017; Rich, LePine, & Crawford, 2010; Robertson, Birch, & Cooper, 2012; Shuck, Adelson, & Reio, jr., 2017; Vorina, Simonic & Vlasova, 2017). In spite of the extensive body of research in job engagement, there is still disagreement among academics and between academics and practitioners of what the meaning of the job engagement construct. Robertson et al. (2012) define engagement as "a positive attitude held by the employee towards the organization and its values." They note that an engaged employee works with colleagues to improve performance within the job for the benefit of the organization (Robertson et al., 2012). This expanded view encompasses job engagement and employee engagement. We focus on job engagement which, we refer to as an employee's cognitive, emotional, and physical investment in his/her work role to advance personal satisfaction and organization performance (Kahn, 1990; Robertson et al. 2012).

The relationship between job satisfaction, other job attitudes and firm performance has had much discourse in the organizational behavior (OB) literature (see Chen et al., 2011; Judge et al., 2002; Judge & Kammeyer-Mueller, 2012; Riketta, 2008) and operations management (OM) literature (see Jiang et al., 2009; Agarwal & Gupta, 2018; Haynie et al., 2017). Despite the extensive treatment in the literature, there is still little common ground on the causal relationship between job attitudes, e.g. job satisfaction and job engagement, and individual performance (Riketta, 2008). The relationship between those variables become more complicated when we introduce supply chain disruptions which occur infrequently but can have a significant impact on employees' job attitudes and ultimately firm performance. Moreover, there is concern about the stability of job satisfaction over time (Bowling, Beehr, Wagner and Libkuman, 2005). Although this gap in the literature exists, we won't be pursuing that line of inquiry here. However, it can be the focus of future research.

THEORETICAL MODEL

The arguments in this study rest on integrating two theoretical perspectives: social exchange theory and contingency theory. We examine two types of relationships in this study: the dyadic relationship between the employer and the employee, and the relationship between the firm and its operating environment, i.e. its supply chain. Following the literature, e.g. (Cropanzano & Mitchell, 2005; Emerson, 1976; Hom et al., 2009), we propose that these relationships are conditioned upon a mutual exchange. Cropanzano & Mitchell (2005) noted that workers can form distinguishable social exchange relationships with their immediate supervisor, coworkers, employer, and suppliers. By extension companies can form mutually beneficial relationships with other partners in the supply chain. Emerson (1976) noted that "social exchange is limited to the actions that are contingent on rewarding reactions from others." However, as Tanskkanen (2015) argued, "exchanges take place within structures of mutual dependence" (p. 580). There are power dependency issues in any relationship. In a supply chain, a monopoly supplier can exert power over a dependent buyer. Concomitantly, a distressed supplier can also exert power over a dependent buyer. The establishment of social exchange relations requires making investments that constitute commitments to the other party (Blau, 1964). This requires a level of trust. We extend the level of trust that should exist between a buyer and a supplier to an employer and an employee. Wang, Craighead & Li noted that disruptions can damage trust in the buyer-supplier relationship. We assert that the level of trust between an employer and employee can be affected by a man-made supply chain disruption which can negatively affect an employee's level of job satisfaction and job engagement. Employees at a company experiencing a disruption may be more concerned with whether they will be continued employment and more likely to experience lower job performance. The level of trust also extends into the supply chain. There is or should be a level of trust between supply chain partners to reduce anxiety and maintain a level of performance.

Organizations seek to maintain fit with their task environment (Thompson, 1967). We apply Van de Ven et al. 2013 logic that contingency theory may be applied to supply chains to understand changing economic and social environments (Van de Ven et al. 2013: 398). Contingency theory posits that firms seek to maintain fit in their task environments (Donaldson, 2001; Lawrence & Lorsch, 1967; Thompson, 1967). The task environment consists of four major sectors: 1.customers (distributors and end-users); 2.suppliers (labor, capital, materials, equipment, and work space); 3.competitors (markets and resources); and 4.regulatory groups (government agencies, unions, and inter-firm associations) (Thompson, 1967). These four sectors mirror those one would find in a supply chain. Firm operating in a task environment can experience a number of contingencies. In our study, we focus on task uncertainty, environemntal change and task interdependence (Donaldson, 2001). Firms operating in a task environment also go through a process of differentiation and integration wherein they insure that the organization is best situated to the specific environment in which the firm operates (Lawrence and Lorsch, 1967; Scott & Davis, 2016). Disruptions in the firms supply chain create misfit. Firms seek to regain fit to return to normal operating equilibrium (Donaldson, 1987).

Proposed Research Model

In this study, we are examining the moderated effects of organization identification and the mediated effects of job attitudes (i.e. job satisfaction and job engagement) on worker productivity (i.e. job performance) relative to a man-made supply chain disruption. Moderation is concerned with factors that influence the strength and direction of the relationship between the independent and dependent variable whereas mediation is concerned with the causal effects of the antecedent variable on the consequence variable (Muller, Judd & Yzerbyt, 2005:852). We discuss two man-made disruptions: supply chain partner insolvency, and labor disputes. In the following sections, we describe the variables in the model which are presented in Figure 1 below and posit our propositions.

Supply Chain Partner Insolvency (SCPI)

Supply chain disruptions, whether man-made or caused by some natural disaster continue to be a significant concern for scholars and practitioners. These adverse events have cascading effects up and down the supply chain stream – what some authors have described as a 'contagion or spillover effect' (Kolay et al. 2016; Wang, Craighead & Li, 2014; Yang, Birge & Parker, 2015). Although there is general interest in the literature on the effects of a disruption on firm performance (Chopra & Sodhi, 2004; Craighead, Blackhurst, Rungtusanatham, 2007; Hendricks & Singhal, 2003; Kleindorfer & Saad, 2005) little attention has been devoted understanding the type of disruption and its effects on employees' job attitudes of either the focal company or affected companies in the supply chain. One type of man-made disruption is supply chain partner insolvency (SCPI). We regard a supply chain partner insolvency as a meta construct which incorporates supplier insolvency. Supplier insolvency has been discussed in the OM literature (see Bode, Hubner, & Wagner, 2014; Chopra & Sodhi, 2004; Zsidisin & Smith, 2005) focusing specifically on those entities that supply raw materials in the supply chain. We extend the discussion to include any supply chain partner whose insolvency can disrupt the supply chain. Much of the literature focuses on tier one or tier two suppliers. For example, in a given manufacturing industry, tier-1 suppliers are those companies that supply the manufacturer directly with components for the product. Tier-2 suppliers provide subcomponents to Tier 1 supplier (Jaber & Goyal, 2009). However, some firms produce services rather than products, and their insolvency can disrupt the entire supply chain. For example, when United Airlines filed bankruptcy in December 2002, the company's filing had a ripple effect across the global supply chain (The Guardian, 2002, The New York Times, 2006). If one conducts a search for 'supplier insolvency', one is likely to get more hits for 'bankruptcy' than the original search term. This is because these two terms are used interchangeably. However, insolvency is an accounting term,

i.e. liabilities are greater than assets; whereas bankruptcy is a legal term involving a process of reorganization or liquidation (Baymout, Chhattani, Helali, Ali & Jegatheesan, 2013).

Corporate failure or death is an intrinsic part of organizational and economic life (Bode et al. 2014). Supply chain partner insolvency (SCPI) and bankruptcy are examples of such corporate failures. Sometimes, the government may become involved to save an industry for larger macroeconomic reasons as the U.S. Treasury Department did in 2009 when it created the Supplier Support Program to stabilize suppliers in the fledgling automobile industry (Kolay et al., 2016). Most often insolvent companies seek protection from their creditors in the bankruptcy courts. Scholars have advanced a couple of approaches describing how companies can mitigate the risk of a SCPI. For example, Zsidisin & Smith (2005) argue that early supplier intervention (ESI) may reduce the risk of supplier insolvency. Wengel (2012) discuss several warning signs of insolvency, including: delayed or missed tax payments, tightened supplier credit terms, poor budgets, cash flow forecasts and business plans, and ageing of creditors increasing. Despite these warnings, companies are still victims of supply chain partner insolvencies and bankruptcies. These "shocks" can wreak havoc on a firm's operations and can significantly and negatively impact its employees.

Supply chain disruptions are costly events. These costs can extend to the firms' cost of capital, or reduction in market value. In their study of nearly 1000 supply chain disruptions Hendricks & Singhal (2005) found that affected companies earned a 30% lower return Companies should be proactive to mitigate these costs. However, as Babich, Burnetas, & Ritchken (2007) note, companies do a poor job of overseeing their supply chain networks.

The foregoing discussion has focused on the effects of supply chain partner insolvency on the affected firm, its supply chain partners, and its position in the market. There is no mention of how this type of disruption affects employees' level of job satisfaction and job engagement. There are power dependencies in any dyadic relationship. The relationship forged between and employer and employee can suffer if there is an external threat, i.e. a supply chain disruption, that undermines the relationship – the trust that exists in that dyadic relationship (Wang et al. 2014). We argue in this study that a supply chain partner insolvency will have a negative effect on those employees in the affected firm and will also negatively affect employees in that affected firm's supply chain network.

Labor Disputes

Although labor is a major cost in almost any business enterprise, it appears that the topic is almost never the subject of discussion until there is the possibility that companies may have issues with their labor forces. A quick search of Google Scholar using the term "labor disputes and supply chain disruptions" does not return many articles. The same holds dearth of informational searches holds for a number of other databases, e.g. Academic Search Complete, Business Source Complete. We found one article in the OM literature (Sydow &Frenkel, 2013) which had "labor" in the title. In their study, which focuses on the employment relationship in the supply chain, Wright & Kaine (2015:489) highlight some of the pressing labor issues: inferior wages and working conditions, precarious employment contracts, work intensification, work health and safety risks, and minimal investment in employee development. These issues relate to the contractors or subcontractors of firms in the supply chain. They do not address similar issues of workers in the focal firm or partners in the same supply chain. Other studies, especially in the economics literature, e.g. Gomez-Paredes, Yamasue, Okumura & Isihara (2015) also address labor directly. The majority of articles discuss labor in the context of risk. This is not so in the practitioner and business press (see Banham, 2009; Butler, 2015; Miller, 2015; MMR, 2015; Welshans, 2015). A review of the risk management literature (see Chopra & Sodhi, 2004; Chopra & Sodhi, 2014; Revilla & Saenz, 2014; Silbermayr & Minner, 2014; Tomlin, 2006) discuss labor risk in relation to the firm. None consider the impact of a labor dispute on

the job attitudes of the employees of the affected companies. This lack of scholarship highlights a significant gap in the literature. There is obvious concern for practitioners. However, researchers have devoted minimal attention to this phenomenon. This study addresses that lack of scholarship.

Given the foregoing discussion, this study posits that there is a negative relationship between a certain types of man-made supply chain disruptions (e.g. labor dispute and supply chain partner insolvency) and employees' level of job engagement and job satisfaction. Basit (2017) noted that employees' social environments make them feel psychologically safe (or unsafe in the case of a disruption) and the level of safety or unsafety influences the employees' willingness to invest cognitive, emotional, and physical energies in their work. Whether these environments allow employees to have a voice, i.e. express their concerns, can also have an impact on organizational goals, employee well-being, external stakeholders, and organizational performance (Knoll & Redman, 2015). Although firms may engage in work design and other ways to motivate employees, there is little evidence that firms are concerned about the negative effects on employees of external events that affect the firm. This study also asserts there is a negative relationship between the various types of man-made supply chain disruptions and worker productivity.

P1: *Man-made supply chain disruptions (e.g. labor dispute or supplier insolvency), are negatively associated with employees' job engagement such that employees who experience a man-made supply chain disruption will have lower job engagement.*
P2. *Man-made supply chain disruptions (e.g. labor dispute or supplier insolvency), are negatively associated with employees' level of job satisfaction such that employees of the company affected by a man-made supply chain disruption are more likely to have lower job satisfaction.*
P3: *Man-made supply chain disruptions (e.g. labor dispute or supplier insolvency), are negatively associated with employees' performance such that employees of the focal firm as well as other firms in the supply chain network who experience a man-made supply chain disruption will have lower performance.*

Organization Identification as a Moderator of Supply Chain Disruption Effects
Identity is defined in the literature as a "self-referential description that provides contextually appropriate answers to the question, "Who am I?" (Ashforth et al., 2008). Employees who identify with a firm are more likely to exhibit higher levels of job engagement. Organizational identification has been shown to relate positively to employee performance (Ashforth, Harrison, & Corley, 2008; Menguc et al., 2016). The degree to which an individual is associated with a firm helps to determine that individual's emotional state if the firm is affected by an exogenous shock. If the firm experiences a supply chain disruption an employee who strongly identifies with the firm is more likely to experience lower levels of job engagement than an employee who does not identify with the firm (Kreiner & Ashforth, 2004). Employees identification with a firm fulfils a psychological need. In their studies, Kreiner & Ashforth, (2004) as well as Ashforth et al., (2008) address the affective state of employees who identify with a firm. Employees who exhibit a psychological linkage to a firm have been shown to experience varying levels of job satisfaction, work engagement, absenteeism, turnover intentions, citizenship behaviors and job motivation (Agarwal & Gupta, 2016; Knoll & Redman, 2016; van Knippenberg & Sleebos, 2006). In their study, Ashforth et al., 2008) regard identification as "the perception of oneness or belongingness to some human aggregate." The human aggregate under discussion here is the individual's employer. Based on the literature it follows that the more an individual identifies with an employer, the more he/she is likely to experience lower levels of job engagement if the firm experiences a man-made supply chain disruption.

P4. *Organization identification moderates the relationship between a man-made supply chain disruption and job engagement, such that this relationship is stronger for employees with strong organization identification.*
P5. *Organization identification moderates the relationship between a man-made supply chain disruption and job satisfaction, such that this relationship is stronger for employees with strong organization identification.*

Job Engagement and Performance

An employee's level of job engagement may be contingent on several factors. One of these factors is the job design. Agarwal & Gupta (2018) citing Hackman and Oldman (1975) noted that a well-designed job contained five characteristics: 1. task identity; 2.job autonomy; 3.job feedback; 4. task variety; and 5. task significance. Job engagement heightens the meaningfulness of work thereby allowing employees to focus on the task and exhibit higher levels of performance (Haynie, Mossholder, & Harris, 2016). Engaged employees feel a sense of connection to their tasks. These employees express themselves physically, cognitively, and emotionally in their job role performances (Chhetri, 2017). In their study, Haynie et al. (2016) utilized items from Rich, LePine, & Crawford (2010) to measure the three subfacets of employee engagement: physical, cognitive and emotional energies invested into work. Firms can create work environments that can engage employees and allow them to fully maximize their potential (Basit, 2017). Job engagement describes the process through which an employee identifies with a group or organization and invests his or her energies to meet the expectations of the entity (Haynie et al. 2016). This study argues that an employee's level of job engagement is negatively affected by disruptions in the firm's operating external environment.

Some scholars have examined the mediating effects of job engagement and various aspects of employee and firm performance (Agarwal & Gupta, 2018, Chhetri, 2017, Haynie, Flynn, & Mauldin, 2017; Haynie, Mossholder, & Harris, 2016). This study posits that an employee's level of job engagement positively mediates the impact of a man-made supply chain disruption on employee productivity. Man-made supply disruptions can have an impact of employees' dispositional states. Highly engaged employees should value changing deteriorating conditions, such as a man-made supply chain disruption (Knoll & Redman, 2016). It follows that employees' emotions and attitudes in response to environmental conditions can have an impact on their level of engagement (Haynie et al., 2017). Although companies focus on the internal environment to create the conditions for greater employee engagement, companies should also devote some energy to understanding those exogenous shocks, such as a man-made supply chain disruption that might impact employee engagement.

A reduction in an employee's level of engagement is likely to have negative effects on other outcomes, especially task performance (Haynie et al. 2016). These negative effects can also extend to firm performance – assuming, of course, that an engaged employee is indeed a productive employee. The link between job engagement and job performance is still a matter of some debate since much of the literature focuses on engagement as the polar opposite of burnout (Martin, 2017; Rich et al. 2010). Researchers have relied on the Maslach Burnout Inventory (BMI) to measure engagement (Martin, 2017). Following the literature, we offer the following proposition.

P6. *Employees' level of job engagement is positively related to employees' performance such that employees experiencing negative job engagement are more likely to experience lower performance.*
P7. *Employees' level of job engagement negatively mediates the impact of a man-made supply chain disruption of employee performance such that employees of a firm experiencing a man-made supply disruption will likely experience decreased job engagement which then leads to lower performance.*

Job Satisfaction and Job Performance

Whether job satisfaction influences job performance remains an unsettled question in the OB literature (Crossman & Abou-Zaki 2003). In their study, Wright, Cropanzano & Bonet (2007) citing Judge and colleagues noted that the relationship can be organized around seven models: 1. job satisfaction causes job performance; 2.job satisfaction is caused by job performance; 3.job satisfaction and job performance are reciprocally related; 4.job satisfaction is spuriously related to job performance; 5.the job satisfaction-job performance relation is moderated by other variables; 6.job satisfaction is not related to job performance; and 7.there are alternative conceptualizations of job satisfaction-job performance. Although Judge et al (2002) found support for the relationship between job satisfaction and job performance, Wright et al (2007) in their study estimated that other variables may moderate the relationship between the two variables. Our research supports Judge et al's (2002) contention. The strength of the relationship can be tested empirically. In their study, Judge et al. (2002) found the correlation to be 0.30.

An employee's level of job satisfaction can significantly impact other areas of his/her work life, e.g. commitment to the firm, quality of service provided to customers, self-efficacy or personal well-being; level of engagement (Crossman & Abou-Zaki, 2003; Carter, Nesbit, Badham, Parker, & Sung, 2016; Menguc, Auh, Katsikeas, & Jung, 2016; Wright et al. 2007). These areas either directly or indirectly relate to performance. In his study, Riketta (2008) found a significant, but weak relationship between job attitudes (job satisfaction and commitment) and performance. There was no support for the reverse relationship.

Job satisfaction is one of the most studied job attitudes (Riketta, 2008). Individuals exhibit some emotional attachment to their organizations and their work. However, whether or not there is a causal link between these two variables is the subject of much empirical investigation. In his study, Riketta (2008) found that job attitudes are more likely to affect performance than vice versa. This is consistent with other studies that have examined the relationship between job satisfaction and firm performance (see Chen et al., 2011; Hemalatha, Krisnaveni, & Deepa, 2015). In their study, Hemalatha et al. (2015) found a direct link between job satisfaction and firm performance. if "Happy employees" are indeed "productive employees" (Saari & Judge, 2004) understanding how to measure and influence job satisfaction is a critical factor for improved and sustained firm performance. Chen and colleagues note in their study that when job satisfaction improves over time, employees will be more motivated to stay with their current organization (Chen et al., 2011). Although these authors were interested in the relationship between level of job satisfaction and job turnover intentions, it is evident from their research that the level of job satisfaction is directly linked to firm performance. Other scholars have sought to explain the importance of job satisfaction. Ilies and colleagues examined the impact of daily job satisfaction on family work-life balance (Ilies, Schwind Wilson & Wagner, 2009), while Judge et al. (2002) investigated the relationship between job satisfaction and the Big Five personality traits. Ilies, Fulmer, Spitzmuller & Johnson (2009) also investigate the relationship between certain personality traits and job satisfaction. While, informative, these studies focus on organizations operating in the normal course of business. No treatment is given to firm experiencing a supply chain disruption and the effect a labor dispute or supply chain partner insolvency can have on the supply chain network. Filling this void is one of the goals of this study.

The relationship between job attitudes and firm performance has been examined to some degree in the operations management (OM) literature (Autry & Daugherty, 2003; Ellinger et al., 2003; Jiang et al. 2009). Some studies have examined how implementing certain management processes, e.g. Just-in-Time, Groebner & Merz (1994); Quality/Total Quality Management (TQM), de Menzes (2010); Rahman & Bullock (2005) impact employees' job attitudes. In her study on the relationship between implementing lean production practices and

employee outcomes, Parker (2003) found that work characteristics mediate that relationship. One key characteristic was employee job satisfaction. The "happy employee hypothesis', assumes that satisfied employees will exhibit higher levels of organizational commitment, less absenteeism, and be more productive (Autry & Daugherty, 2003; de Menezes, 2010; Saari & Judge, 2004). This assumption seems not completely borne out in the study by Groebner & Merz (1994) who found little statistical significance in job satisfaction between two groups of workers on some dimensions of job attitudes: those implementing Just-in-Time practices and those employees not implementing J-I-T. However, the authors did find support for the relationship between job attitudes and job performance on other dimensions. In a follow up study, the authors found that "changing to JIT had a positive effect on job attitudes" (Groebner & Merz, 1994). We expect that we will find a positive relationship between job satisfaction, job engagement and employee performance.

The results of Groebner & Merz's (1994) demonstrate the difficulties of understanding the relationship between job satisfaction, employee and firm performance. Nevertheless, we argue in this study that there is a relationship between the level of employee job satisfaction and job performance and by extension firm performance. Given the relationship between job satisfaction and employee performance, we offer the following propositions:

P8. *Employees' level of job satisfaction is positively related to employee performance such that employees experiencing negative job satisfaction are more likely to experience lower performance.*

P9. *Employees' level of job satisfaction negatively mediates the impact of a man-made supply chain disruption of employee performance such that employees of a firm experiencing a man-made supply disruption will likely experience job satisfaction and lower performance.*

DISCUSSION AND IMPLICATIONS

We are undertaking this study to examine the mediating and moderating effects of several variables on employee performance under the conditions of a man-made supply chain disruption. OM scholars have not systematically utilized the mediation process to examine the relationship between and among variables (Rungtusantham, Miller & Boyer, 2014). We examine two type of man-made supply chain disruptions: 1. supply chain partner insolvency; and 2. labor disputes. These types of disruptions have been addressed in the extant OM literature (Sydow and Frenkel, 2013; Samvedi et al. 2013; Yang et al. 2015). However, scholars have not advanced the discussion on the risk of these disruption and the effects on employee job attitudes. For example, Jiang et al (2009) discuss the operational risk of labor problems; the reputational risk of labor problems, and the supply chain risk of labor problems. The authors note that little is known about the factors that affect job attitudes of suppliers' laborers in developing countries (p.170). While we do not focus on developing countries, we assert that the disruptive nature of labor strikes can have impacts on various nodes in the supply network and can negatively affect employees' job attitudes. Further, although there is considerable discussion in the literature of the effects that distressed firms can have on the economic health of their rivals, suppliers and creditors (Kolay et al (2016). To the best of our knowledge, there is no discussion of the impact of the distressed company on the job attitudes of the firm's employees.

Companies facing financial distress also create problems along the supply chain. In his discussion of how to spot the signs of insolvency in companies, Wengel (2012) noted the demeanor of the staff provided an indication of the business' overall health. We assert that the job engagement and job satisfaction of employees pose a significant risk to their overall performance. We argue that the relationship between these two types of supply chain disruptions and employee and firm performance is mediated by the employees' level of job

engagement and job satisfaction. We also argue that the level of job engagement is moderated by the employee's level of organization identification. We do not address the relationship between the employee's commitment, i.e. level of identification with the organization and the level of job satisfaction. Future research should address this relationship in the context of a man-made supply chain disruption.

The "happy-productive employee" thesis continues to be debated in the literature (Cropanzano & Wright, 2001; Staw, 1986; Wright & Staw, 1999a, 1999b). We assert that engaged and satisfied employees will generally be more productive employees and this combination generally leads to greater firm performance. Much of the existing literature focuses on the mediating roles of job engagement and job satisfactions on job/task performance (Carter et al., 2016; Chhetri, 2017; Knoll & Redman, 2016; Rich et al. 2010; among others). Employees bring the full self in terms of physical, cognitive and emotional energies to the task and ultimately its performance (Rich et al., 2010). In a Marxian sense, there is no separation of the individual from his/her work. The individual commits to the task because there is a tacit understanding that the employer will not abuse the trust that exists in this relationship (Basit, 2017). This level of engagement and satisfaction leads to increased job performance.

Implications for Theory

This study integrates two theoretical perspectives: social exchange theory and contingency theory to examine whether man-made supply chain disruptions directly or indirectly affect employees' work attitudes, specifically, job engagement and job satisfaction? Further, does the change in employees' job attitudes affect their productivity and ultimately firm performance? Social exchange theory is useful in understanding the dyadic relationship between and employee and an employer. These relationships occur within a structured environment where workers can form distinguishable social exchange relationships with their immediate supervisor, coworkers, employer, and suppliers (Cropanzano & Mitchell, 2005). This study departs from the literature by examining how each of these relationships can be impacted by a disruption in the focal firm's supply chain. Extending social relationships to firms in a supply chain allows researchers examine the power dependencies that may exist. These relationships should serve the mutual interests of those parties. Often times, one party in the relationship dominates. Our investigation seeks to determine whether the power dependencies that exist in a structured environment also hold in a supply chain context and determine the moderating effects of organization identification on employees' job attitudes in the context of a man-made supply chain disruption.

The other theoretical perspective employed in this study is contingency theory. Following (Drazin & van de Ven (1985) and van de Ven et al. (2013), we utilize contingency theory to understand how firms respond to the changing economic and social environments in which they operate. Thompson (1967) noted that the task environment consists of four major sectors: 1.customers (distributors and end-users); 2.suppliers (labor, capital, materials, equipment, and work space); 3.competitors (for markets and resources); and 4.regulatory groups (government agencies, unions, and inter-firm associations). These sectors constitute the various nodes in a supply chain. We posit that the nature of the dyadic relationship that exist between firms in the supply chain may be a determinant in how the firm's employees respond to a supply chain disruption. We believe such relationships may enable the firm to regain fit with the operating environment. Disruptions create uncertainty for the firm operating in its task environment. We integrate these two theoretical perspectives to examine how the nature of the social relationship can reduce task uncertainty and increase task interdenepdence (Donaldson, 2001). This integration is a departure from how these issues are addressed in the OM and OB literatures.

This study examines the direct and indirect effects of a man-made supply chain disruption on employee job attitudes and employee performance. There is little theoretical or empirical evidence to support the link between job attitudes and employee performance. This

study seeks to establish a link between these two constructs. We also examine to effects of supply chain partner insolvency and labor disputes on the job attitudes of the employees along various nodes of the supply chain. Although practitioners are plagued frequently by these types of disruptions, these issues have not garnered sufficient interest in the academic community. This study may also engage OB scholars to investigate issues in operations management (OM).

Implications for Practice

Supply chain disruptions are an almost every day occurrence. Yet, companies seem ill-prepared to plan for and to manage various kinds of disruptions. Much of the existing literature focuses on supply chains as the unit of analysis. This study focuses on the individual employee as the unit of analysis. Managers can benefit from the analysis in this study and develop various strategies to help affected employees cope with the disruption. Firms may reduce operations and provide opportunities for training while they work through the disruptive event.

LIMITATIONS AND FUTURE RESEARCH

This study does not address employee engagement relative to job engagement in the context of a man-made supply chain disruption. Nor does it explore the relationship between job engagement and job satisfaction. We surmise that the relationship between these two constructs might have an impact on employee and firm performance. Employee engagement is a measure of an employee's positive or negative emotional attachment to their job, colleagues and organization (Vorina et al. 2017). Future research can investigate this relationship in the context of a man-made supply chain disruption. This study also does not address employee engagement relative to job engagement in the context of a man-made supply chain disruption. An employee's emotional well-being can be affected by a disruption which would negatively affect performance. We believe a future research would provide a greater understanding of this phenomena. Nor does it explore the relationship between job engagement and job satisfaction. We surmise that the relationship between these two constructs might have an impact on employee performance. Future research can investigate this relationship in the context of a man-made supply chain disruption.

CONCLUSION

This study seeks to examine the effects of a man-made supply chain disruption on employees' level of job engagement and job satisfaction and the attenuating productivity and firm performance. We argue that a disruption interrupts the normal processes within an organization and has an impact on the individual employee's psyche. The uncertainty created by the disruption may cause the employee to worry more about losing his/her job than about the company's stated goals. This uncertainty creates anxiety and may lead to reduced job engagement and job satisfaction. If one assumes that a happy employee is a more productive employee, it follows that an anxious employee will be a less productive employee.

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DECISION SCIENCES INSTITUTE
The Efficiency Assessment of Renewable Energy Sources
with Data Envelopment Analysis

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ABSTRACT

In this paper, we compare the efficiencies of seven primary renewable energy technologies that generate electricity. We use Data Envelopment Analysis (DEA) to determine the most efficient renewable energy source with predetermined input and output variables. We apply four different analytical approaches to rank these energy sources with respect to their efficiency scores. According to our analysis, geothermal is the most efficient and solar thermal technologies are the least efficient renewable energy sources.

KEYWORDS: Data Envelopment Analysis (DEA), Efficiency Ranking, Electricity Generation, Multi-Criteria Decision Making, Renewable Energy Sources.

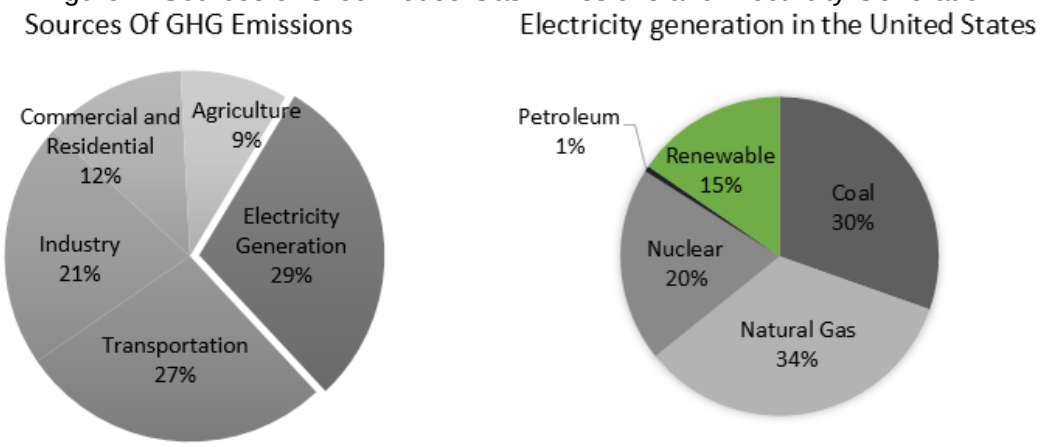
INTRODUCTION

Global warming is defined as the average temperature increase in Earth's surface, air, and oceans. It was first recognized by Fourier (1827), and Arrhenius (1897) developed the earliest model for the relationship between the temperature of the ground and carbon dioxide concentration. However, its perceived effects on human beings became more detectable and measurable within the last five decades. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the average global surface temperature increased by 0.85°C (1.53°F) since 1850 because of irrepressible increase of the concentration of greenhouse gasses such as carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. According to the IPCC the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, if we will be successful to keep the level of the concentration of the greenhouses gasses constant, the global average surface warming would be about 0.2°C for a decade which may lead to severe problems in ecosystems all over the world. According to the scenario projections in this report, when the warming increases by 2°C, approximately 25% of the plant and animal species will be in danger of extinction. Also, crop productivity will decrease leading to food scarcity in many regions of the world. Millions of people will have health problems because of increase in malnutrition. Moreover, deaths, diseases, and injuries will increase due to severe weather conditions. Climate change also results in significant rising of sea levels; this will lead islands in Asia, Africa, and the Caribbean to become vulnerable to storms surge inundation and erosion. A rising on sea level also the cause of some islands will even vanish. The report adds that, by 2020, climate change will cause between 75 and 250 millions of people to have fresh water problems in Africa. Shortly, climate change would cause many severe problems if the global warming is not restrained. Not surprisingly, global warming and climate change become the most critical environmental and political issue between the countries. A total of 192 countries have signed the Kyoto Protocol, and 197 countries have signed the Paris Agreement, that aim to reduce the global average temperature to the pre-industrial levels by delimiting the production of greenhouses gas (GHG) emissions.

According to the Inventory of U.S. Greenhouse Gas Emissions and Sinks, the United States Environmental Protection Agency (EPA) reported that there are five primary sources of GHG emissions in the United States: electricity production 29%, transportation 27%, industry 21%,

commercial and residential 12%, and agriculture 9%. These values are consistent with the worldwide data of IPCC, where the electricity production contributes most to the total of GHG emissions. The U.S. Energy Information Administration (EIA) data shows that in 2016, 65% of electricity was generated by burning of fossil fuels (natural gas 34%, coal 30%, and petroleum 1%) which are the primary sources of GHG emissions for the electricity production. Only 13% of electricity in the United States, is generated by renewable energy sources, which produce a negligible amount of GHG emissions. Therefore, in this study, we focus on efficiencies of the renewable energy sources that generate electricity.

Figure 1: Sources of Greenhouse Gas Emissions and Electricity Generation



Renewable energy is produced and replenished by natural resources such as sunlight, wind, tides, and rain. There are five primary sources of renewable energy: wind power, solar, geothermal, biomass, and hydropower. Approximately, twenty percent of the total energy consumption is produced by these renewable energy sources and, the annual growth rate of the market share of the renewable energy since 1990 is about two percent (Owen 2004). According to Prindle et al. (2007), the synergies between energy efficiency and renewable energies are the twin pillars of sustainable energy policy that reduce GHG emissions. Therefore, in this study, we model a linear programming model to compare the efficiencies of these seven primary renewable energy sources that generate electricity. We evaluate the efficiency scores of each renewable energy source using Data Envelopment Analysis (DEA), which is a multi-criteria decision-making tool.

The remainder of this paper is organized as follows: Section 2, provides detailed literature review for DEA-related articles in the energy sector. Section 3, presents an overview of the DEA framework with the four different ranking approaches that we use in this study. Section 4, describes the model in detail with input and output variables. We also present each one of the renewable energy sources in detail in this section. Section 5, reports the results of each approach that we consider in DEA framework. Summary and concluding remarks are discussed in Section 6.

LITERATURE REVIEW

Data Envelopment Analysis (DEA), is a standard management tool for evaluating and improving the efficiency of both manufacturing and service operations. It was developed by Charnes et al. (1978). The DEA has been studied by a large number of researchers for various applications in: banking (Paradi and Zhu, 2013), education (Palocsay and Wood, 2014), environment (Goto et al., 2014), health (Kemp, 2015), and transportation (Zhou et al., 2014).

In the literature, there are more than thirty DEA – related articles for the energy sectors. Bagdadioglu et al. (1996) applied DEA to discover the relationship between privatization and ownership on the efficiency of Turkish electricity supply industry. Sueyoshi and Goto (2001) studied the performance of the electric power in Japan. Miliotis (1992) looked at Greece electricity distribution districts, Forsund and Kittelsen (1998) compared electricity distribution companies in Norway, by using DEA efficiency scores. Chen (2002) studied the cross efficiency of the electricity distribution sector in Taiwan, Pacudan and Guzman (2002) looked at the effectiveness of electricity distribution in the Philippines. Resende (2002) studied Brazilian electricity companies, and Korhonen and Syrjanen (2003) studied the efficiency of electricity distribution in Finland.
Boyd and Pang (2000) studied the linkage between energy efficiency and productivity in two segments of the glass industry. They compared the level of electricity and fossil fuel intensity by using regression analysis. They also showed that there is a strong correlation between energy intensity and productivity. Ramanathan (2001) applied DEA to the comparative risk assessment of eight different energy supply technologies. He concludes that solar photovoltaic and nuclear power are the most efficient energy sources. Jha and Shrestha (2006) used DEA to measure the efficiency of hydroelectric plants in Nepal. Chien and Hu (2007) apply DEA to the 45 OECD and non-OECD economies to determine the effects of renewable energy sources on the technical efficiency. They used macroeconomic data such as labor, capital stock, and energy consumption for the input variables where the real GDP served as the only output variable. They concluded that there was a positive correlation between use of renewables and technical efficiency and a negative correlation with the traditional energy. Jayanthi et al. (2009) applied DEA to U.S. photovoltaic industry. Cristobal (2011) applied DEA to evaluate the efficiency of the renewable energy sources in Spain. Kasap and Kiris (2013) develop an AHP and DEA approach to evaluate electricity generation companies of OECD countries. More recently, Chiu et al. (2016) compared productivity efficiencies of G20 countries by using DEA and Malmquist Index. Saglam (2016) compares the efficiencies of the eight primary renewable energy sources that generate electricity using four different analytical approaches. Saglam (2017a, 2017b) develop DEA models to quantitatively evaluate the relative efficiencies of the 39 states' wind power performances. Saglam (2017a) develops a two-stage DEA to quantitatively evaluate the relative efficiencies of the 39 state's wind power performances. Saglam (2017c) compare 236 large utility-scale wind farms' productive efficiency by applying two-stage DEA models. Saglam (2018) evaluate 95 large utility scale wind farms by using a two-stage data envelopment analysis and Tobit regression models.
In this study, we use DEA to compare the efficiencies of seven renewable energy technologies that generate electricity. We develop one of the most comprehensive models in the literature for this comparison. We apply four different approaches of DEA to rank relative efficiency of renewable energy technologies. The data is obtained from the most recent studies, which allow us to take into account any recent changes in these technologies. Also, cost function includes future projections as well. Therefore, the results of this study put some light on the future of these technologies for the policymakers.

DATA ENVELOPMENT ANALYSIS (DEA)

DEA is a non-parametric, multi-factor relative efficiency measure for evaluating and improving the efficiency of both manufacturing and service operations. Charnes et al. (1978) introduced the DEA framework to calculate the relative efficiency score with the division of the weighted sum of outputs and a weighted sum of inputs to obtain decision-making units (DMU). Equation 1 formulates the scenario where we have *N* number of maximized DMUs, which are obtained by *s* number of output and *m* number of input variables:

$$\begin{aligned} max \quad & E_e = \frac{\sum_{k=1}^{s} v_{ke} y_{ke}}{\sum_{i=1}^{m} u_{ie} x_{ie}} \\ s.t. \quad & \frac{\sum_{k=1}^{s} v_{ke} y_{kj}}{\sum_{i=1}^{m} u_{ie} x_{ij}} \leq 1; \;\; j = 1, 2, 3, \dots, n \\ & v_{ke}, u_{ie} \geq 0; \; k = 1, 2, 3, \dots, s; \;\; i = 1, 2, 3, \dots, m \end{aligned} \quad (1)$$

where E_e is the maximized efficiency score which belongs to the e^{th} DMU. Hence this set of equations can be easily converted to a linear programming problem by fixing the denominator to one:

$$\begin{aligned} & max \; E_e = \sum_{k=1}^{s} v_{ke} y_{ke} \\ & s.t. \;\; \sum_{k=1}^{s} v_{ke} y_{kj} - \sum_{i=1}^{m} u_{ie} x_{ij} \leq 0; \;\; j = 1, 2, 3, \dots, n \\ & \sum_{i=1}^{m} u_{ie} x_{ie} = 1 \\ & v_{ke}, u_{ie} \geq 0; \; k = 1, 2, 3, \dots, s; \;\; i = 1, 2, 3, \dots, m \end{aligned} \quad (2)$$

This linear programming formulation provides only two groups of results, efficient DMUs, and inefficient DMUs. Therefore we apply four different analytical approaches: (1) the benchmark ranking model, (2) the super efficiency model, (3) the cross-efficiency model, and (4) the virtual efficiency model, to find out the most efficient renewable energy source. Moreover, we rank all of the renewable energy technologies according to their cumulative efficiency ranking.

Benchmark Ranking Approach

The benchmark ranking method is one of the most popular ranking methods that focus on inefficient DMUs. This ranking method aims to improve inefficient DMUs with benchmarking of the efficient DMUs. The references are obtained by dual problem of the linear programming problem. The total number of references determine the rank of efficient DMUs. The most referenced efficient DMU ranks first, and inefficient DMUs rank equally.

Super-Efficiency Approach

Andersen and Petersen (1993) develop a super-efficiency approach for ranking efficient DMUs. In this method, linear programming problem is relaxed with omitting the unity constraint. This relaxation creates inefficient DMUs which are greater than 1, for initially efficient DMUs. Then the ranking is obtained by ordering these inefficient DMUs.

Cross-Efficiency Approach

The cross-efficiency approach, which was developed by Sexton et al. (1986), evaluates the performance of each DMU on the optimal input and output weights of other DMUs. Peer evaluation forms the cross efficiency matrix, and then the ranking is obtained by the simple average of each DMU's efficiency score.

Virtual DMU Approach

The virtual DMU approach was developed Golany and Roll (1994) by selecting the best values of each input and output variable. The original model is run one more time for each DMU by including new virtual DMU. After this process, virtual DMU becomes only efficient one, and the ranking is obtained in descending order of inefficient DMUs.

THE MODEL

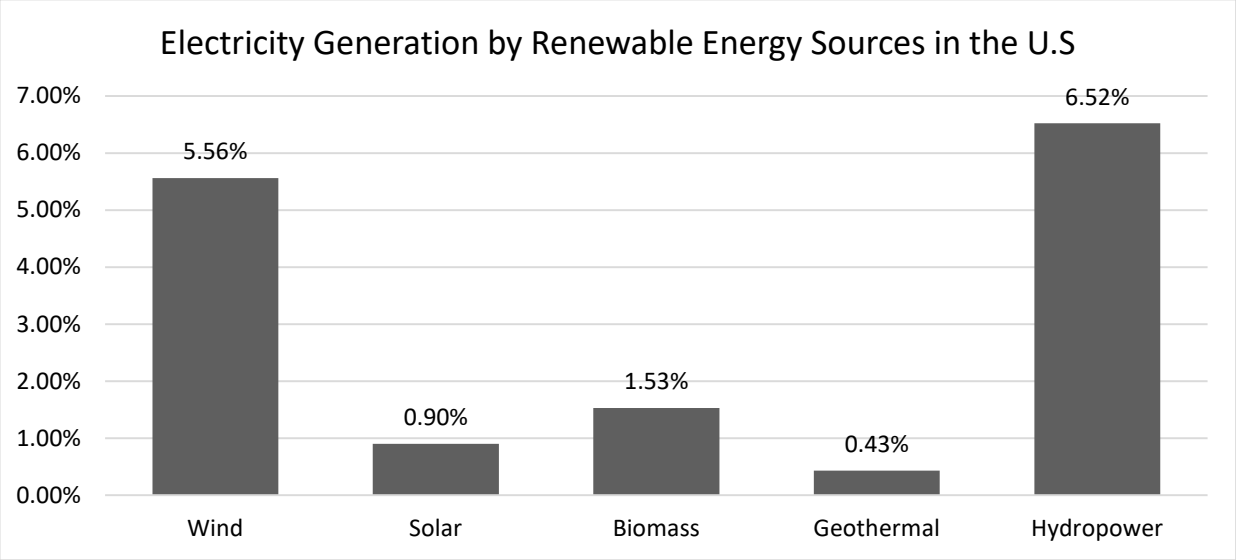
In this study, we want to rank the renewable energy sources by using pre-determined input and output variables. This study evaluates seven primary renewable energy technologies: Wind Power (both onshore and offshore), Solar Photovoltaic (PV), Solar Thermal, Geothermal, Biomass, and Hydropower. Only 15% of electricity in the United States, is generated by renewable energy sources and the distribution is shown in Figure 2.
In the next subsection, we look at each one of these renewable energy sources in detail. We also provide detailed information for each input and output variables in this section.

DEA Evaluations

Wind Power:

Wind power is one of the most expanded renewable and sustainable energy sources worldwide. According to EIA data, the entire installation of wind power is about 5.56 percent of the U.S. electricity supply. Electricity is generated by the conversion of kinetic energy of wind by using a wind generator. There are two types of wind farms that we consider in this study: An onshore wind farm is located on a land, where an offshore wind farm is located in the water.

Figure 2: Electricity Generation by Renewable Energy Sources in U.S.



Solar Photovoltaic (PV):

The solar photovoltaic technology generates electrical power by converting sunlight into direct current electricity. Although photovoltaic is one of the fastest growing power-generation technology, the entire installation of Solar PV supply is only 0.90 percent of U.S. electricity.

Solar Thermal:

The solar thermal technology generates solar power from solar energy by using solar thermal collectors. There are three major categories of solar thermal technology: (1) low-temperature collectors for heating and cooling systems; (2) medium temperature collector provides hot water

for both residential and commercial areas, and (3) high-temperature collectors for electricity generation.

Geothermal:

Geothermal energy is one the oldest renewable energy sources and is almost emission free. It is generated and stored in the Earth. Although the amount of geothermal energy is enormous, only a tiny fraction may be profitably exploited. Therefore, the entire installation of geothermal power is about 0.43 percent of the U.S. electricity supply.

Biomass:

Biomass is a widely available and naturally distributed renewable energy source which is derived from distinct energy sources like garbage, wood, waste, landfill gasses, and alcohol fuels. There are various applications of biomass energy such as direct burning, electricity generation, gasification, biofuels and anaerobic digestions to obtain heat, electricity, or another form (bio-fuel, biogas).

Hydropower:

Hydropower is both a renewable and sustainable energy source. It is derived from the force of falling or fast-moving water. Hydroelectricity is the most contributing renewable energy sources of the U.S. electricity supply. According to EIA data, the entire installation of hydropower is about 6.52 percent of the U.S. electricity supply.

The Inputs

In this study, we consider three input variables for the DEA analysis: (1) the total system levelized cost (TSLC), (2) land requirement, and (3) water consumption. Table 1 presents the related data, and Table 2 presents the statistical summary of variables for these input variables.
Total system levelized cost is one of the most critical input variables which combines different cost values: levelized capital cost, fixed and variable operations and maintenance expenditures, transmission investment and levelized tax credit. This data is obtained by EIA, Annual Energy Outlook 2016 Report. The cost function includes future projections for 2022 in this report. The TSLC of the renewable energy sources ranges between 41.90 $/MW (geothermal) and 179.90 $/MW (solar thermal). Land requirement is another critical input variable for this DEA analysis because some power plants require extensive land area, and some of them require none. Fthenakis and Kim (2009) studied life cycle land use of power sources. The data is obtained from this study. Water consumption is the last input variable for the DEA framework. This is also a critical input variable because some sources (wind and solar PV) are almost water-free during their operations, but some plants need an extensive amount of water for their operations (geothermal and hydropower) during their entire life cycle. The data is obtained from Fthenakis and Kim (2010), who studied life-cycle uses of water in U.S. electricity generation.

The Outputs

In this study, we consider four output variables for the DEA analysis: (1) the plant size, (2) the capacity factor of each power plant, (3) employment, and (4) greenhouse gas (GHG) emissions. Table 1 presents the related data, and Table 2 presents the statistical summary of variables for these output variables.

Table 1: Power Plants Data with Input and Output Variables							
	INPUTS			OUTPUTS			
	Input 1	Input 2	Input 3	Output 1	Output 2	Output 3	Output 4
Power Plant	TSLC ($/MW)	Land Req. (m^2/GWh)	Water Con. (L/MWh)	Plant Size (MW)	Capacity Factor (%)	Employment (1000s)	GHG Emis. (g/kWh)
Wind-Onshore	56.9	2410.0	8.0	1.0	40.0	88.0	16.0
Wind-Offshore	146.7	0.0	8.0	1.0	45.0	0.0	13.0
Solar PV	66.3	359.2	30.0	1.0	25.0	194.2	60.8
Solar Thermal	179.9	424.0	5462.5	1.0	20.0	14.6	39.6
Geothermal	41.9	206.7	26430.0	1.0	91.0	35.0	50.0
Biomass	96.1	488160.0	3775.0	1.0	83.0	152.0	88.0
Hydropower	67.8	25000.0	17000.0	1.0	58.0	8.0	20.0

In our framework, we use unit values for each power plant, so that the plant sizes are constant, and they are all equal to 1 for each renewable energy source. Capacity factor is the ratio of the actual output of a power plant and the total energy that plant would have produced at full capacity. The capacity factor of the renewable energy sources ranges between 20% (solar thermal) and 91% (geothermal). We obtained the capacity factor data from EIA's Annual Energy Outlook 2016 Report.

Table 2: Statistical Summary of Variables						
Variable	Description	Unit	Mean	Minimum	Maximum	Standard Dev.
Input 1	TSLC ($/MW)	$/MW	93.66	41.90	179.90	47.37
Input 2	Land Requirement	m^2/GWh	73794.27	0.00	488160.00	169373.71
Input 3	Water Consumption	L/MWh	7530.50	8.00	26430.00	9521.98
Output 1	Plant Size	MW	1.00	1.00	1.00	0.00
Output 2	Capacity Factor	%	51.71	20.00	91.00	25.25
Output 3	Employment	-	70.26	0.00	194.20	71.23
Output 4	GHG Emission	kg/MW	41.06	13.00	88.00	25.45

In May 2016, edition of the Renewable Energy and Jobs (Annual Review 2016), the International Renewable Energy Agency (IRENA) reported that in 2015, renewable energy industry employed 769,000 people in U.S. and 8.1 million people in all over the world. The employment data is critical output variable for this study because the contribution of each renewable energy sources varies almost in between 0 and 200,000. The data is obtained from this report. Lastly, greenhouse gas (GHG) emissions are the most significant output variable to find out the most efficient renewable energy source because they are the primary source of global warming and climate change. In this context, we use data from Amponsah et al. (2014), for GHG emissions of the renewable energy sources, and we incorporated it with taking the inverse of the actual values because it is the undesirable output of the operation.

DEA RESULTS

We model the linear programming problem for each one of the renewable energy sources by using the coefficients of input and output variables that are presented in Table 1. We solve these models with LINGO 16.0 which is a comprehensive software designed to build and solve linear optimization models quickly and efficiently.
Table 3 presents the DMU values of each renewable energy sources. According to Table 3, wind-onshore, wind-offshore, solar PV, geothermal, and biomass are efficient energy sources because they reach the maximum efficiency score, 1.0. On the other hand, solar thermal and hydropower are inefficient renewable energy sources because their efficiency scores are less than one. Solar thermal is inefficient because of high TSLC value, and hydropower is inefficient because it requires significant land area and high volume of water. According to these results, land requirement is a critical input variable for the efficiency scores of power plants. Although wind-onshore plant's TSLC is much less than wind-offshores', because of land requirement, both wind-onshore and wind-offshore reached the maximum efficiency score even wind-offshore does not create any employment.

Table 3: DEA Results for the Renewable Energy Sources

Power Plant	Efficiency Score	Efficiency	Inefficiency	References
Wind-onshore	1.0000	X		
Wind-offshore	1.0000	X		
Solar PV	1.0000	X		
Solar thermal	0.5115		X	2, 3, 5
Geothermal	1.0000	X		
Biomass	1.0000	X		
Hydropower	0.7876		X	1, 5

Table 3 also includes the reference sets of the benchmark ranking approach. As can be seen from Table 3, geothermal energy has the highest reference score because both of the inefficient energy sources referenced geothermal energy as the benchmarked energy source. High capacity factor and low TSLC makes geothermal energy source very preferable. According to this approach, wind-onshore, wind-offshore, and solar PV are referenced once. Therefore geothermal is ranked first and then wind-onshore, wind-offshore and solar PV share second highest rank, Inefficient
DMUs and biomass share the lowest rank according to the benchmark ranking method.
Table 4 presents the super efficiency and the virtual efficiency score of these seven different power technologies. For both of these two approaches, highest efficiency score refers the highest ranking, and then we rank the renewable energy sources in descending order. According to the super efficiency approach, solar PV has the highest efficiency score, which refers to the most efficient renewable energy source. Geothermal is ranked first for the virtual efficiency approach.
Table 5 shows the cross-efficiency matrix of these seven power plants. This is an *nxn* matrix where *ij* represents the efficiency score of a j^{th} power plant with the weights of the i^{th} power plant. The highest average efficiency score represents the most efficient power plant concerning its peers. According to these averages of these cross-efficiency scores, wind-onshore has the highest average efficiency score, which refers to the most efficient renewable energy source, and the solar thermal energy source is least efficient (or inefficient) renewable energy source according to the cross-efficiency approach.

Table 4: Super Efficiency and Virtual Efficiency Scores for the Renewable Energy Sources		
Power Plant	Super Efficiency	Virtual Efficiency
Wind-onshore	2.4154	0.7364
Wind-offshore	-	0.2856
Solar PV	14.7726	0.6320
Solar thermal	-	0.2329
Geothermal	5.8574	1.0000
Biomass	1.0876	0.4360
Hydropower	-	0.6180

Table 5: Cross-Efficiency Scores for the Renewable Energy Sources							
Power Plant	Wind-Onshore	Wind-Offshore	Solar PV	Solar thermal	Geothermal	Biomass	Hydropower
Wind-Onshore	1.000	0.265	1.000	0.102	1.000	0.719	0.524
Wind-Offshore	0.889	1.000	0.148	0.001	0.001	0.004	0.001
Solar PV	1.000	0.256	1.000	0.093	0.484	0.533	0.395
Solar thermal	0.246	1.000	1.000	0.511	1.000	0.001	0.026
Geothermal	1.000	0.437	0.536	0.144	1.000	1.000	0.662
Biomass	1.000	0.437	0.536	0.144	1.000	1.000	0.662
Hydropower	0.213	0.093	0.114	0.034	0.658	0.262	0.259
AVERAGES	0.764	0.498	0.619	0.147	0.735	0.503	0.361

Table 6 shows the summary of the ranking of the renewable energy sources according to efficiency scores, using benchmark ranking, virtual efficiency, and cross efficiency approach. In this comparison, we exclude super efficiency approach, because we cannot get efficiency scores of the inefficient power plants. Therefore final ranking is obtained by the cumulative scores of each power plants for these three approaches. Therefore overall ranking of the renewable energy sources should be as follow: (1) geothermal, (2) wind-onshore, (3) solar PV, (4) wind-offshore (5), biomass, (6) hydropower, and (7) solar thermal plant.

Table 6: Results of Comparing Ranking of the Renewable Energy Sources					
Power Plants	Benchmarking Approach	Virtual Efficiency	Cross Efficiency	Cumulative Scores	Overall Ranking
Wind-onshore	2	2	1	5	2
Wind-offshore	2	6	5	13	4
Solar PV	2	3	3	8	3
Solar thermal	7	7	7	21	7
Geothermal	1	1	2	4	1
Biomass	5	5	4	14	5
Hydropower	6	4	6	16	6

SUMMARY AND CONCLUSION

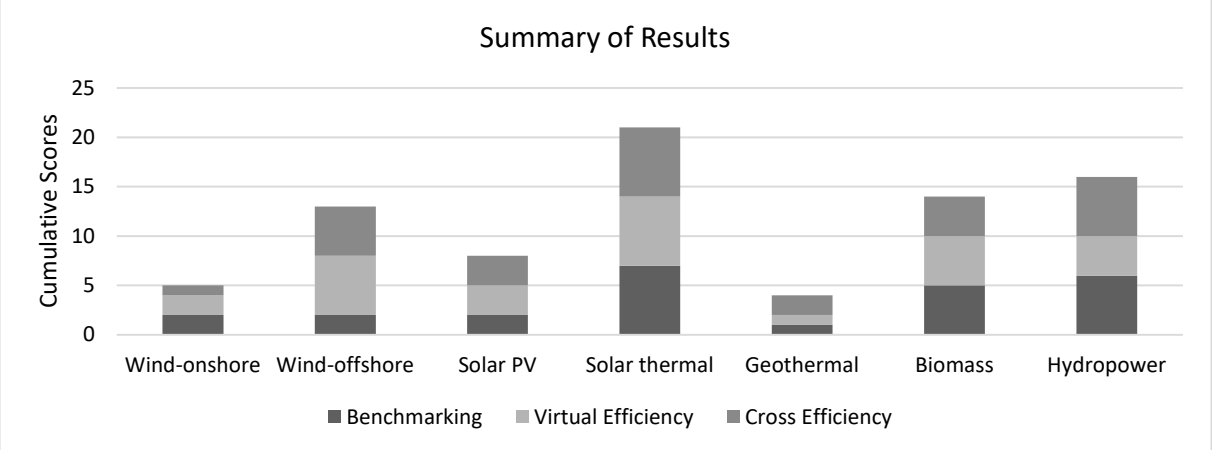
In this paper, we want to determine the most efficient renewable energy source(s), with pre-determined input and output variables. We construct DEA framework to find efficiency scores of each power plant. We apply four different analytic approaches, benchmark ranking, cross-efficiency, super efficiency and virtual efficiency. We rank each power plant by using three of these approaches, and then we calculate the cumulative scores. Finally, we rank these power plants according to their cumulative scores. Figure 3 and Table 6 summarizes the contribution of each analytic technique to the cumulative scores of each plant.

As can be seen from Figure 3 and Table 6, geothermal is the most efficient renewable energy source, even though the cumulative scores of wind-onshore and solar photovoltaics is very close to the leading source. Although both biomass and wind-offshore are also efficient energy sources, their cumulative scores are very low, concerning the top three renewable energy sources. Wind-offshore is a relatively new technology for U.S. so that the TSLC cost is very high and it is ranked (4). Although biomass had a high capacity factor and created more than 150,000 jobs in 2015, it is ranked (5) because it requires an enormous amount of land. This also shows us the land requirement is an essential input variable for this analysis. Hydropower is ranked (6) in our analysis because it requires large land and water consumption for its operation. Lastly, solar thermal is labeled as the least efficient renewable energy sources for each analytical approach that we covered in this study. This is due to its highest TSLC and lowest capacity factor value.

Solar PV is the fastest growing power-generation globally. Last year, the total installation increased by 20% concerning the previous year, and it created direct and indirect 2.8 million jobs. About ten years ago, the TSLC of Solar PV was almost 400 $/MW, and it was the most expensive energy source in the IPCC the Fourth Assessment Report (2007). However in the IPCC the Fifth Assessment Report (2014), it is about 66 $/MW. Technological advances and subsidies lead this cost reduction and make photovoltaic technology one of the most efficient renewable energy sources. In our analysis, solar thermal technology is the least efficient renewable energy source because of its highest TSLC value. However, in the future, the advancements in these technologies, may make them more preferable with the reduction of cost functions.

Renewable energy sources are our essential weapons to fight global warming and reduce GHG emissions all over the world. According to the EIA data, with the expansion of these renewable energy sources, GHG emissions started to decline in the United States in last five years. Therefore, policymakers should encourage and subsidize these technologies, especially the most efficient ones: geothermal, wind power and solar PV to prevent severe consequences of global warming and climate change.

Figure 3: The Cumulative Scores of the Renewable Energy Sources



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The Emergence of Entrepreneurial Ecosystem: How Early-stage Startups Build Partnerships

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ABSTRACT

How early-stage new ventures develop partnerships has remained underinvestigated mostly due to the difficulty of observing their dynamic development processes. In this study, I have observed eighteen startups in embryonic stage directly every day by working as an in-house mentor for six months. My longitudinal in vivo observations result in three distinctive types of partnerships among early-stage startups: transaction-, relationship-, and collaboration-based partnerships.

KEYWORDS: partnership, startup, network development

INTRODUCTION

Recently alliance networks of new ventures have attracted research interests significantly, such as what type of network they govern and how the governance structures work (Hoang & Antoncic, 2003). One area of research interest is the contents of alliance network: how and through which media actors in these networks gain access to other parties' resources and what type of resources they gain access to. Startups without much resource to leverage are particularly at needs of alliance networks to be able to access more resources. Prior studies have found that startups benefit from alliance networks in diverse ways, such as superior innovation performance (Baum, Calabrese, & Silverman, 2000), raising more venture capital investment (Baum & Silverman, 2004), or accelerated launching at the stock market (Chang, 2004). Yet early-stage startups usually lack legitimacy, or minimum level or track records, to appear viable and attract partner candidates due to their liability of newness (Stinchcombe, 1965). Therefore, early-stage startups, especially those in their embryonic stage, find themselves at disadvantage to find alliance partners.

How early-stage startups find and build partnerships has been underinvestigated mostly due to the difficulties of observing and investigating the contents directly. Moreover, prior studies in alliance and network research have mostly look at the static nature of alliance networks, whereas developing and maintaining alliance networks are dynamic processes by nature (Parkhe, Wasserman, & Ralston, 2006). Recently a few studies have responded to this criticism and adopted a longitudinal research design to investigate the prolonged impact of startups' partnerships (e.g., Milanov & Fernhaber, 2009). Still the process of partnership development by startups in an embryonic stage of ideation and incorporation has been underinvestigated. Therefore, in this study, I investigate early-stage startups by directly observing how they identify potential partners and build the partnerships to pursue various objectives.

LITERATURE REVIEW

Prior studies in alliance and network research have shown the beneficial influence of alliance networks, such as new venture performance (Baum et al., 2000), new product

development (Deeds & Hill, 1996), or absorptive capacity (George, Zahra, Wheatley, & Khan, 2001). More specifically for startups, those with more alliance networks are likely to take less time to file for initial public offerings (Chang, 2004), and raise more investment from venture capitalist (Baum & Silverman, 2004). In general, alliance networks are beneficial for firms to certain degrees. What has been far less investigated is how these alliance networks emerge in the first place among early-stage startups.

For early-stage startups, one of the biggest challenges is resource constraints. Without much resource to start from, early-stage startups' appeal as alliance partner candidates is lukewarm at best. Non-existent track records to prove their legitimacy hardly help these startups to find potential partners, either. Startups' liability of newness combined with limited resource availability aggravates startups' attempt to search for partnership candidates. Yet lack of alliance networks becomes even further liability for startups (Oliver, 2001). In this grim situation, how do startups search and identify potential partners, and subsequently develop future partnerships to pursue mutually beneficial goals?

In order to answer this research question, I have directly observed 37 early-stage startups during a six-month period by mentoring them every day as an in-house mentor at the Korean incubator for international startups. In the following sections, I describe the research context and the findings.

METHODS

In this study, I have adopted a longitudinal single case study methodology to investigate the process of partnership building by early-stage startups. Single case study method is considered to be particularly suitable for revelatory cases (Eisenhardt & Graebner, 2007; Yin, 1994). Since the current case of K-Global not only describes a unique phenomenon of a hybrid incubating program for international startups but also benefits from direct, *in vivo* observation in a continuously longitudinal way, revelatory longitudinal single case study is an appropriate methodology for this study.

Research Context: K-Global

I had worked for K-Global (pseudonym) in Seoul, South Korea, as an in-house mentor and lecturer for six months from November 1st, 2016 to April 30th, 2017. K-Global is a public incubator run by a private incubating company. Seoul Metropolitan City (SMC) came up with an idea of launching K-Global, the very first startup incubating center for international startups in South Korea. By international startups, SMC refer to a team of entrepreneurs whose nationalities include at least one foreign country. Since all South Korean government's grants for entrepreneurs had been only for Korean citizens before the launch of K-Global, SMC's first attempt to subsidize foreign entrepreneurs had attracted quite an interest from foreigners in South Korea who were considering starting their own businesses. SMC provided the budget to launch K-Global, and teamed up with one of top private incubating companies to plan, establish, and manage everyday operations of K-Global. As a result, K-Global's management direction was uniquely carved out by two competing perspectives of public and private sectors' managers.

The first batch of 37 resident startups was selected in August 2016, and officially enrolled themselves at K-Global in October same year. SMC provided each startup with KRW10,000,000 (USD10,000 approximately) The official six-month program started in November 2016, when I also joined K-Global as an in-house mentor. Thanks to my position, I was able to observe startup entrepreneurs' interactions with one another directly. Since all

resident startups were given an office space at K-Global, physical propinquity of all 37 resident startups gave me a unique opportunity to conduct *in vivo* observations. K-Global became a giant petri dish for me to observe how each startup entrepreneur interact and subsequently create various types of relationships with one another.

Data Collection

During the six-month period, I had mentored the resident startups at K-Global every weekday from 10am to 3pm. In addition to myself, K-Global hired two more mentors who would visit K-Global once a week to provide mentoring sessions for their designated mentees. I was the only in-house mentor who closely mentored my designated mentees, but also provided advice to all other resident startups when requested. My responsibility as an in-house mentor was largely set in three folds: (1) face-to-face mentoring sessions with anyone who needs advice; (2) weekly offline/online communications, or face-to-face mentoring sessions if needed, with my eleven designated mentees; and (3) regular lecture sessions for all resident startups at K-Global. Majority of my work fell into the first category: advising startups in an ad-hoc basis whenever they need my advice, which is completely pull-based. The second category of having offline/online communications or face-to-face mentoring sessions with my eleven mentees was more of a push-based approach: I initiate communications to check the current status of each mentee.

During these two categories of work, I not only advised and handled their requests, but also inquired their status in terms of interactions with other resident startups. For my inquiry, I adopted a semistructured interview technique to garner process information on how startup cofounders' interactions with those of other startups had evolved. Among 37 resident startups, I found 18 startups developing and managing partnerships during the six-month period of my residency. Table 1 lists Table 1 lists 18 resident startups and quick descriptions on their products or services. Following Bhave's (1994) process model of entrepreneurial venture creation, each startup's commercialization stage is categorized into three stages: opportunity stage, technology setup and organization creation stage, and exchange stage. All startup names are pseudonyms.

Table 1. List of 18 resident startups at K-Global

Startup	Product/service	Startup Stage
BebeCo	Ergonomically designed babycare products for infants	Technology setup and organization creation
BuddyCo	Real-time mobile application that connects foreign tourists and local tour guides	Technology setup and organization creation
CareerCo	Online and mobile application to create smarter resumes	Opportunity stage
CodeCo	Education kit for kids to learn both hardware and software programming	Technology setup and organization creation
ConciergeCo	Travel platform that provides highly customized tours	Exchange stage
CosCo	Curated Korean beauty products that targets European markets	Exchange stage
CultureCo	Contents platform of Korean entertainment	Exchange stage
DesignCo	Design platform that connects consumer firms and entry-level designers	Exchange stage
DeviceCo	Affordable yet high-quality 3D printer	Exchange stage

EdutainCo	Contents creator that targets Spanish consumers who want to learn Korean language and culture	Technology setup and organization creation
EventCo	Platform service for organizing events and booking tickets	Technology setup and organization creation
FitCo	Mobile application that provides customized fitness assistance	Opportunity stage
FunCo	Media contents creator that focuses on Korean culture	Exchange stage
GlobalCo	Overseas education platform for Korean students who want to study abroad	Technology setup and organization creation
IncaCo	Korean beauty products that targets Latin American markets	Exchange stage
MetroCo	Entertainment and political news contents of Korean market for foreign consumers	Exchange stage
StyleCo	Burlesque-inspired style items	Technology setup and organization creation
ToyCo	Social network service for toy collectors	Exchange stage

RESULT

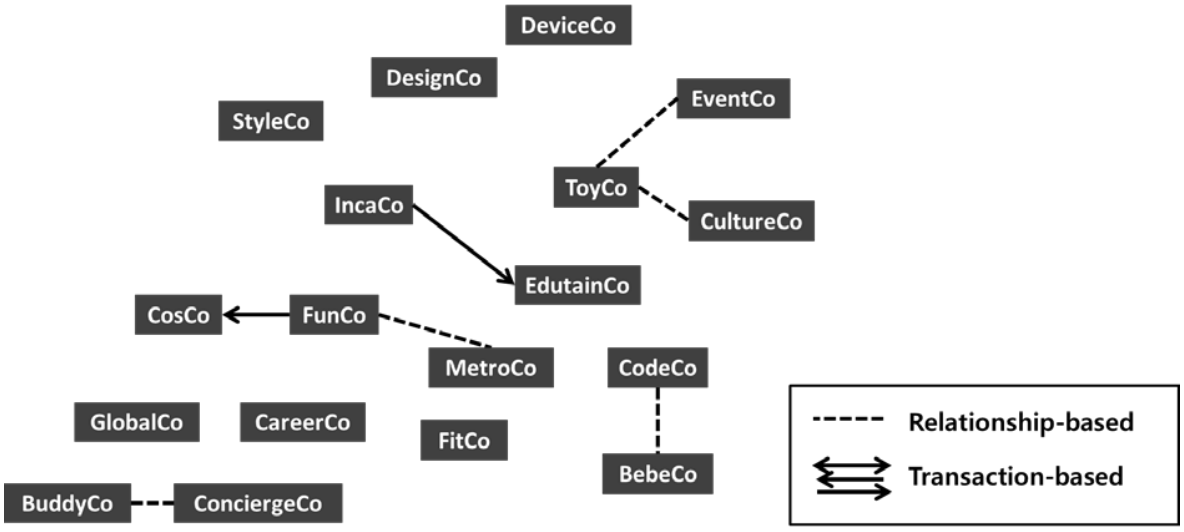
During the first two months, from November to December 2016, I had only witnessed casual and social interactions among resident startup entrepreneurs. Gradual clustering based on social relationships emerged during the first two months, largely based on two factors: (1) physical propinquity, such as sharing the same office, or close proximity of their offices, and (2) homophily in terms of their business ideas and nature of their businesses, such as targeting the same products or markets, and being technology-based or service-oriented startups. In this period, some entrepreneurs stood out as “social bees,” yet no distinctive patterns or concrete partnerships had emerged. Starting from January 2017, the third month of startups’ residency at K-Global, consistent patterns started to appear. These patterns show temporal clusters of three phases: (1) Phase 1 between early January and mid-February 2017, (2) Phase 2 between mid-February and early March 2017, and (3) Phase 3 between early March and late April 2017. I share my observation and analysis by following each phase in a chronological order.

During Phase 1, a few partnerships started to surface. Two distinctive patterns had emerged: (1) transaction-based partnerships started to happen among resident startups whose needs and solutions were matched, and (2) casual social relations started to be transformed into significantly strong relationship-based partnerships, such as dyadic relationships of informal mentor-mentee connections. The very first partnerships turned out to be mostly transaction-based partnerships, such as service contracts under which one startup provides its service to a fellow resident startup which happened to need that service. For instance, FunCo, a team of two media contents creators, which produces and distributes short video clips to introduce interesting aspects of Korean culture to English-speaking audience, had already equipped themselves with necessary capability to create media contents by themselves. On the other hand, CosCo, a team of a beauty specialist and a business person who curate Korean beauty products to cater to European consumers, was in need of an inexpensive media production service to create video clips for promotional purposes. Transactional partnership between FunCo and CosCo was sealed immediately, as CosCo’s demand- and FunCo’s supply-side factors were well aligned.

At the same time, unusually strong social relationships also sprang up. Unlike casual social relationships I have observed during the first two months, these strong ties were found to resemble a type of mentor-mentee bond. Majority of these strong relationships I had observed had happened between two startups which share a certain level of resemblance in terms of their target products or the type of industry where they were operating in. For instance, EdutainCo, a team of Spanish-speaking Korean students and Spanish nationals who develop an online platform for Spanish audience to learn Korean language and culture, started to seek advice from CultureCo, which had already launched an online platform to share media contents about Korean entertainment culture with wider audience in overseas countries. CultureCo was at the exchange stage: it already had secured the first batch of active online customers and had successfully organized entertainment events internationally. By constantly giving advice to EdutainCo, CultureCo unintentionally had assumed a role of informal, junior mentor of EdutainCo. This type of unusually strong relationship-based partnerships also happened between FunCo and MetroCo, both of which create media contents for English-speaking audience, and CodeCo and BebeCo, both of which develop working prototypes for their hardware products.

One interesting exception was ToyCo, a team of three engineers and a marketer which develops a social network service for toy collectors. Although ToyCo hardly shares any similarity in terms of target products or their nature of business, ToyCo had developed strong relationships with CultureCo and EventCo mostly by giving advices on entrepreneurial experiences in general, including its various experience in raising funds from both public and private sectors. Moreover, one of cofounders of ToyCo shared his own observations of other resident startups at K-Global with me, in such a way that he was proactively and intentionally looking for not only ToyCo's potential partners but also candidates for matchmaking. Figure 1 shows the partnerships developed during Phase 1.

Figure 1. Partnerships among startups in Phase 1

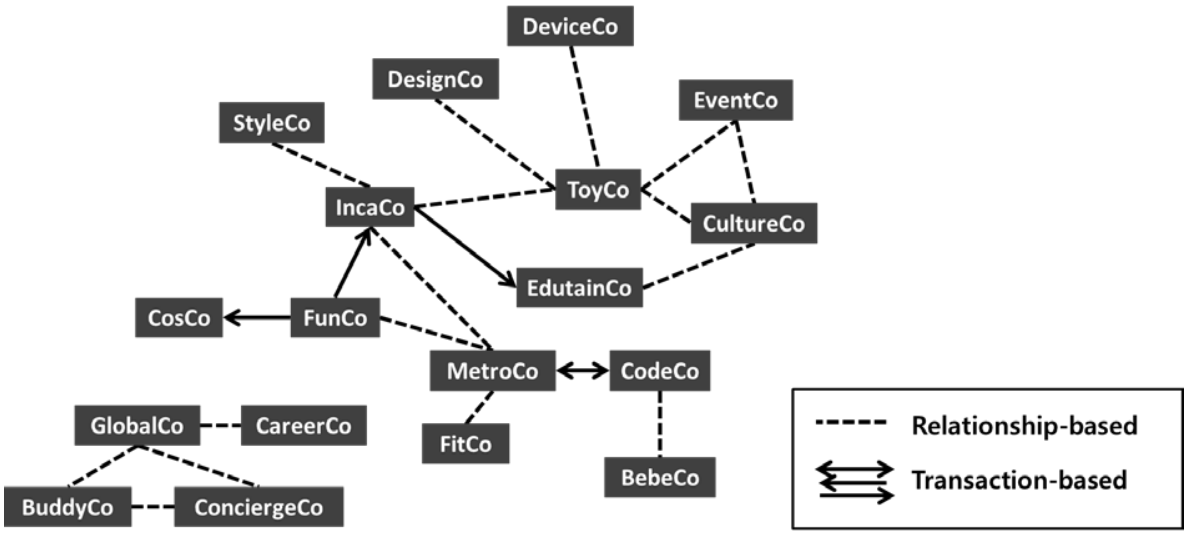


In sum, during the embryonic stage of creating a startup, entrepreneurs create primitive forms of alliance partnership based on a simple transaction-based partnership. Their rationale behind these decisions is more likely to use the very first partnership as a type of litmus test on how their partnerships would work out effectively. Therefore, I propose a following proposition based on my observation during Phase 1:

Proposition 1. Early-stage startup entrepreneurs are likely to engage themselves in simple transaction-based partnerships in order to coopt limited resources.

During Phase 2, more transaction- and relationship-based partnerships had sprung up, following the same patterns I had observed during Phase 1: (1) transaction-based partnerships, and (2) casual social relations transformed into significantly strong relationship-based partnerships. Figure 2 shows the partnerships developed in this period. As shown in Figure 2, startups develop mostly same types of partnerships. For instance, ToyCo and MetroCo were heavily involved in relationship-based partnerships with multiple startups, whereas FunCo was mostly developing transaction-based partnerships. One interesting exception was IncaCo, a husband and wife duo who try to establish Korean skincare service in Latin American countries. IncaCo developed both transaction- and relationship-based partnerships with almost equal dexterity. Moreover, I observed that IncaCo was an information conduit at K-Global. Not only IncaCo was an apt at scanning and searching for new information, it was also an effective information communicator for other resident startups at K-Global.

Figure 2. Partnerships among startups in Phase 2



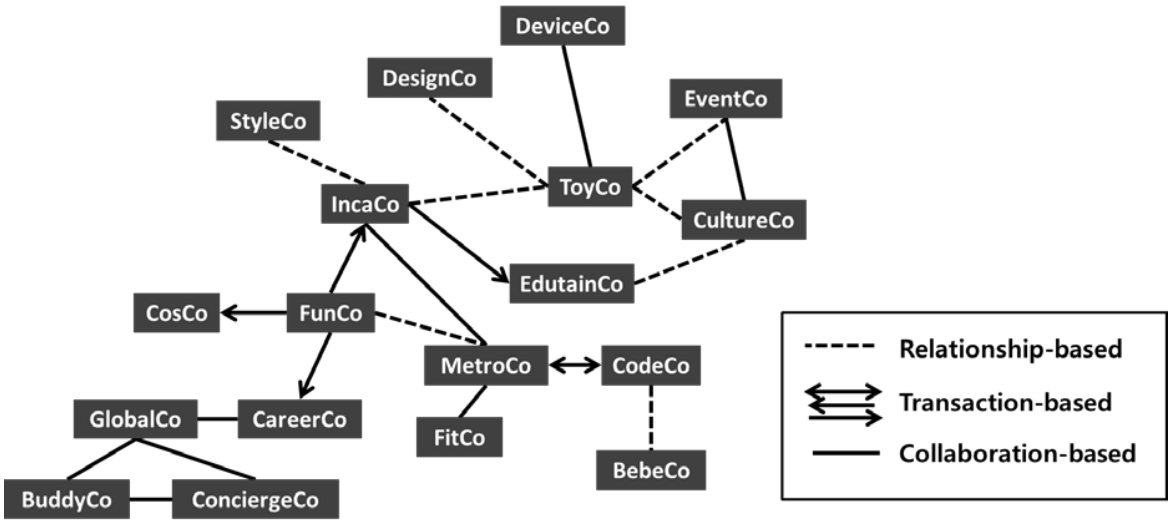
During Phase 3, the structure of partnerships among resident startups had rarely changed, except a new transaction-based relationship between FunCo and CareerCo. On the contrary, the nature of some partnerships show dramatic changes in this period. As shown in Figure 3, a group of relationship-based partnerships during Phase 2 had been transformed into collaboration-based partnerships, such as developing new business ideas together by pulling both parties' resources together. Eight relationship-based partnerships, which are DeviceCo-

ToyCo, EventCo-CultureCo, IncaCo-MetroCo, MetroCo-FitCo, GlobalCo-CareerCo, GlobalCo-BuddyCo, BuddyCo-ConciergeCo, and GlobalCo-ConciergeCo, had quickly been turned into collaboration-based partnerships to either develop new business ideas or expanding their product portfolio together for growth purposes. Interestingly, this transformation was never observed with transaction-based partnerships, which remained almost identical as a relationship between customer and service provider throughout Phase 2 and 3.

In comparison to startups which engage in transaction-based partnerships, those leveraging relationship-based partnerships are more likely to move forward to the next stage of collaboration-based partnerships. Therefore, I propose the following proposition based on my observation during Phase 2 and Phase 3:

Proposition 2. Early-stage startup entrepreneurs who start relationship-based partnerships with other entrepreneurs are likely to move forward their alliances into collaboration-based partnerships.

Figure 3. Partnerships among startups in Phase 3



DISCUSSION

In this study, I have observed early-stage startups directly during a six-month period, and identified three types of partnerships of early-stage startups: (1) transaction-based partnerships between startups one of which needs solutions and the other of which provides them, and (2) relationship-based partnerships between startups which build strong dyadic social relationships between advice-providers and advice-recipients, and (3) collaboration-based partnerships among startups which transform their relationship-based partnerships into more formal collaborations to develop future business ideas or expand the current businesses by pooling participating parties' resources together.

Transaction-based partnerships either happen at one point of time or continuously depending on the needs of startups which fall into the role of customers. Throughout the six-

month period of observation, the nature of transaction-based partnerships remains unchanged. In contrast, both relationship- and collaboration-based partnerships are observed to be strongly related, in such a way that relationship-based partnerships work as antecedents to pursue collaboration-based partnerships. Startups without much resources available or track records to prove their legitimacy have difficulties with defining assessment criteria to identify potential partners. By building relationship-based partnerships first, startups may be able to concretize assessment criteria heuristically. Positive experience of both parties that are engaged in relationship-based partnerships provide much needed assurance for both parties to pursue further partnerships which gradually turn into collaboration-based partnerships.

The findings of this study contributes to both academia and industry. By directly and longitudinally observing how early-stage startups develop partnerships in their embryonic stage, the dynamic process of partnership development is explained. Moreover, different types of partnerships are found to be leveraged in different ways to either solve problems efficiently or collaborate for new business opportunities. For practitioners, the findings of this study provide insights on how to develop incubating environments to enhance partnership developments among resident startups.

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The Future of Business Analytics Education: Efforts to Close the Gap between Academia & Industry

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ABSTRACT

The job market has been experiencing a rapidly growing demand for business analytics professionals. In this fast-paced business world, current analytics programs need to follow the trends, tools, and concepts frequently used by industry to continuously improve their programs. Thus, this research-in-progress aims to identify the skills that industry is looking for in analytics professionals and determine the tools and concepts covered in the courses offered through analytics programs at numerous universities. The primary objective of this evolving study is to help the academic world to align their analytics curricula with business needs and expectations.

KEYWORDS: Analytics, Curriculum Design, Masters, and Job Market

INTRODUCTION

The number of job openings for business analytics positions (e.g., operations analytics, data scientist) is increasing at a remarkable pace. It is predicted that by 2020, the number of analytics jobs will increase by 28% and reach 2,720,000 (PWC, 2017). The salaries for business analytics jobs are also expected to go up. Nevertheless, the industry still faces difficulties in hiring analytics professionals; and the analytics job postings remain open for longer durations than other positions (Manyika et al., 2011; Columbus, 2017). The growth in demand for business analytics jobs has been the center of focus for several years in industry reports (Manyika et al., 2011; Columbus, 2017; PWC, 2017) and academic research (Chiang et al., 2012; Gorman & Klimberg, 2014; Mamonov et al., 2015; Rienzo & Chen, 2018). Hence, both industry and academia have placed efforts to train the future analytics workforce.

Universities, by designing business analytics (BA) programs, have been making a significant contribution to resolving this demand shortage. However, the major problem is the broad and often vague use of the business analytics job descriptions and the terms used, and the lack of definitions of the specific skills required by industry practitioners (Rienzo & Chen, 2018). Association to Advance Collegiate Schools of Business (AACSB) has been active in recent years to keep track and provide guidance for curriculum development for the discipline of Business Analytics. At a recent Summit organized by AACSB “to provide faculty participants

with a forum to learn about, share & discuss, and identify strategies & resources for Data/Business Analytics in the curriculum at their university" over 200 participants met from several different countries to discuss the scope of an effective BA/data analytics (DA) curriculum. Findings shared through best practices and lessons learned indicated very similar experiences of university programs: diversity of students' backgrounds and readiness, lack of clarity on industry needs, challenges of competent and experienced faculty, administrative challenges of developing interdisciplinary BA/DA programs, industry support for internships and capstone courses. With fast evolving technologies and vendor products the challenges of BA/DA curriculum get very difficult.

Many endeavors have strived to define the specific skills needed for business analytics graduates; however, most of these endeavors were restricted to data collected from a limited number of firm managers. We believe that, given the increasing demand for analytics professionals and ever-changing job descriptions, there still is a need to design a framework to help academia shape their business analytics curriculum in accordance with the industry needs. Hence, this paper proposes a novel framework based on a testbed consisting of tens of thousands of business analytics jobs analyzed to examine the fit against the curricula adopted by universities. In order to serve the industry practitioners and educators of business analytics, the primary objective of this study is to provide a framework that will help universities align their analytics curricula with industry needs and expectations. Specifically, this research-in-progress will focus on the following question: What are the computational tools, technical knowledge, and soft skills needed in the industry for business analytics graduates?

LITERATURE REVIEW

In our literature review, we first elaborate on the history of analytics and explain why the term "analytics" has become so popular in the last ten years. Then, we summarize publications regarding the development of analytics programs. The discussion in this literature review is particularly essential to readers to have a better understanding of the development process and the evolution of the analytics field in industry and how academia has been responding to this trend by initiating new programs.

Brief History of Analytics

The manufacturing industry, which was the backbone of the U.S economy during the late 20th century, widely used Operations Research (OR) for resource management and scheduling, and frequently employed descriptive and inferential statistics for quality and process management. Throughout the 1950s to 1970s, Business and Engineering schools developed new programs to satisfy the demand for newly emerging quantitative fields (e.g., Industrial Engineering, Management Science, and Operations Management). In the 1970s, although the computers were available before in the form of giant calculators, they were becoming commercially available. Thus, companies started using them for real-world purposes, such as storing and processing data. Universities witnessing the use cases of computers in the business world started offering programs in Information Technology (IT). Throughout the 1980s and 1990s, the collaboration among the three pillars of analytics, namely, statistics, optimization, and information technology remained negligible. Starting from the early 2000s, when companies realized that the use of technology in making business decisions was a differentiator and key to surviving in the market, they integrated statistical and optimization tools with computer systems under the umbrella of Business Intelligence (BI).

In today's world, with exponentially increasing computational power and data storage capabilities of computers, companies can store petabytes of information using distributed file systems (e.g., Hadoop). Big Data, as an emerging phenomenon, impacts numerous industries and how they conduct business. For instance, telecommunication companies use classification methods to predict which customers may churn; finance industry employs reinforcement learning to make stock buy/sell decisions; logistics firms determine the best route and inventory needs using real-time traffic data and optimization methods, etc. In the era of Big Data and Information Technology, Statistics, Operations Research, and Computer Science fields are more intertwined than ever before, and have merged as a new interdisciplinary field named "Business Analytics (BA)", "Data Analytics (DA)", or "Data Science". Therefore, academia is responding to this new and developing field by designing programs that will educate the next generation of analytics professionals.

Past Research Exploring Analytics Curriculum

In our literature review, we have examined several articles regarding the best practices to design and improve a business analytics curriculum. Table 1 summarizes the list of nine identified journal articles written between 2012 and 2018. Since many educators argue that math and programming are the pillars of data analysis, Aasheim et al. (2015) have investigated the requirements of analytics programs and found that existing business analytics curricula don't require general math or programming courses. Their study also states that business analytics programs lack emphasis on data capture and ethics.

Table 1: Summary of Literature Review

Article	Outlet	Scope	Methodology
Aasheim et al. 2015	Journal of Information Systems Education	Compare data science and BA programs	Analysis of 13 universities curricula and course descriptions
Cegielski & Jones-Farmer 2016	DS Journal of Innovative Education	Skills for entry-level BA jobs	Expert Panel (27 participants), Content Analysis (186 job postings), Survey (160 participants)
Chiang et al. 2012	ACM Transactions on MIS	IS discipline & programs challenges and opportunities	Discussed examples of curriculum design in universities
Gorman & Klimberg 2014	Interfaces	Comparison of different undergraduate and graduate BA programs	Examined 32 programs and interviewed 17 program representatives.
Mamonov et al. 2015	IS Education Journal	Discussing the design of BA curricula	Analyzed 8 BA job announcements and 6 BA programs
Rienzo & Chen 2018	DS Journal of Innovative Education	Apply Disruption Theory to guide design of BA curricula	Analyzed 70 BA programs and 400 indeed job announcement.

Tang & Sae-Lim 2016	Education for Information	Comparison of programs across disciplines: description, curriculum, focus, and courses.	Content analysis on 30 data science programs from 8 disciplines.
Wilder & Ozgur 2015	Informs Transactions on Education	Undergraduate curriculum design	Reviewed 5 curricula and 8 publications/ industry reports
Wixom et al. 2014	Communications of AIS	Assess the response to industry demand to BA and big data	Analyzed "BI Congress" events: Survey of 319 prof/614 students/446 practitioners.

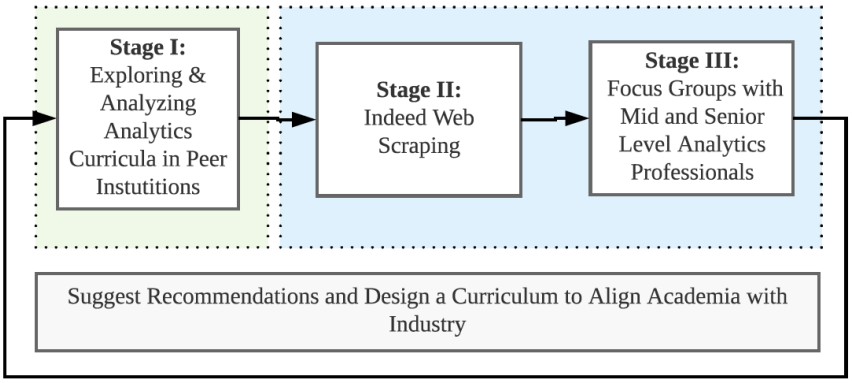
Cagielski and Jones-Farmer (2016), as well as Chiang et al. (2012), have discussed the development stages of business analytics curriculum and identified critical skills, tools, and languages. Their study reveals that technical skills in SAS, SQL, and Excel are essential for entry-level jobs. A survey conducted by Wixom et al. (2014) finds that industry is not satisfied with graduates' practical experience because academia does not focus on real-world application of analytics using real datasets, and many programs do not require internships to graduate. Gorman and Klimberg (2014) have conducted a comparative analysis using thirty-two programs to identify the differences among them. Their research indicates that there are significant differences in business analytics definition and directions of the programs. In a similar comparison analysis, after analyzing job announcements and business analytics curricula, Mamonov et al. (2015) also conclude that there is variance between programs regarding length, flexibility, tools, and methods. A study done by Tang and Sae-Lim (2016) reveals that there are significant differences across disciplines in curriculum requirements, domain knowledge or analytical focus, and courses. Wilder and Ozgur (2015) propose seven major courses and implementation guidelines. After analyzing seventy programs and four hundred job announcements, Rienzo and Chen (2018) recommend flexible, adaptable, and dynamic curricula.

FRAMEWORK & ANALYSIS

Our methodology to propose a business analytics curriculum that can satisfy industry's needs and expectations includes three stages:

- Stage 1: Peer university analysis: collecting and analyzing data regarding the current state: Analyzing universities that offer Master of Science in Business Analytics Programs- MSBA.
- Stage 2: Indeed.com web scraping: identifying industry's needs and expectations from analytics specialists using web scraping of thousands of job posts.
- Stage 3: Focus groups: Determining the needs and expectations of managers from entry-level analytics practitioners using focus groups

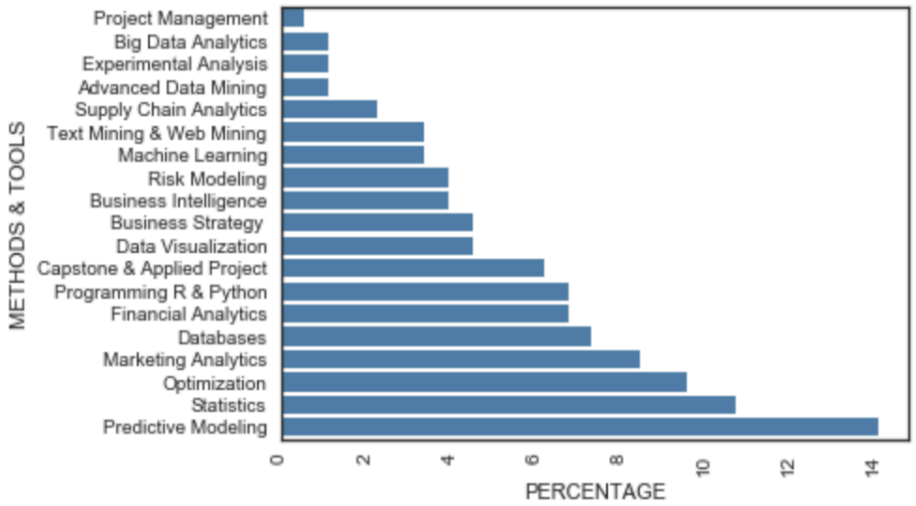
Figure 1: Proposed research framework



Peer University Analysis

In the peer university analysis stage, we have explored the curricula of Business Analytics programs in the Northeast Region of the US. To collect data, we have utilized the list of graduate business analytics programs maintained by the Institute for Advanced Analytics; then, we have narrowed down the list by filtering the location by state. We have reviewed the websites of the universities to collect the necessary data regarding the structure of the program and the list of courses. Our final list consists of 15 programs with a full Master's program in Business Analytics. We have coded each course in each program using the categories listed in Figure 2 and computed the percentage of courses in each category relative to the total number of courses required in the business analytics curricula across the different universities.

Figure 2: Percentage of course categories



The results of the peer university analysis show that programs in our sample have a focus on the basic analytics skills (e.g., predictive modeling) and the application of the skills in the financial and marketing sectors. However, the results show that less focus is on the managerial and organizational aspects such as project management which was highlighted as an important skill by prior research (Rienzo & Chen, 2018). Furthermore, big data concepts and programming

tools such as R and Python have less emphasis in our sample. We also think that cloud computing and the Hadoop ecosystem has not made into the curricula of these programs. Additionally, one of the most important pillars of business analytics that deals with design and analysis of experiments (e.g. A/B design for marketing) is not taught in the current analytics curricula of peer institutions.

WORK IN PROGRESS

Stage 2 and Stage 3 are still work-in-progress. In the following, we present a summary of the steps that we propose to implement.

Stage 2: *"indeed.com"* Job Scraping

In the second stage, we plan to employ a web scraping script in Python to collect job posting data (e.g., job name, description, and salary) from indeed.com. Our developed script automatically searches the website for user-defined job titles in given locations. We will conduct a job search for the postings that include the following keywords: *business analytics, data analytics, data analysis, data scientist, and analytics*. We will limit our search to the Northeast Region in the US following our analysis in stage 1. Specifically, we will focus our analysis on the following key areas:

- *What is the Importance of Advanced Degrees in Industry?*
- *What are the Concepts and Methods Required by Employers?*
- *What are the Tools needed?*
- *What is the Importance of Big Data in Analytics Curriculum?*

Stage 3: Focus Groups

In this section of our analysis, we will organize focus groups with mid-level and senior level analytics practitioners working in prominent companies in the US. Specifically, we will ask them the following questions and summarize their responses.

1. What are the tools you expect from entry level analytics specialist to know?
2. What are the concepts and methods entry level analytics practitioners in your team should know? How important is prior work experience for entry level analytics jobs?

CONCLUSION

In this research-in-progress paper, a framework for identifying the skills that industry is looking for in analytics professionals has been presented. The framework consists of exploring and analyzing business analytics curricula in universities, web scraping of thousands of business analytics jobs, and conducting focus groups with mid and senior level analytics industry professionals. The results of the first stage in the framework show the common courses emphasized across universities, as well as highlight the topics that have less focus in existing curricula. Topics that need more emphasis include managerial and organizational aspects such as project management, big data concepts, cloud computing, and analytics programming tools. In addition, the steps that will be implemented in stage 2 and stage 3 were discussed.

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DECISION SCIENCES INSTITUTE
The Impact of Green Supply Chain Integration on the Triple Bottom Line

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ABSTRACT

This study establishes a comprehensive framework of green supply chain integration (GSCI) based on the supply chain integration (SCI) literature and the natural-resource-based view (NRBV) and investigates the effects of different dimensions of GSCI on environmental, social, and economic performance. Model was tested based on data collected from 206 manufacturers.

KEYWORDS: Green supply chain management, Supply chain integration, Triple bottom line

INTRODUCTION

Green supply chain management (GSCM), which integrates environmental concerns into supply chain management (Srivastava, 2007), has emerged as an important strategy for companies to respond to the growing public environmental awareness and the rising government regulations (Rauer & Kaufmann, 2015; Vanpoucke et al., 2016). However, in practice, except for addressing environmental issues, companies continue to struggle with benefiting from GSCM (Wong et al., 2018). The main reason may be that supply chain managers have limited knowledge about how to effectively implement GSCM. This necessitates the research focus on “how to be green”, in addition to the traditional focus on “does it pay to be green”.

The majority of previous studies exploring GSCM practices have adopted a functional approach to GSCM and focused on specific functional areas (e.g., Kirchoff et al., 2016; Geng et al., 2017; Vanalle et al., 2017), such as green purchasing. This approach does extend environmental initiatives across supply chains. However, it fails to enable the concerted efforts of supply chain partners and does not exert the synergistic effect of supply chains. Since GSCM faces multiple complexities and uncertainties (Zhu et al., 2012) and involves a tremendous amount of investments and resources exchanges (Chen & Hung, 2014), an integrated approach to GSCM is much needed for companies to green their supply chains and reap performance benefits (Vachon & Klassen, 2008; Zhu et al., 2012; Yu et al., 2014).

Even though some recent studies have identified the importance of the integrated approach to GSCM and have coined the term green supply chain integration (GSCI) (Wu, 2013; Wong et al., 2015; Song et al., 2017), the conceptualization of GSCI is still ambiguous and fragmented. Some research highlights the integration of practices, such as integrating environmental management practices into supply chains (Wong et al., 2015), while others emphasizes the integration of participants, such as integration with suppliers and customers when managing environmental issues (Wu, 2013; Yu et al., 2014). In addition, the integration activities covered by existing literature are far from comprehensive and complete, making it difficult to distinguish the integrated approach from the collaborative approach. Overall, these mixed conceptualizations and operationalization of GSCI studies fail to capture the nature of supply chain integration (SCI).

In addition, our knowledge about how GSCI influences performance is still very limited and incomplete. To the best of our knowledge, there are no studies that have investigated the effect of GSCI on the triple bottom line (TBL) which includes economic, environmental, and social performance (Elkington, 1998). Furthermore, despite numerous studies on the link between GSCM and performance, social performance has received limited scholarly attention (De Giovanni, 2012). Existing literature mainly focuses on the effect of GSCI on environmental performance (e.g., Wong et al., 2018), financial performance (e.g., Song et al., 2017), operational performance (e.g., Yu et al., 2014; Song et al., 2017), and innovation performance (e.g., Wu, 2013; Dai et al., 2015).

Overall, the purpose of our study is twofold: building a comprehensive framework of GSCI based on SCI, addressing "how to be green"; and building a link between GSCI and the TBL, addressing "does it pay to be green". Our study integrates and extends the literature on GSCM and SCI, and provides significant guidelines for supply chain managers to leverage SCI to green their supply chains and earn benefits.

THEORETICAL BACKGROUND AND HYPOTHESES DEVELOPMENT

The Impact of GII on GSI and GCI

Extant literature has delineated that internal environmental management is the first step to GSCM (e.g., De Giovanni & Vinzi, 2012; Green et al., 2012). It lays the foundation for effective green collaboration with external supply chain partners (Yang et al., 2013). We argue that this assertion still holds for GSCI and postulate that GII is positively related to GSI and GCI. First, internal green information sharing means that internal departments are able to track real-time green-related information about products from raw materials to end products. Once they detect any problems, they will have to share this information with suppliers in that suppliers provide raw materials and may be responsible for some problems. In addition, getting green-related data also enhances the level of communication with customers about customers' environmental requirements and how companies are conforming to these requirements (Zhao et al., 2011). Therefore, internal green information sharing facilitates green integration with suppliers and customers.

Second, internal green process coordination breaks down functional barriers (Flynn et al., 2010) and enable different departments to work together to ensure all the internal processes are green (Yang et al., 2013). It creates a learning atmosphere across functions, which is likely to be expanded across companies and motivates companies to learn from their supply chain partners. As a result, the level of information sharing and communication with suppliers and customers will be high and suppliers and customers are more likely to involve in all processes of companies' green efforts. Dai et al. (2015) reported that internal integration of green product development process is positively related to supplier and customer integration of green product development process. Therefore, we argue that, internal green process coordination is positively related to green integration with suppliers and customers.

Third, internal strategic alliance implies that all departments are aware of green objectives and strategies and are willing to be subordinate their functional objectives to companies' objectives (Zhao et al., 2011). To achieve these objectives, employees from purchasing and marketing departments have to communicate with suppliers and customers about the green objectives and gain their support. From this perspective, internal green strategic alliance will facilitate green information sharing with suppliers and customers. In addition, internal strategic alliance shows

company commitment to the environment. Under this circumstance, companies will do their best to involve their supply chain partners in the environmental management and collaborate with them at all levels. Therefore, internal strategic alliance will have a positive effect on GSI and GCI. De Giovanni (2012) and Yang et al. (2013) both found that internal environmental management facilitates external environmental management with suppliers and customers. Therefore, we propose:

H1a: GII is positively related to GSI.
H1b: GII is positively related to GCI.

The Impact of GSCI on the TBL

The Impact Of GSCI on Environmental Performance

A positive relationship between internal environmental management and environmental performance is increasingly evidenced in the literature (Yang et al., 2013; Geng et al., 2017). For example, Yang et al. (2013) found that in the container shipping context, internal green practices have a significant positive effect on green performance. Geng et al. (2017) conducted a meta-analysis on the relationship between GSCM practices and performance and found that intra-organizational management enhances environmental performance. We argue that GII, as a better strategy to internal environmental management, will significantly increase environmental performance. First, green information sharing enables employees to detect green-related information in a timely manner. Then companies can adopt pollution prevention mechanisms to limit their emission. Real-time information about energy consumption also forces companies to constantly seeking ways to reduce the energy consumption. Second, internal green process coordination enables employees from different functions to voice their opinions, which will generate more solutions to environmental issues and increase environmental performance. Third, internal strategic alliance across functions enables a concerted effort of all employees to achieve the green objective. Therefore, we propose:

H2a: GII is positively related to environmental performance.

Environmental management being extended to supply chains is because it is well acknowledged that external environmental collaboration with suppliers and customers could significantly help companies go green (Rao & Holt, 2005). Previous studies pointed out that supplier and customer environmental collaboration influence performance in different ways. The results of their impact on environmental performance are mixed. For example, Geng et al. (2017) found that supplier integration positively influences environmental performance, while the effect of customer collaboration is nonsignificant. On the contrary, Jabbour et al. (2017) reported that environmental collaboration with customers is more effective for Brazilian companies to achieve environmental performance. In addition, Vachon and Klassen (2007) claimed that supplier collaboration is more effective at pollution prevention, while customer collaboration is more effective at pollution control. In this study, we argue that both GSI and GCI are positively related to environmental performance. First, green information sharing with suppliers clearly communicates environmental requirements to suppliers and enables companies to supervise whether suppliers are conforming to these requirements, forcing suppliers to follow the standards and provide green raw materials. In this regard, environmental performance can be ensured at the source of supply chains. Second, green process coordination with suppliers and customers involve them in all the processes of the value chain. This integration will help companies advance their environmental management technologies and improve their

environmental management capabilities (Geffen & Rothenberg, 2000), leading to better environmental performance. Third, green strategic alliance with suppliers and customers indicates that suppliers and customers have a clear understanding of companies' green objectives and strategies. In this case, suppliers are more likely to provide raw materials that are more environment-friendly and customers are more likely to ask for green packaging. Therefore, we propose:

H2b: GSI is positively related to environmental performance.
H2c: GCI is positively related to environmental performance.

The Impact of GSCI on Social Performance

Social performance has not received much scholarly attention in the literature on GSCM (De Giovanni, 2012). Only several studies have investigated the effect of GSCM on social performance. De Giovanni (2012) and Geng et al. (2017) both found that internal environmental management has a positive relationship with social performance. We argue that this relationship still holds for GII. First, internal green information sharing enables all employees from different departments to have access to green-related information. Some of this information may be related to workplace safety and employee health. Having this information, employees are able to take actions to protect themselves. As a result, the workplace safety of employees is likely to be enhanced. Second, internal process coordination enables a concerted effort of different functions in such processes as product design, increasing the likelihood that companies provide more environmental-friendly products into the markets. These environmental-friendly products may be able to improve the environmental safety of the community. Third, internal green strategic alliance reflects a company's determination to go green, which might be perceived by people from the community. This perception may increase their awareness of protecting environment and society. Therefore, we propose:

H3a: GII is positively related to social performance.

Though previous studies did not reported a positive relationship between external environmental collaboration and social performance (De Giovanni, 2012; Geng et al., 2017), we argue that green integration with suppliers and customers is able to increase social performance. This is because green integration with supply chain partners is different from the previous approach of environmental collaboration. On the one hand, it highlights a more close and integrated relationship, which may produce a wide range of performance. On the other hand, our approach of green integration includes all three strategies of NRBV, which may generate more competitive advantages. Specifically, green information sharing with suppliers and customers enables companies to get more information about the needs and requirements of stakeholders. It provides the opportunity for companies to address these needs and improve the well-being of stakeholders. In addition, green process coordination enables customers to solve environmental problems together with suppliers and customers. This significantly improves their problem-solving capabilities and efficiencies (Dai et al., 2017). As a result, serious pollutions may be solved immediately, reducing their potential damage to stakeholders. Green strategic alliance with suppliers and customers improves their commitment to environment. Suppliers may provide more environmental-friendly raw materials and customers may require more environmental-friendly products. This may require companies to build more environmental-friendly production lines, which will directly improve employees' working conditions and ensure their health and safety. Therefore, we propose:

H3b: GSI is positively related to social performance.
H3c: GCI is positively related to social performance.

The Impact of GSCI on Economic Performance

A lot of scholars have claimed that economic benefits are the major driver for companies to green their supply chains (e.g., Bowen et al., 2002; Kirchoff et al., 2016). Despite the numerous studies, the findings of whether GSCM improves economic performance are still mixed (Golicic & Smith, 2013; Geng et al., 2017). For example, Zhu and Sarkis (2004) and Zhu et al. (2005) argued that for Chinese manufacturers, GSCM practices are unable to create better economic performance. On the contrary, recent studies mainly reported a positive relationship between GSCM and economic performance (e.g., Geng et al., 2017; Schmidt et al., 2017). For example, Geng et al. (2017) found that internal environmental management, green collaboration with suppliers and customers all lead to a better economic performance. In line with this study, we argue that each dimension of GSCI has the possibility to increase economic performance. GII increases economic performance in three ways. First, internal green information sharing facilitates communication among different functions, reducing the cost of communication. Second, internal process coordination establishes a coordinated mechanism for different functions to work together, reducing the cost of coordination and conflict revolution. Third, internal strategic alliance is a signal to customers that this company commits to environment, which may increase product sales. Therefore, we propose:

H4a: GII is positively related to economic performance.

Li et al. (2016) found that green supply chain processes play an important role in improving financial performance. Yang et al. (2013) also reported that external collaboration with supply chain partners influence firm competitiveness positively. Similarly, we argue that GSI and GCI may be able to improve economic performance. First, green information sharing with supply chain partners enables companies to have real-time information about how suppliers are operating, reducing supervision cost. Second, green process coordination with supply chain partners promotes joint problem-solving which may generates more economical solutions. It also encourages supply chain partners to share the risks and costs when solving environmental problems, leading to better economic performance. Third, green strategic alliance with suppliers and customers indicates that companies view environment as a strategic objective, which may help companies build a good reputation and attract more customers. As a result, sales will be improved. In addition, to be green also implies to reduce waste. Therefore, the implementation of GSCI will inevitably save cost for companies. Therefore, we propose:

H4b: GSI is positively related to economic performance.
H4c: GCI is positively related to economic performance.

METHODOLOGY

Sampling and Data Collection

We collected data from manufacturing companies located in four representative regions in China (i.e. Bohai Bay Economic Rim, Pearl River Delta, Yangzi River Delta, and other areas in China) for its large size with uneven economic development (Chan et al., 2016). Specifically, other areas include northeastern, central, and western parts of China, which represent a relatively lower stage of economic development compared with coastal areas. We randomly

selected sampling companies from the directory provided by National Bureau of Statistic of China, covering diverse industries including automobiles, electronics, computers, food, chemicals, and so on. Phone contacts were made before mailing the questionnaire so that the key informant who was knowledgeable about supply chain management could be identified and ensured his/her agreement to participate in the survey.

Table 1: Profiles of Responding Companies			
INDUSTRY	PERCENTAGE	REGION	PERCENTAGE
Metal, Mechanical & Engineering	42.7%	Bohai Bay Economic Rim	32.2%
Electronics & Electrical	18.7	Yangzi River Delta	24.6
Textiles & Apparel	11.7	Pearl River Delta	21.6
Chemicals & Petrochemicals	8.2	Other areas in China	21.6
Building Materials	4.7		
Publishing and Printing	5.3		
Rubber & Plastics	3.5		
Food, Beverage, Alcohol & Cigarettes	3.5		
Pharmaceutical & Medicals	1.8		

A questionnaire with a cover letter highlighting the objectives of this survey and some guidelines on how to answer it was emailed to informants. Follow-up phone calls and reminding emails were made to improve response rate (Chen et al., 2016). We contacted 2710 companies in total, and distributed questionnaires to 696 companies that agreed to participate in the survey. 206 usable samples were finally returned, reflecting a response rate of 24.6 percent. Table 1 shows the profile of the samples. Table 2 shows the information of the respondents. Most of them were middle or top managers and had been in their positions for six or more years, suggesting that they were knowledgeable about GSCM practices of their company.

Table 2: Respondent Characteristics	
TENURE OF CURRENT POSITION IN FIRM (YEARS)	PERCENTAGE
≤1	4.1%
2–5	22.8
6–10	39.8
11–15	18.7
≥16	14.6
POSITION OF RESPONDENT	PERCENTAGE
Top manager	20.5%
Middle manager	74.9
Others (e.g. purchaser and salesman)	4.7

Measures

We developed the measures based on previous literature, as well as the interviews with managers. First, we developed an English version of the questionnaire based on a thorough review of relevant literature. Second, we translated initial questionnaire into Chinese, and then back-translated by two professionals to ensure the conceptual equivalence. Finally, we refined

the measures based on the in-depth interviews with managers from 18 companies during the pilot test stage. We modified the wording of some items to ensure all items were understandable and relevant to GSCM practices in China. The constructs were all measured on a seven-point Likert scale.

The measures for green information sharing, green process coordination, and green strategic alliance were adapted from Vachon and Klassen (2006), Flynn et al. (2010), and Wong et al. (2015). Respondents were asked to rate the extent their companies implement these practices, with "1" indicating the practices were not at all implemented and "7" indicating they were extensively implemented. The measures for economic performance were adopted from Dong et al. (2016) and the measures for environmental performance were adopted from Flynn et al. (2010). The respondents rated the performance measures compared with their major competitors, with "1" meaning "much worse" and "7" meaning "much better".

Non-response Bias and Common Method Bias

Following the procedure suggested by Armstrong and Overton (1977), we compared the demographic variables and key constructs of the first and last quartile of responses. This comparison revealed no significant differences between the two quartiles. We also made random follow-up calls to 30 firms that declined to participate in the survey to identify the reasons for their non-participation. These reasons included lack of time, lack of resources, and no interest. None of these reasons alluded to the possibility of systematic bias. Thus, non-response bias was not a big concern in this study.

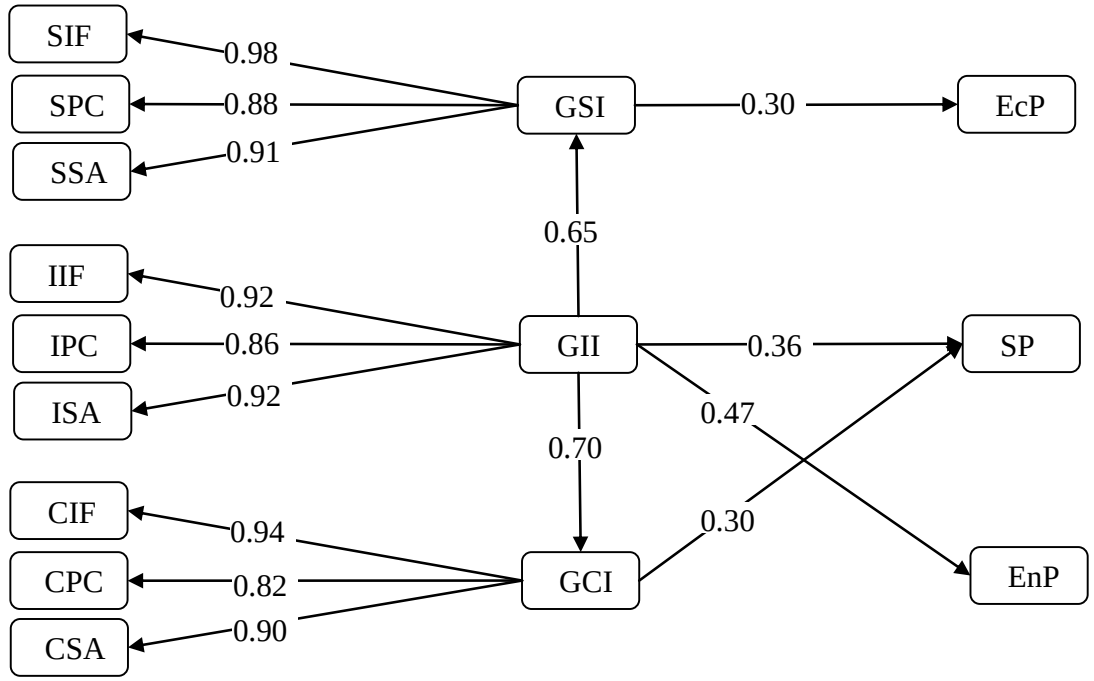
Because we only had one respondent for each questionnaire, common method bias might be a problem. We undertook several procedures to reduce the potential common method bias. First, in the questionnaire design stage, we appropriately arranged the order of questionnaire items, keeping adjacent variables in the conceptual model far away, to reduce the respondent's consistent tendency. This decreases common method bias to a certain degree (Podsakoff & Organ, 1986; Podsakoff et al., 2003). Second, we made sure we only targeted respondents that were very familiar with the content of our constructs. The accurate understanding of the items would decrease respondents' consistent possibility. After data collection, Harman's single-factor test was performed using exploratory factor analysis (EFA) (Podsakoff & Organ, 1986; Podsakoff et al., 2003). The results showed eight distinct factors with eigenvalues above 1.0, explaining 74.40% of the total variance. The first factor explained 42.71% of the variance, which are not the majority of the total variance.

Construct Validity

Confirmatory factor analysis (CFA) was conducted to assess convergent and divergent validity. To assess convergent validity, a CFA model was tested in which each item was linked to its corresponding construct, and the covariances among constructs were freely estimated. The model fit indices were χ^2=2475.84 with d.f.=1473, RMSEA=0.057, NNFI=0.98, CFI=0.98, Standardized RMR=0.044, indicating that the model was acceptable (Hu & Bentler, 1999). Furthermore, all factor loadings were greater than 0.50 and all t-values were greater than 2.0, ensuring convergent validity (Fornell & Larcker, 1981). To assess discriminant validity, we built a constrained CFA model in which the correlation between each possible pair of constructs was fixed to 1.0. This model was compared with the original unconstrained model, in which the correlations were freely estimated. All differences of χ2 were significant at the 0.01 significance level, indicating that discriminant validity was ensured (Fornell & Larcker, 1981). The

Cronbach's alpha values were all above 0.80. Thus, reliability of these constructs was ensured (Flynn et al., 1990)

Figure 1: SEM results



IF-information sharing; PC-process coordination; SA-strategic alliance; EcP-economic performance; SP-social performance; Enp-Environmental performance

Analyses and Results

In this study, we use structural equation modeling (SEM) to test our hypotheses. The results were run by LISREL 8.54 with the maximum likelihood estimation method. The goodness of fit indices of our model is acceptable (χ^2 (1519) = 2723.66, NNFI = 0.98, CFI = 0.98, RMSEA = 0.062, and SRMR = 0.10). Figure 1 shows the SEM results with standardized coefficients for the paths significant at the 0.05 level.

DISCUSSION

Consistent with the findings of previous studies, such as Wong et al. (2018) and De Giovanni (2012), our results find that GII is positively related to GSI and GCI. This indicates that GII lays the foundation for green integration with supply chain partners. On the one hand, GII shows a company's commitment to environment. This may get supply chain partners much more serious about going green, so that they will be more willing to involve in companies' green processes. On the other hand, green integration is a new approach to GSCM. It includes three important aspects. Companies may bring this knowledge to supply chain partners on how green integration should be conducted (Simpson et al., 2007).

Out of the three dimensions of GSCI, only GII is positively related to environmental performance, while GSI and GCI have no relationship with environmental performance. These findings are

consistent with those of Wong et al. (2018), which also adopted an integrated approach and only found a positive relationship between internal sustainable development and economic performance. However, in terms of green collaboration, both Tachizawa et al. (2015) and De Giovanni (2012) pointed out that green collaboration with supply chain partners has the ability to enhance environmental performance. These inconclusive results suggest that the integrated approach is different from the collaborative approach and that green integration with supply chain partners has not yet been able to improve environmental performance. In other words, the process of green integration with suppliers and customers is very complex and has been implemented at a very low level. It is difficult to influence environmental performance at the current level of green integration with supply chain partners.

In terms of social performance, our results find that GII and GCI are positively related to social performance, while GSI has no effect on social performance. These findings are partially supported by previous studies. For example, De Giovanni (2012) and Geng et al. (2017) both found that internal environmental management has a positive relationship with social performance, while external collaboration with supply chain partners is not significantly related to social performance. One possible explanation is that companies always want to attract customers with their green image (Lo, 2014). Under this circumstance, they will value customers' voice in the process of going green. As one important stakeholder to companies, customers may put themselves in the shoes of stakeholders and urge companies to address the well-being of all stakeholders. A close and integrated relationship with customers may also prompt customers to help companies improve the well-being of all stakeholders.

In terms of economic performance, we find that out of the three dimensions of GSCI, only GSI leads to a better economic performance, while GII and GCI are not related to economic performance. These results are in line with some of the previous literature. For example, Zhu and Sarkis (2007), Green et al. (2012), Golicic and Smith (2013), and Schmidt et al. (2017) all pointed out that working with suppliers on green practices is less costly than the other green practices and it is the best indicator of economic performance. The other green activities, such as GII and GCI may take more time to generate profitability (Golicic & Smith, 2013; Wong et al., 2018). Thus, our research reinforces the importance of GSI in proving economic performance.

CONCLUSIONS AND LIMITATIONS

Our study adopts a SCI approach to GSCM, builds a comprehensive framework of GSCI based on SCI and NRBV, and tests the effect of the three dimensions of GSCI on the TBL. Our results show that GII is positively related to GSI and GCI. GII has the broadest effect on performance, improving both environmental and social performance. GSI is the only dimension that improves economic performance and GCI is the only dimension that improves social performance.

Despite the significant theoretical and managerial contributions, this study still suffers from some limitations which may provide directions for future research. First, cross-sectional data were used to test the concept model in this study. This only provided a snapshot of the relationship between GSCI and the TBL. Future research should use the longitudinal data to examine the set of relationships. Second, we only focused on the performance of focal companies. This limits our understanding of the benefits of GSCI from the supply chain perspective. Future studies could consider collecting performance data from suppliers and customers. Third, we used one respondent to answer the entire questionnaire, which may lead

to common method bias. Though our test showed that common method bias was not a big concern in this study, future studies are recommended to avoid using one respondent.

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The Implications of Disruptive Innovations for the Outcomes of RE Businesses in Developed Economies

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ABSTRACT

Disruptive innovations such as wireless communications and disruptive business model innovations deployed by Airbnb and Uber have changed the value propositions and value creation of long established and emerging businesses. The primary objective of this research is to quantify the impact of key exogenous variables such as disruptive innovation on sustainable value creation of an entrepreneurial engagement in the renewable energy sector in developed economies. The outcome of this research has enhanced our knowledge base on how key antecedents disruptive innovation, and knowledge creation assist in creating verdant value propositions, delivery, and sustainable value in RE markets in developed economies.

KEYWORDS: Disruptive Innovation, Renewable Energy, Value Proposition, Sustainable Value, and Developed Economies

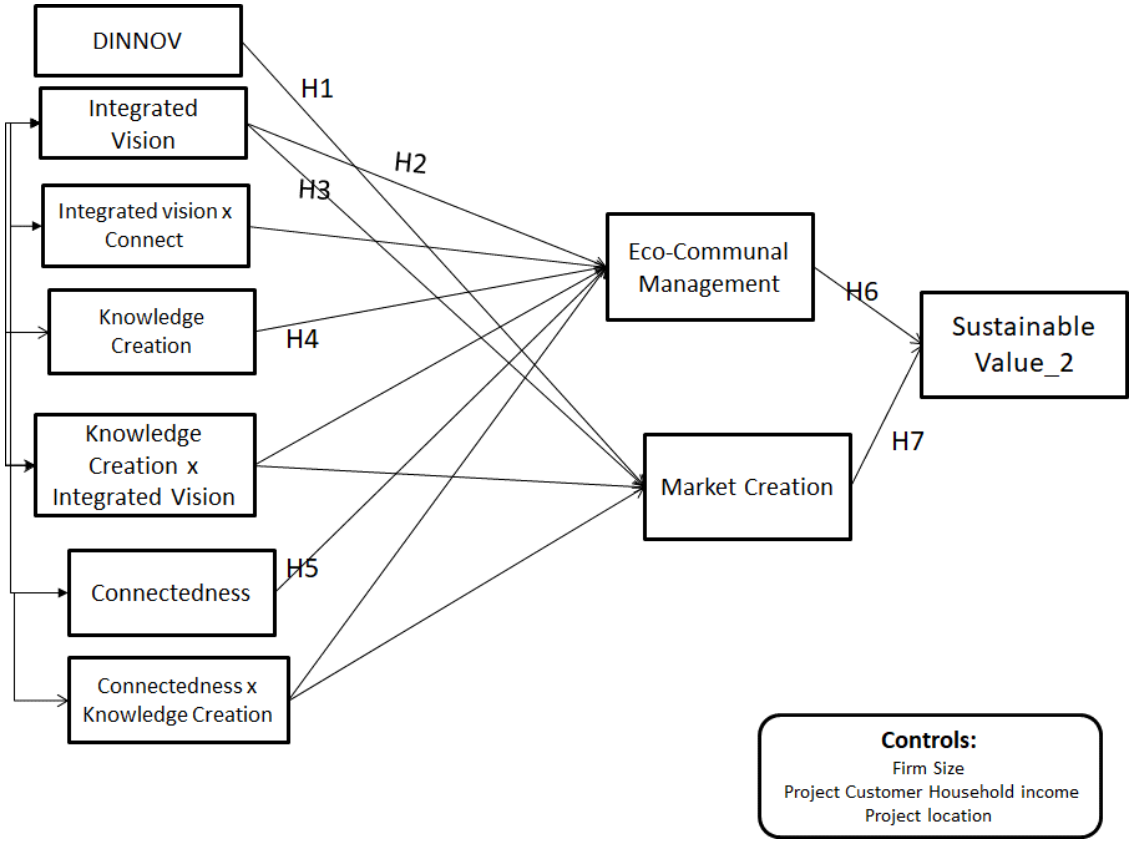
INTRODUCTION

Technological and business innovations play major roles in the functioning of developed economies. Technological developments are especially heavily utilized to optimize the cost of power generation from renewables, and have made considerable advances in achieving cost parity for wind power generation in recent years. Disruptive business models and technological revolutions have significant and substantial implications for the outcomes of renewable energy projects. Disruptive business model innovations reconfigure business opportunity recognition, value proposition and co-creation, and deliverables in the rapidly changing business and technology landscape of today (Hart & Christensen, 2002; Massa & Tucci, 2013). Multisided business models, in conjunction with multipurpose platforms and increasing web capabilities, are hastening changes in techno-economic paradigms (Bughin, Chui, & Manyika, 2010) and market orientations, resulting in significant implications for renewable energy businesses long-desired in developed economies (Viswanathan, Seth, Gau, & Chaturvedi, 2009).

Moreover, disruptive innovations attenuate the impacts of environmental selection on the genesis and diffusion of inventions enabled by the workings of embedded institutional and market structures (Luhmann, 1995; Nelson & Winter, 1977; Smits, Kuhlmann, & Shapira, 2010). In the context of developed economies, sustained innovation plays a more prevalent role than disruptive modernization. However, we predict that a disruptive revolution that includes both technology and business model innovations will play an appreciable role in changing socio-technical paradigms and have important implications for the outcomes of RE businesses (Boons et al., 2013; Hall et al., 2010).

Based on this framework, we have developed a model and associated hypotheses, as shown in Figure 1.

Figure 1. Hypothesized Model for Determining the Implications of Disruptive Innovations for the the Outcomes of RE Businesses in Developed Economies



HYPOTHESES

Disruptive Innovation (DINNOV)

Disruptive innovations that include technological and business model inventions have significant and substantial implications for the outcomes of renewable energy businesses. Disruptive innovations reconfigure business opportunity identification, value proposition and creation, and deliverables in this rapidly changing business and technology landscape (Christensen, Horn, & Johnson, 2008; Hart & Christensen, 2002; Massa & Tucci, 2013). Emerging multisided business models, in conjunction with multipurpose platforms in the 4th Industrial Revolution (where integrated cyber-physical-biological systems are hastened by additive manufacturing, AI, autonomous systems, advanced robotics, and decision support systems) are changing fundamental buyer-seller relationships and hastening socio-technological paradigm shifts (Bughin, Chui, & Manyika, 2010; Elfring & Hulsink, 2003). Such transitions are altering market orientations and have significant implications for renewable energy businesses in developed economies (Viswanathan, Seth, Gau, & Chaturvedi, 2009). Based on these recent changes, we hypothesize that disruptive innovation will have a positive and direct impact on market creation.

Hypothesis 1. Disruptive innovation is positively related to market creation, after controlling for firm size, project customer household income, and project location.

Integrated Vision

Integrated vision, which sets the overarching business strategy and rationale of a firm as an engagement with entrepreneurial action, has a significant and substantial impact on the formulation of management and market strategies of business interest (Ireland et al., 2009; Elfring & Hulsink, 2003). A clear and well-articulated strategic vision enables the establishment of capable management techniques that allow RE businesses to differentiate themselves from competitors; this is accomplished by creating aggregated value chains that optimize economic, social, and ecological benefits. In the context of developed economies, the formulation and deployment of such integrated strategic visions are imperative for successful renewable energy businesses hoping to create sustainable value. This is due to the highly competitive market structure supported by an established regulatory framework and significant sunk capital in conventional energy generation and distribution systems (Schoemaker, 1992).

Based on this rationale, we believe that integrated vision will be positively related to eco-communal management, after controlling for firm size, project customer household income, reflective practices, and project location, as stated in Hypothesis 2.

> *Hypothesis 2. Integrated vision is positively related to eco-communal management, after controlling for firm size, project customer household income, and project location.*

Integrated vision defines the perimeters of the markets served through entrepreneurial actions by providing creative solutions to challenging energy and related problems and demands. Based on these assertions, we hypothesize that integrated vision has a positive, significant, and substantial relationship with market creation, as stated in Hypothesis 3.

> *Hypothesis 3. Integrated vision is positively related to market creation, after controlling for firm size, project customer household income, and project location*.

Knowledge Creation

Knowledge creation refers to information formation related to customer needs, the project itself, related technologies and resources, and the overarching economic, ecological, and social issues accessed through socialization, externalization, internalization, and combined processes (Nonaka et al., 1994). In developed economies, knowledge creation plays a major role in the functioning of the economy and society at large. Based on these reasons, we hypothesize that knowledge creation (Dewey, 1929; Hessels & Van Lente, 2008) is positively related to eco-communal management, as presented in Hypothesis 4.

> *Hypothesis 4. Knowledge creation is positively related to eco-communal management, after controlling for firm size, project customer household income, and project/business location*.

Impact of Connectedness on Eco-communal Management

Connectedness, which involves the relational dynamics of the key decisionmaker of an RE business with stakeholders (including business staff, end users, the business/project host community, the ecosphere, and relevant investors and regulators) of a business or project, has a significant impact on the strategic management of that business. The relational spheres and embeddedness of the business establishes essential attributes of the business culture and impinges on its long-term and day-to-day operations (Dhanaraj, Lyles, Steensma, & Tihanyi, 2004). Based on these reasons, we predict that connectedness is positively related to eco-communal management, as stated in Hypothesis 5.

Hypothesis 5. Connectedness is positively related to eco-communal management, after controlling for firm size, project customer household income, and project location.

Impact of Eco-communal Management on Sustainable Value 2 (SV2)

Eco-communal management, which we have defined as the key management strategy of a renewable energy business (or project) that creates integrated economic, ecological, and social benefits for all stakeholders, is the primary pathway for translating the integrated vision, know-how, resources, and relational capabilities of the RE business into sustainable value (Schaltegger & Wagner, 2011). Sustainable value 2 (SV2) is a second-order factor with three first-order variables; it contains 12 items. Based on this premise, we reason that eco-communal management has a positive, significant, and substantial relationship with sustainable value.

Hypothesis 6. Eco-communal management is positively related to sustainable value 2 (SV2), after controlling for firm size, project customer household income, and project location.

Impact of Market Creation on Sustainable Value 2 (SV2)

Market creation, which is framed by the entrepreneurial drive of an RE business, is an essential part of product/service offerings, opportunity recognition, value proposition and delivery, and monetization; it has a significant impact on the sustainable value created by a businesses (Schaltegger & Wagner, 2011; Laszlo, 2008). Based on these assertions, we hypothesize that market creation is positively related to the desired outcomes integrated into an RE business or project (SV2).

Hypothesis 7. Market creation is positively related to sustainable value 2 (SV2), after controlling for firm size, project customer household income, and project location.

RESEARCH METHODS

Measures

All variables used in this research employed 5-point Likert scales.

Disruptive Innovation (DINNOV)

Disruptive innovation (α = .88) was measured using five items adapted from the works of Govindarajan and Kopalle (2006).

Integrated Vision (IVN)

We measured integrated vision with two first-order factors and a total of four items (α = .82) adapted from the works of Carroll et al. (2005).

Knowledge Creation (KC)

Knowledge creation was measured with four first-order factors and a total of 13 items (α = 0.94) adapted from Schulze and Hoegl (2006, 2008).

Connectedness (Connect)

We used two first-order factors and a total of six items (α = .93) from van Bel et al. (2009).

Eco-communal Management (EcoMng)

Eco-communal management is a management strategy for RE businesses that creates a symbiotic and synergistic partnership among profit-based, environmental, and societal goals (Hart & Dowell, 2010). It was measured using five items (α = .84).

Transition Engagement (TranEng)

Transition engagement refers to transformational changes brought about by RE development that is contextualized to local needs and capabilities and facilitates socio-technical paradigm shifts. It was measured with two items (α = .82) adapted from Bono and Anderson (2005) and Kayworth and Leidner (2002).

Market Creation (MKC)

Market creation was measured using five items (α = .78) adapted from the works of Jain and Kaur (2004).

Sustainable Value (SV2)

We used three first-order factors and a total of 12 items (α = .94) from Zhu et al. (2008) and meaningfulness items adapted from the works of May et al. (2004).

Controls

We utilized three controls in this research:

1. Firm size, which was expressed by the number of people the company employed. We used firm size as a control because of the thematic differences in entrepreneurial strategies that established and start-up renewable energy businesses tend to deploy (Hockerts & Wüstenhagen, 2010).
2. Project customer household income assesses the before tax income (in USD) of RE project customers (Whitmarsh & O'Neill, 2010). We utilized household income as a control because of its multilevel relationships with energy consumption, GDP growth, income generation, and environmental implications associated with increased energy consumption (Fang, 2011).
3. Project location was utilized to account for regional differences in the applications of renewable energy businesses and projects. These differences include market conditions, entrepreneurial climate, regulatory policies, financing instruments, and environmental selections, all of which impact RE business outcomes (Reiche & Bechberger, 2004).

Instrument Development and Testing

To ensure the reliability, validity, and appropriateness of the survey instrument, we conducted a pilot test administered to 40 key decision-makers engaged in renewable energy businesses in developed economies.

Data and Samples

Data were gathered from 222 key decision-makers in renewable energy businesses and projects, primarily in five developed economies (US, Canada, Germany, Japan, and the UK) but with a few responses from France and Norway. These key decision-makers were identified through the personal networks and business relationships of the researchers.

A total of 45.5% of the respondents were senior executives (CEO, COO, CFO, or CTO), and 54% were senior manager/managers with titles of project director or program manager.

Data Screening

We collected 222 complete survey responses that were free of missing data and contained data adequate for further analysis.

Analysis

As a part of our overall investigation, we conducted an exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) with and without common latent factors, followed by structural equation modeling (SEM).

RESULTS

Exploratory Factor Analysis

We submitted the 47-item scale to an EFA. Several statistics indicated that the data were adequate and appropriate for further examination. These included a Kaiser-Meyer-Olkin (KMO) statistic of 0.921 and a significant Bartlett's test of sphericity ($\chi 2 = 21{,}708$, df = 5253, and $p < 0.000$) indicating sufficient inter-correlations. All commonalities were above 0.40, further confirming that each item shared some common variance with the other items (Hair et al., 2010).

Measurement Model

The confirmatory factors analysis of the measurement model yielded good model fit statistics with $\chi^2 = 1802.69$, degree of freedom (df) = 977, CFI = .900, and RMSEA = .062 (Hair et al., 2010), as shown in Table 1. Together, these indicate the validity of the factor structure.

Table 1. CFA Model Fit Statistics

	DE CFA SM_2
χ^2	1802.69
df	977
p	0.0000
CMIN/df	1.845
CFI	0.900
TLI	0.889
RMSEA	0.062
SRMR	0.09
PCLOSE	0.00

The CFA value met all validity and reliability requirements, indicating that the model fit the data well. The composite reliability for all of the constructs was greater than 0.7, and the average variance extracted (AVE) met the requirement for convergent validity. The maximum shared variances (MSV) and average shared variances (ASV) were less than the AVE, meeting the discriminate validity requirements (Fornell & Larcker, 1981). The reliability requirements were met with both the Cronbach's alpha and composite reliability for each construct greater than 0.7.

The effects of common method bias were checked by comparing the CFA results with and without common latent factors (CLFs), following Gaskin's (2012) recommendations. Also, there was no difference between the CFA results with and without CLFs, indicating that common method bias did not have a significant and substantial effect on the data collected.

Structural Equation Modeling (SEM) Results

The hypothesized model tested as shown in Figure 2 fit the data well, with model fit statistics of: $\chi^2 = 19.08$, df = 11, CMIN/df = 1.73, CFI = .998, and $p > .05$ (Hu & Bentler, 1999; Tabachnick & Fidell, 2007). A summary of the key model fit statistics can be found in Table 2.

Table 2. SEM Key Model Fit Statistics

	SEM Model SM_2_V3 + DiNNOV
χ^2	19.08
df	11
p	0.0597
CMIN/df	1.734
CFI	0.998
TLI	0.982
RMSEA	0.058
SRMR	0.014
PCLOSE	0.342

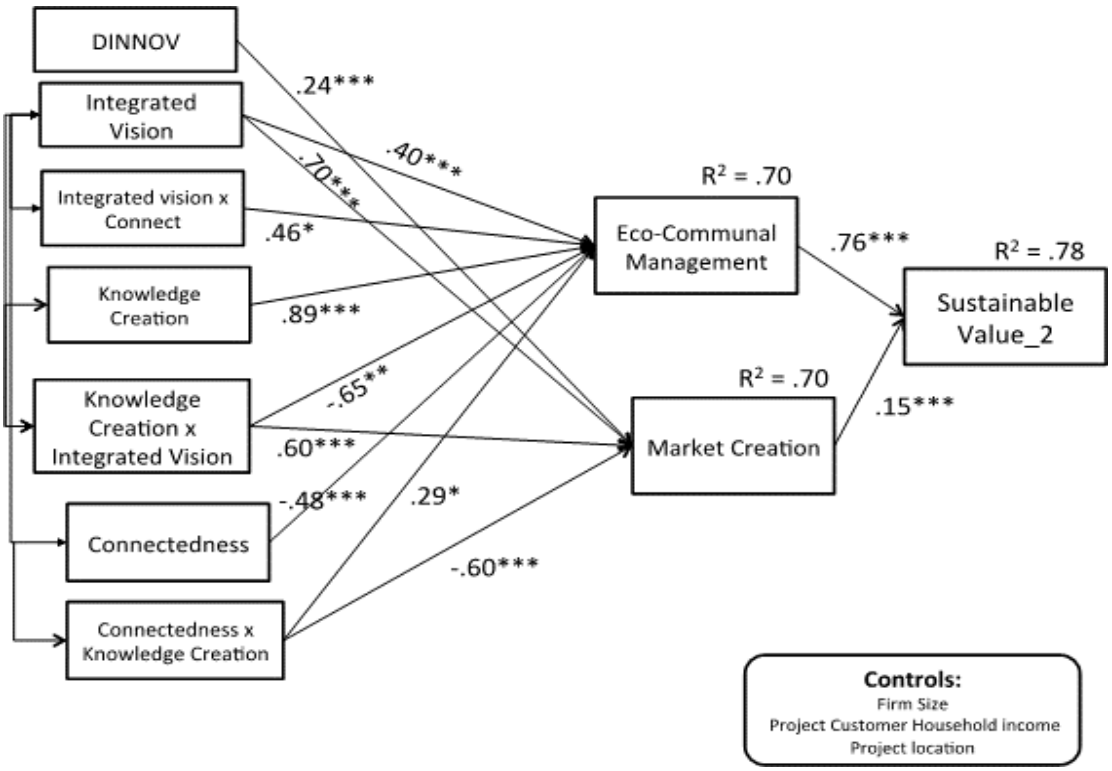
As can be seen above, all of the antecedents had substantial and significant impacts on the mediators, and the mediators had significant and substantial impacts on the outcome.

Hypotheses Test Results

As we predicted, Hypothesis 1 was supported (β = 0.24, p < 0.001), indicating that disruptive innovation had a significant and substantial positive impact on eco-communal management. Hypotheses 2 and 3 were also supported, with a positive and significant relationship between integrated vision and eco-communal management (β = 0.40, p < 0.001), and an even stronger relationship between integrated vision and market creation (β = 0.70, p < 0.001). The test results for Hypothesis 4 further highlighted the importance of knowledge creation in creating markets for RE businesses in developed economies. The strongest relationship coefficient was 0.89, which was highly significant (β = 0.89, p < 0.00).

However, our prediction regarding the relationship between connectedness and eco-communal management (Hypothesis 5) was not supported. Contrary to our expectation, the relationship was negative, with a highly significant beta of -0.48 (β = - 0.48, p < 0.001).

Figure 2. SEM Results for Disruptive Innovation's Effects on RE Outcomes in Developed Economies



*** < 0.001, ** < .01, * < 0.05

Consistent with our predictions, Hypotheses 6 and 7 were supported, with β = 0.76, p < 0.001 and β = 0.15, p < 0.001, respectively. These values confirm that eco-communal management and market creation had significant and substantial positive impacts on the

outcomes of renewable energy businesses in developed economies, as measured by sustainable value. A summary of the hypotheses test results is presented in Table 3. Further verifying the robustness of the model, the predictor variables were found to explain 78% of the variance in the outcome variable.

Table 3: Summary of Hypotheses Test Results

Hypothesis	Path	β	p	Supported?
H1	DINNOV -> MKC	0.24	***	Yes
H2	IVN -> EcoComMng	0.40	***	Yes
H3	IVN -> MKC	0.70	***	Yes
H4	KC -> EcoComMng	0.89	***	Yes
H5	Connect -> EcoComMng	-0.48	***	No
H6	EcoComMng -> SV2	0.76	***	Yes
H7	MKC -> SV2	0.15	***	Yes
*** p < .001, ** p < .01, * p < .05, ns ≥ .05				

In developed economies, the primary path for creating sustainable value for RE businesses is underpinned by knowledge creation; through eco-communal management, key management strategies of commercial enterprises are deployed to enhance business outcomes, improve competitive positioning, and meet market demands for integrated economic, ecological, and social benefits (Hart & Dowell, 2010; Schaltegger & Wagner, 2011). Knowledge creation, which includes technological and business model innovations, opportunity recognition, value creation, and socio-ecological knowledge all shape the management strategies employed by these types of businesses, and in turn have significant and substantial implications for the desired business outcomes (Hitt, Ireland, Sirmon, & Trahms, 2011).

KEY FINDINGS

Value creation for RE businesses in developed economies is undergirded with knowledge creation and translated into desired outcomes via eco-communal management. Knowledge creation includes both entrepreneurial and tacit knowledge, opportunity recognition, value creation, and socio-ecological information, all of which are adaptive and complex. Innovative strategic management based on emergent and systemic knowledge creation improves the competitive positioning of these types of businesses and creates symbiotic and synergistic relationships among return on investment and environmental and social benefits (Armitage et al., 2008).

Disruptive innovation and integrated vision have significant and substantial implications for market creation, resulting in market creation having a positive impact on sustainable value (SV2). Hence, it is imperative for RE businesses to engage in emergent technological and business model innovations, accompanied by appropriate sustainable marketing orientations that are congruent with the DNA and business rationale of the firm and its placement in this dynamic socio-technological landscape (Kumar et al, 2011).

Limitations

This research has investigated the implications of disruptive innovation, integrated vision, connectedness, and knowledge creation on entrepreneurial engagement and RE

business outcomes in developed economies. As such, the model developed here must be verified for contextual applicability (i.e., generalizability and transferability) before it is utilized in other sectors.

Future Research

In light of the emergent and fast-paced technological and business model innovations that are part and parcel of the cyber-physical-biological landscape, the implications of disruptive innovations and knowledge and market creation on creating sustainable value in the RE space (and other businesses) is of paramount importance for entrepreneurs and established businesses alike. Hence, the current research framework and model could be modified and applied to other emerging business opportunities to optimize the configuration of innovation input (i.e., technology and business model) and management approaches to create sustainable value for all stakeholders.

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DECISION SCIENCES INSTITUTE The Influence of Student Engagement on Retention

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ABSTRACT

Student retention has been a persistent concern of institutions of higher education. Theory postulates that student peer and institutional engagement are significant influences of retention. Our study quantifies student peer engagement by measuring their networking in co-curricular activities, and develops a model that can successfully predict student retention.

KEYWORDS: Peer Engagement, Critical Time Period, Graph Modelling, Student Retention, and Regression

INTRODUCTION

Student retention remains a continuing concern of higher educational institutions, and with recent years seeing an increasing number of students leave college before completing their degree or taking longer to complete their program. According to (Berkner, He & Cataldi, 2002), students at a traditional 4-year institution complete their baccalaureate degrees over a six-year period, while in 2013, 41% did not finish college within six years. Another study found an attrition rate of 20% for students just after one year in an institution (Zobel, 2016). Researchers have identified factors that influence retention including financial status, demographic characteristics, academic performance, and using these factors, built models that are used to predict those most likely to attrite (Delen, 2010). These factors are readily quantifiable and used for predictive models than some other factors. In particular, Tinto (2006) theorizes that institutional engagement and student peer engagement are primary influences of student retention. The concept of student peer engagement has been studied in various forms such as a peer learning (Davies & Barak, (2013). However, according to the National Association of Student Personnel Administrators (NASPA), student engagement is often overlooked in prediction of student retention (Burke, Parnell, Wesaw & Kruger, 2017). Our research focuses on student peer engagement. This form of engagement can be defined as the ability to develop relationships with others and a means to promote connectedness (Sagenmüller, 2018). Between institutional and peer engagement, peer engagement has been studied less frequently, possibly because it is particularly difficult to quantify. In this paper, we study student peer engagement and evaluate its' impact on retention. Our approach leverages the social network perspective (Wasserman & Faust, 1994) where we identify, measure and evaluate interactions of actors in the form of student engagement. Here, we measure engagement in the form of degree centrality which we

track over time to determine its' impact on student retention. We postulate that when students engage with others, the quality of their academic experience improves, which helps to increase student retention (Sagenmüller, 2018). We measure peer engagement over time and aim to identify key time points in a student's career that can be used as stepping-stones to predict student retention and support institutional decision-making.

METHODS

This section presents a detailed description of our methodology as used in this study.

Data Description

The data used in this study was obtained from the Management Achievement Program (MAP). MAP is a requirement for all undergraduate students in business administration at a state university. This program which started in Fall 2006, is designed to engage participants in cocurricular activities, in contrast to the assimilation of content delivered only through lectures or seminars. Students in MAP are required to select and participate in events and activities designed to build professional and career skills. Among the types of events and activities regularly offered are career workshops, seminars, forums, company visits, presentations by senior executives, student clubs, and service learning activities such as volunteer work. Each MAP event offers a number of miles depending on the involvement and initiative it requires. Upon admission into the college, each participant's record is assessed to determine the number of MAP miles that will be required to graduate. Over the course of their study, a student's attendance of MAP events is captured and recorded. Table 1 illustrates a sample of the attendance records.

Table 1: Management Achievement Program (MAP) Sample Attendance Records

Student ID	Student start semester	Event	Event Type	Event Date	Event Miles
21425	Fall 2010	Building Team Pride and Purpose	Workshop	8/24/2010	50
21425	Fall 2010	InterviewTrak Seminar	Seminar	8/5/2010	50
21425	Fall 2010	Information Systems Club Membership	Student Club	10/1/2010	50
21425	Fall 2010	Speaker from Staples – Using analytics for pricing decisions	Seminar	9/24/2010	50
21425	Fall 2010	Mock Interviews with IS Executives	Career Cafe	10/22/2010	50
52129	Spring 2009	Boston Globe company tour – How analytics are used	Company tour	3/26/2011	75
52129	Spring 2009	Leadership Workshop	Workshop	2/12/2011	75
47874	Spring 2010	Interviewing success	Workshop	5/24/2010	50
47874	Spring 2010	Myers-Briggs/Joyce Morgan	Workshop	9/18/2010	75
47874	Spring 2010	Prep for Career Fair	Career Cafe	10/4/2010	50
54644	Fall 2008	Microsoft speaker series	Seminar	12/8/2010	50
54644	Fall 2008	Spring 2009 Career Expo	Workshop	5/19/2011	100
54644	Fall 2008	Career Exploration workshop	Workshop	10/14/2010	50
54645	Fall 2008	Dynamic Resumes	Workshop	10/20/2010	50

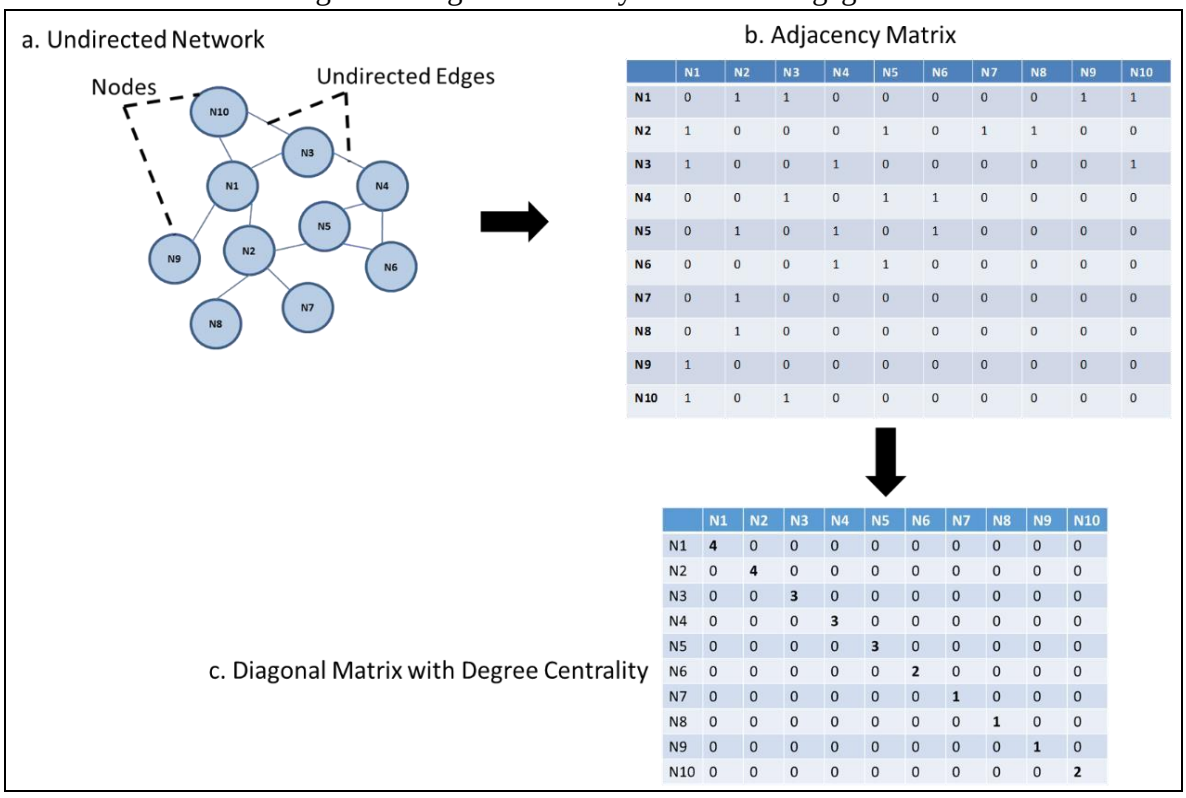
For our experiments, we select de-identified unlabeled data from Fall 2006 to Spring 2016 with a total of 46,521 MAP attendance records. This data captures students who have completed the program and others who are still in progress based on their starting semester. We utilize the

unlabeled data to model student interactions in the form of a graph, which we then use to evaluate student peer engagement over time.

Measuring Student Peer Engagement

We measure student peer engagement by their networking at MAP events. We model their interactions as a graph G = (N, E), where N is the number of nodes in the network, and E is the number of edges such that $a_{ij} = 1$ if nodes i and j are connected by an edge, and $a_{ij} = 0$ if otherwise. For this we create graphs by identifying links between students based on similar events that they have attended. Thus each student represents a node and the event establishes the link between two nodes to form an edge. Our goal is to determine degree centrality which is defined as the number of adjacent nodes (Freeman, 1979; Kosorukoff, 2011). We use degree centrality to indicate the level of connectivity amongst students, and thus a measure of student engagement. In this study, we consider an unweighted graph where the nodes and edges are not assigned weights. Hence, if a pair of students have one or more events in common, only a single unweighted edge is established. Figure 1 shows an example of how degree centrality is determined.

Figure 1: Degree Centrality as Student Engagement



	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
N1	0	1	1	0	0	0	0	0	1	1
N2	1	0	0	0	1	0	1	1	0	0
N3	1	0	0	1	0	0	0	0	0	1
N4	0	0	1	0	1	1	0	0	0	0
N5	0	1	0	1	0	1	0	0	0	0
N6	0	0	0	1	1	0	0	0	0	0
N7	0	1	0	0	0	0	0	0	0	0
N8	0	1	0	0	0	0	0	0	0	0
N9	1	0	0	0	0	0	0	0	0	0
N10	1	0	1	0	0	0	0	0	0	0

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
N1	**4**	0	0	0	0	0	0	0	0	0
N2	0	**4**	0	0	0	0	0	0	0	0
N3	0	0	**3**	0	0	0	0	0	0	0
N4	0	0	0	**3**	0	0	0	0	0	0
N5	0	0	0	0	**3**	0	0	0	0	0
N6	0	0	0	0	0	**2**	0	0	0	0
N7	0	0	0	0	0	0	**1**	0	0	0
N8	0	0	0	0	0	0	0	**1**	0	0
N9	0	0	0	0	0	0	0	0	**1**	0
N10	0	0	0	0	0	0	0	0	0	**2**

Figure 1 (a.) shows an undirected network with students as nodes and the shared events as edges. Figure 1 (b.) shows an adjacency matrix as a square matrix representing node connectivity where 1 represents an edge between two adjacent nodes and 0 otherwise. For example, N1 and N2 are connected as portrayed by 1 and N1 and N4 are not connected as portrayed by '0'. Figure 1 (c.) shows a diagonal matrix where the number of adjacent nodes are summed up into degree centrality. For example, N1 has a degree of 4, as does N2, N3 has a degree of 3, and so on.
We capture degree centrality over time for each student. Here we analyze student peer engagement per academic year that they are enrolled in the institution. We also take into consideration that an academic year may vary for students based on their starting semester. For example, students starting in Fall will have an academic year of Fall – Spring, while students starting in Spring will have an academic year of Spring – Fall. Our objective is to evaluate the impact of student engagement on retention for varying cohorts of students. It should be noted that a student can attend zero or more MAP events during an academic year. Also, if a student attended an event by themselves (which is very rare) then there is no peer engagement, and thus these records are eliminated from the analysis.

Predictive Model

In order to evaluate the impact of student peer engagement on retention, we first process the de-identified unlabeled data in Table 1 to determine if a student is retained or not which is based on a function of the Map Miles Requirement and the Total Event Miles acquired throughout their enrollment in the institution. Hence, we assign a binary value to each student to indicate retention and attrition, where "Yes" is for a student who meets a given threshold for the Map Miles Requirement and is retained, and "No" for otherwise. Table 2 provides a sample of the labeled data as used in this study.

Table 2: Management Achievement Program (MAP) Sample Labeled Data

StudentID	Starting Semester	MapMiles Requirement	TotalEventMiles	Retained
21425	Fall 2010	250	250	Yes
52129	Spring 2009	1000	150	No
47874	Spring 2010	250	175	Yes
54644	Fall 2008	250	200	Yes
54645	Fall 2008	500	50	No

In order to predict student retention, we utilize logistic regression where our goal is to determine what level of engagement is critical to retention. We select a set of independent variables, which include the MAP Miles Requirement as a categorical variable representing 250, 500, 750 and 1000 miles respectively based on a student's MAP requirements. We also select the degree centralities per student captured over time (per academic year) as continuous variables. The dependent variable is a binary variable representing Yes or No for retention.

Given that the starting semester for students varies, our approach accounts for these variations because it is important to evaluate retention levels for students in similar cohorts. Hence, we

consider a sliding-window approach where we eliminate any times prior to the official starting semester for each cohort and as a result, develop several models based on starting semester. For example, for students who started in Fall 2006, we have 10 academic years, for those who started in Fall 2007, we have 9 academic years, for Fall 2008, we have eight academic years, and so on. Following this, for each cohort of students with the same starting semester, we select the MAP miles required, and then select their degree centrality over time.

Furthermore, any student who participates in an event prior to their official starting semester as well as any students whose starting semester was before the inception of MAP are eliminated from the model. It should be noted however that these students are included when determining centrality because they do contribute to others' engagement.

Potentially Significant Predictors

With varying student participation over time, the resulting matrix is sparse because some students attend MAP events within a short time window while others may spread them out and thus take longer to complete MAP requirements. Our assumption is that such variability is key in identifying critical time periods that may be essential in determining how early retention can be predicted based on the level of engagement within specified time windows. Hence we evaluate the correlation of each time period to retention. Here we study the correlation between the independent variables representing each academic year respectively in association to retention. Hence, given an alpha of 0.05, Tables 3 shows a summary of p values obtained for all academic years for each cohort of students.

Table 3: Correlation Analysis for Degree Centrality Over time

	Spring 2007	Fall 2007	Fall 2008	Fall 2009	Spring 2010	Fall 2010	Spring 2011	Fall 2011	Spring 2012	Fall 2012	Spring 2013	Fall 2013	Spring 2014	Fall 2014	Spring 2015	Fall 2015
AY1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AY2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
AY3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
AY4	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00					
AY5	0.00	0.00	0.00	0.14	1.00	0.09	0.10	0.00	0.00							
AY6	0.66	0.06	0.44	0.00	0.73	0.52	1.00									
AY7	0.09	0.18	0.22	0.06	1.00											
AY8	1.00	0.53	1.00													
AY9	0.66	1.00														
AY10	1.00															

Our findings in Table 3 indicate that across cohorts, starting with the first year of a student's career there is a high level of correlation between peer engagement and retention. This is portrayed by the p values <=0.05 (which are highlighted) in Table 3. It should be noted that for groups starting in Fall 2006, Spring 2008 and Spring 2009, no significant time periods were identified and are thus eliminated from the Table 3.

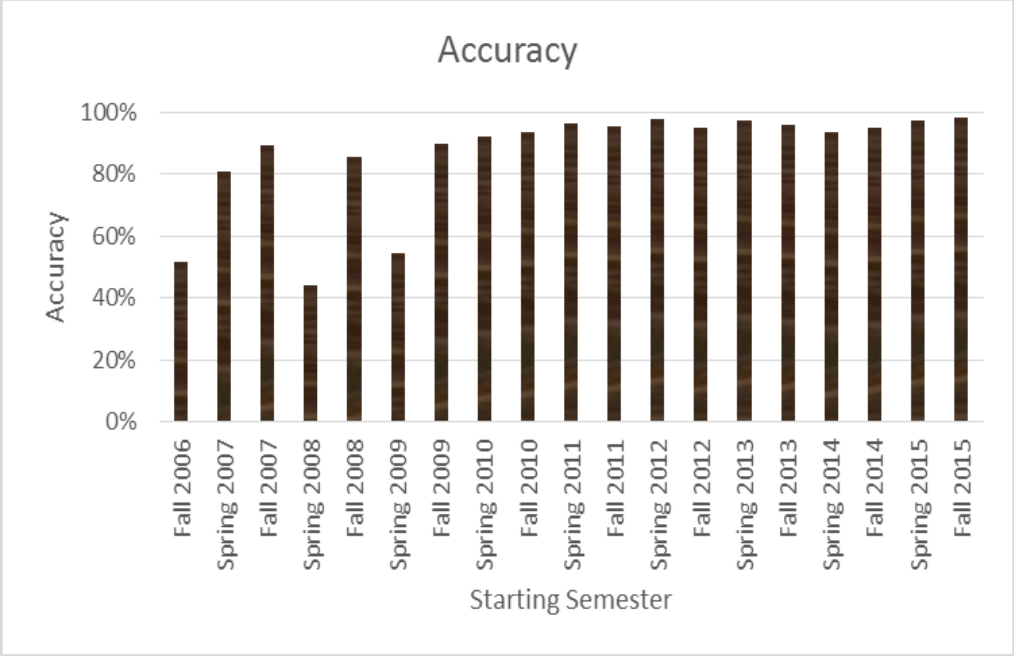
RESULTS

For our analysis, we evaluate our model using accuracy which captures if instances are classified correctly, and Receiver Operative Characteristic (ROC) curve's Area Under Curve (AUC) which aims to capture overlaps between classes. We present our findings based on the starting semester to represent the varying student cohorts.

Evaluation of Accuracy

Here we evaluate the level of correctly and incorrectly classified instances for retention for each cohort of students.

Figure 2: Evaluation of Accuracy for Predicting Retention for Varying Cohorts



Our findings in Figure 2 indicate high accuracy for predicting retention based on student engagement. This is observed for most student cohorts where the accuracy for our model is >= 80%. A high level of accuracy points to the ability of our model to correctly label instances as retained or not retained respectively. On the other hand, for those cohorts that started in Fall 2006, Spring 2008 and Spring 2009, the performance of the model indicates accuracy levels <

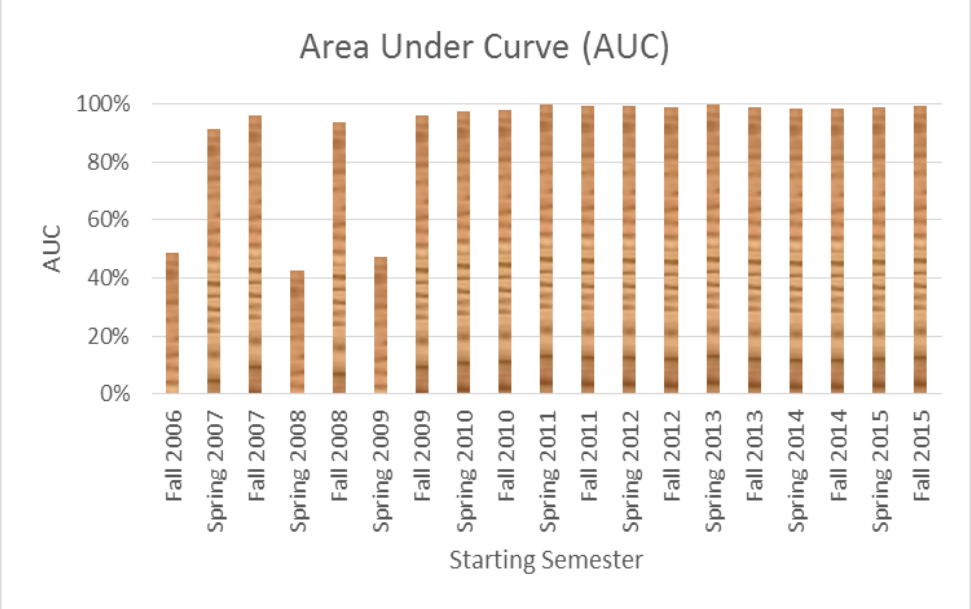
60% which is lower in comparison to other cohorts. In this case, our model aligns labels for retained to non-retained cases and vice versa.

Evaluation of Area Under Curve (AUC)

Here we evaluate the area under curve for the Receiver Operative Characteristic (ROC) curve to determine overlaps between retention and attrition for each cohort of students.

Our findings in Figure 3 indicate area under curve (AUC) levels > 80% which signifies a clear distinction between cases of retention and attrition in our model. However, for those student cohorts starting semesters of Fall 2006, Spring 2008 and Spring 2009, we observe high overlap between the two classes of retention and attrition as indicated by lower AUC < 60%. This overlap can be attributed to similar behavior in engagement observed between retained and non-retained students within these cohorts. Our findings for AUC follow a similar pattern to our findings in accuracy shown in Figure 2.

Figure 3: Evaluation of Area Under Curve (AUC) for Predicting Retention for Varying Cohorts



DISCUSSION AND CONCLUSIONS

Our approach is based on evaluating the level of student peer engagement over an academic year period and its' impact on retention. Student engagement is measured as the number of

peers a student interacts with during academically oriented co-curricular activities or events during their academic career. Our findings indicate that even the first year of student participation in co-curricular activities are critical to student engagement and thus significant determinants of retention. Based on these and our initial results, we believe that we have a strong base to further evaluate student engagement through co-curricular activities as an influencing factor in student retention and develop predictive models with an even higher level of accuracy. For our future work, we would like to drill down into an academic year and evaluate student engagement at the semester level and its' impact on retention.

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DECISION SCIENCES INSTITUTE

The Investigation of Mobilization and Service-Dominant Logic: Evidence from the Service Ecosystems of Inward Investment Agencies of Taiwan, Singapore, and Korea

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ABSTRACT

This paper links the research streams of service-dominant logic, service ecosystems, and mobilization, and uses a multi-case study that looked at the service ecosystems of the inward investment agencies of Taiwan, Singapore, and Korea, to investigate how key actors were motivated by the inward investment agencies, and how the emergent systems were mobilized and coordinated, evolving towards mature service ecosystems. The research findings permitted us to enrich the understanding into ecosystems from a mobilization perspective. We were also allowed to develop implications for practitioners as well as policy makers.

KEYWORDS: Service systems and operations, Ecosystem, Mobilization, Service-dominant Logic, Resource Integration, Value Co-creation, Case Study

INTRODUCTION

With decades of development, the sharing of individual resources for others (Belk 2014, Sundararajan 2016), have vividly marked the business and economic environments nowadays. Facing the drastically changing environments, value co-creation has emerged as a dominant logic that determines the strategic advantage of firms and organizations and their resulting survival and prosperity (Prahalad and Ramaswamy 2004, Vargo and Lusch 2008, Kohtamäki and Rajala 2016). Within the emerging paradigm of value co-creation, the development of "ecosystems" has attracted increased attention from scholars, policy makers and practitioners (Moore 1996, Iansiti and Levien 2004, Winn and Pogutz 2013, Lusch, Vargo et al. 2016).

Emphasizing the symbiosis of interconnected and interdependent actors, an ecosystem not only prescribes the scope of a firm's action but also provides important ingredients on which the firm's operation relies (Ansari, Garud et al. 2016). Being able either to develop an ecosystem or to leverage ecosystem advantage thus becomes a pivotal issue. Despite its importance, the present understanding into ecosystems remains constrained, particularly in terms of how actors and subsystems are attracted, linked and coordinated in the emergence of an ecosystem. The extant literature of value-based ecosystems tends to focus attention on resource integration across organizational boundaries (Jaakkola and Alexander 2015, Frow, McColl-Kennedy et al. 2016, Vargo and Lusch 2016), but neglects the fact that actors who contribute their resources in interaction need to be mobilized and coordinated so that they could enact their roles on performing adequate activities in the co-creation practices. Additionally, although an ecosystem can be seen as aggregation of interconnected systems or subsystems (Vargo and Lusch 2011,

Akaka, Vargo et al. 2013, Porter and Heppelmann 2015), few efforts are devoted to investigate how these subsystems are mobilized and coordinated to shape an ecosystem.

Due to the increasing importance of foreign direct investment(FDI) to economic growth and the global competitions, many countries have established national inward investment agencies to provide services in recruiting new investment, removing investment obstacles, and facilitating administrative process for investment. To function efficiently and effectively, those national inward investment agencies, though in the past have simpler structure and network, nowadays tend to operate through single-window mechanism with wilder participation of stakeholders across foreign and domestic, private and public sectors, which created more complicated service ecosystems. Previous research stream in this field was few and only looks at the network from perspectives of traditional marketing theories, such as place marketing (Kotler, Hamlin, Rein & Haider 2002). As the changes in the characteristics of the ecosystems surrounding those inward investment agencies causing by environmental challenges such as global competition, there is a need to look at the services systems from new perspectives.

As a result, this paper aims at exploring the mobilization process in the emergence of service ecosystems. We drew a linkage between the research stream of service-dominant logic (e.g. Vargo and Lusch 2017), existing studies of business ecosystems (e.g. Iansiti and Levien 2004, Winn and Pogutz 2013), and the literature of mobilization(e.g. Möller & Halinen 2017, Bockhaven & Matthyssens 2017), to lay the theoretical foundations. We explored this research issue through a multi-case study that looked at the emergence process of the ecosystems of Inward investment agencies of Taiwan, Singapore, and Korea. Those cases, with a time-span of five years, detailed the development process of how key stakeholders, including foreign and domestic companies, institutional investors, private and public organizations, were motivated by the national single-window platforms of Inward Investment agencies, and how the emergent systems were mobilized and coordinated, evolving towards mature service ecosystems. The research findings permitted us to enrich the understanding into ecosystems from a mobilization perspective. We were also allowed to develop implications for practitioners as well as policy makers.

LITERATURE REVIEW

Literature Review of Mobilization

Previous Research Streams of Mobilization

Previous researches have explored how business actors can tackle the behavioral challenges faced when they introduce radical innovations that go against the institutionalized rules, interests and logics of their field. Often, such innovations get stuck on the unwillingness of actors, other than customers or users, to adopt or accommodate the innovation (Adner & Kapoor 2010). Resistance arises because the innovation infringes on actors' behavioral drivers such as shared meanings, identities, interests and influence structures, and thus unsettles the consensus within an existing field. Because of this dynamic, scholars investigating the genesis of (radical) innovations by intentionally governed networks of business actors – the strategic nets view – have turned to studying the development of business fields (Moller & Svahn 2006). Unlike markets, such fields acknowledge the role of not just the players directly involved in value creation and exchange from the innovation – the value-creating system (VCS), – but also that of the outsiders influencing it, even before a market is formed (Möller & Svahn 2009). To get the innovation adopted therefore involves a need to “move” the surrounding field – the aggregation of all the relevant actors connected to the value creation process, the cultural, normative and

regulative principles governing their behavior and the network inter relating them (DiMaggio & Powell 1983; Kenis & Knoke 2002) – toward a new consensus (Vargo,Wieland & Akaka 2015). To move a field implies a challenge to mobilize actors and to guide their sensemaking (Möller & Svahn 2009; Dimaggio 1988). All relevant interdependent actors need to be convinced of the innovation's value, and their diverse interests aligned (Mouzas & Naude 2007; Öberg & Shih 2014).

In mature fields, these behavioral processes arguably constitute the main challenge for the adoption of radical innovation – warranting a strategic analysis of their own. Innovation originates outside the conformist center of such fields, and thus imports divergent logics that conflict with deeply institutionalized habits, norms and regulations (Rao, Morrill, & Zald, 2000; Van Bockhaven, Matthyssens, & Vandenbempt, 2013). This is especially true in a services system surrounded around the inward investment agency of a country when facing challenges outside the center, such as global competitions, internal and external forces (Kolter, Hamlin, Rein &, Harder 2002). Innovation success is constrained by the diverse interests of numerous players, highly professional factions with limited accountability for outcomes and extensive government-led regulatory and funding influence (Herzlinger 2006). Still, the strategic nets framework focuses mainly on the information and capability needs to develop the VCS, such as the capabilities which need to be mobilized and the coordination mechanisms and structures sustaining mobilization (Partanen & Möller 2012). It recognizes the need for agenda-setting, bargaining and contracting to enable mobilization (Möller 2010; Mouzas & Naude 2007). Yet, it has not yet examined in sufficient analytical detail the dialectical (reciprocally contested) processes of actor mobilization and how they might be steered by the mobilizer.
Previous investigations into the dialectics of actor mobilization have borrowed from more socially-focused lenses such as institutional (Brito, 2001; Ritvala & Salmi 2010), social networks (Araujo & Brito 1998), stakeholder and social movement theory (Ritvala & Salmi 2011). Since the latter two are especially cited for the analysis of the micro-foundations of collective agency (Rowley & Moldoveanu 2003), following research use them to enrich the strategic nets analytical frameworks for mobilization. By breaking down the business actor's network mobilization problem into three challenges, the most fitting theoretical perspective is introduced to analyze it for per challenge: stakeholder theory to identify the players; social movement theory to align and mobilize collective action and strategic nets with a focus on business actors as mobilizers.

1. Stakeholder Analysis
   The Gold Standard for Actor Identification: Stakeholder Analysis Tools

Stakeholder theory is a quite influential framework to explain actor dynamics, drawing attention to the diverse and self-interested groups of actors that affect or are affected by a firm's strategy (Freeman 1984). It has the merit of bringing stakeholders' reactions to firms' strategies into the equation for network strategizing, based on whether their interests align or conflict (Freeman 1994; Rowley & Moldoveanu 2003). To this end, stakeholder literature has developed analytical tools to identify, prioritize, and assess the demands of stakeholders.

Stakeholder analysis starts with the identification of relevant stakeholders, actors who can affect, or who are affected by, the firm's activities, something that is especially true of those with power, or a demand that is seen as urgent or legitimate in the eyes of the broader public (Mitchell, Agle, & Wood 1997). Based on these elements, one can map the relevant actors on what is likely the most well-known stakeholder management tool: the interest-power grid (Freeman 1984). This framework is a response to the complexity of dealing with the differing demands of multiple stakeholders. It helps to prioritize stakeholders (i.e., those who are high in

regards to interest and power ought to receive more attention) and differentiate the ways of involving them in decision-making (Frooman 1999). Further analytical contributions for network mobilization from the stakeholder framework consist mainly of more dimensions to differentiate how stakeholders should be treated. Introducing a social movement lens to stakeholder identification, Rowley and Moldoveanu (2003) point to how identity further explains situations when stakeholder groups act irrationally in relation to their interests. In their model, stakeholders act against their interest if they value a common identity that favors mobilization, and they will not defend their interest when such threatens the integrity of a valued group identity.

Others point to the importance of not just mapping stakeholders on an interest-power grid, but also of taking into account the coalitions and relationships between them (Frederick, Post, & Davis 1992). In a comprehensive evaluation and elaboration of stakeholder identification tools, Ackermann and Eden (2011) further mention the possibility of using stakeholders' dispositions toward a strategy (positive or negative), and of drawing their full network of (in)formal 'influence paths' – the visualization of net dyadic influence relationships between stakeholders as directional arrows – to assess centrality (Rowley 1997). Such a visualization helps the formulation of pathways toward mobilization targets.

Stakeholder theory opens the analysis of external actors to the dialectics of reciprocal self-interest. However, it only examines the outcomes that fit the 'unidirectional' and competing self-interest of either the firm or its stakeholders separately (Donaldson & Preston 1995). Stakeholder theory automatically assumes a kind of bargaining mode and disregards mutually beneficial shared goal achievement. With a repertory based on bilateral claims, rights and justice, it focuses on how much value is captured by each party and neglects how stakeholders and firms can co-create value toward a joint outcome as one VCS (Priem 2007). Given stakeholder theory's conflict ontology and dyadic focus, its tools have a limited appreciation of collective dynamics and outcomes. So, whereas stakeholder theory offers perhaps the furthest developed analytical tools for stakeholder identification, and prioritization, it does not delve into how to mobilize for a shared interest.

2. Addressing the Collective Alignment Challenge: Social Movement Mobilization Foci

Mobilization and the pursuit of collective outcomes do take center stage in social movement theory. It studies the bottom-up collective action of interest groups striving for social change – social movements. Its empirical tradition focuses on three interrelated tactics enabling such collective action: resource mobilization (McCarthy & Zald 1977), issue framing (Benford & Snow 2000) and political opportunity processes and structures (Goodwin & Jasper 1999; Kriesi 2004). Their analytical contributions to the mobilization process lie mostly in specific mechanisms that promote the alignment and active participation of disparate actors toward a co-constructed shared interest (Klandermans 2004). This mobilization process consists of a diagnostic (problem identification), a prognostic (solution identification) and a motivational (stimulation of action) task (Benford & Snow 2000). Whereas the stakeholder frameworks offer managerial tools for the diagnosis of current actor interest, power and identity barriers to collaboration, the three social movement tactics aim to achieve momentum in promoting a solution.

The first tactic, resource mobilization focuses on the strategic use of material resources, human actors (McCarthy & Zald 1977), organizational cadres and resources (Jenkins 1983), as well as the concepts of moral legitimacy and support (Cress & Snow 1996), and cultural resources such as field embedded vocabularies, conceptual tools, prior activist experience and contextualized understanding of the issue (Edwards & McCarthy 2004). It considers how these resources can address social movements' problem of inducing participation for collective action.

Secondly, social framing captures movements' construction, legitimation and support gathering for a collective identity (Goffman 1974). Frames are “purely individual cognitive structures or mental schemata” (Snow 2004), and much of this work investigates how these frames become widely adopted. These politicized processes contain both a discursive component, as well as cognitive strategies to attract and align a critical mass using for alignment processes of strategic framing (Benford & Snow 2000). The latter offer the mobilizer certain analytical clues for action to gain resonance with a targeted group. Frame bridging involves linking the mobilizer's frame toward sentiments shared by a separate group (Gerhards & Rucht 1992). The frame can also be amplified by clarifying and emphasizing the norms that it stands for (Snow, Rochford, Worden, & Benford 1986). Frame extension implies that movements enlarge their repertory of issues, symbols or values to also attract yet unmobilized groups, for instance such as if a PM network would emulate the vocabulary of nutraceuticals to move them toward personalized active foods. Frame transformation aims for frame reinstitutionalization in the broader field by over-turning, renewing or replacing old beliefs, meanings and myths (Benford & Snow 2000; Veugelers 2011).

A third tactic elaborates how social movements' political-cultural context, their organizing structures and contentious processes spark and constrain collective action (Tarrow 1996). This strand contributes how mobilizing actors can make use of preexisting formal and informal structures (McAdam & Scott 2005; Tilly 1978) and contextual opportunities. The latter may consist of adversaries' weakened ability to oppose or the focus of mass media, public figures or other channels to broadcast the issue of interest (King 2008b; Kriesi 2004). The tactics mainly boil down to identifying weaknesses or opportunities in outsiders' situations, and ways to leverage and exploit one's own social or organizational capital (Koopmans 1993). The concrete analytical foci of this concept are the attention to influential intermediaries, coalition building and for the timing and adaptation of mobilization strategies to match the readiness of the field to actually receive them (King 2008a).

Although social movement theory is the most widely used framework for mobilization analysis, the mobilization process and goal are different for business actors and societal interest groups (Hart 2004). The main discrepancies reside in the primary goals (commercial self-interest vs. a shared group interest), incentive structures (employees are paid, unlike voluntary movement members), and interpretation (different vocabularies, outcome aspirations and relational norms) (Laursen & Andersen 2016; Polsky 2000; Selsky & Parker 2005). Social movement theory assumes an assimilation of self-interest with that of the collective and does not really consider the continuing influence of individual interests, which is a cause of concern when members have profit-seeking motives. Thus, mobilization by a for-profit actor comes with specific challenges.

3. Mobilization by Business Actors: Contributions of Strategic Nets

To explain a business actor's analytical challenges as mobilizer, Bockhaven & Matthyssens (2017) adopts and extends the strategic nets perspective's focus on the classification, dynamics and structure of deliberately created and managed – thus strategic nets. The latter are coalition networks of organizations that are linked in a VCS involved in the commercialization of a joint product or service output (Moller & Svahn 2006). The framework specifically contributes to our understanding of how networks can be (partially) governed by network orchestrators or mobilizers (Halinen, Salmi, & Havila 1999; Mouzas & Naude 2007; Paquin & Howard-Grenville 2013). In this network agency perspective, mobilization is a micro-level sub-process in the early stages of the meso-level field emergence process (Araujo & Brito 1998; Möller, 2010; Möller, Rajala, & Svahn 2005). This is when an ‘emerging business net’ (a strategic net aimed at radical

innovation changing or creating a field) forms around a new dominant technological design (Möller & Rajala 2007). The perspective's contribution to mobilization analysis lies mainly in the recognition of the mobilizer's responsibility to envision a new VCS, to engage with other actors' mental models, and to pay attention to interdependencies within the current and the new VCS. The mobilizer's analytical challenge in this perspective can be broken down into four tasks that focus mainly on cognitive strategies and capability needs.

A mobilizer's first task is recognizing and making sense of the new VCS architecture (Moller & Svahn 2006) by developing a mental model of it, consisting mainly of vague ideas and affective intuitions (Hill & Levenhagen1995). Envisioning a new VCS amid unsettled positions, and before a market has formed, is enabled by one's network picture (actors' situated understanding of their activities in the net), and by spanning actor categories for exposure to diverse ideas and perspectives (Möller & Svahn 2009; Mouzas, Henneberg & Naudé 2008). The radically new VCS that require field development are characterized by their involvement of a wide range of actors (Aarikka-Stenroos, Sandberg & Lehtimaki 2014). This complex and ambiguous task hinges on the absorptive capacity to recognize, select and focus on the development of a business concept, and to derive the activities and boundaries of the VCS (Möller & Svahn 2009; Partanen & Möller 2012).

The next task lies in developing critical sense-making routines to develop the vision into a clear, adoptable frame that reduces uncertainty and attracts sympathy from others (Ritvala & Salmi 2010). It involves developing the joint heuristic that outlines how value will be created by the entire VCS in the form of business propositions that incentivize relevant actors (Hermes & Mainela 2014; Mouzas & Naude 2007). This implies, besides the ability to envision the VCS, the identification of actors with key roles in the emerging network based on insight into which capabilities are required for the collective goal, and where they reside (Möller & Rajala 2007; Möller & Svahn 2009; Mouzas & Naude 2007). The latter requires an understanding of the logics driving the behavior of different actor categories so that integration strategies can be developed (Brito 2001; Öberg & Shih2014).

Thirdly, mobilizers further reduce uncertainty by communicating a joint network development agenda. This extends the joint frame into a project plan with concrete steps, challenges and activities (Cova & Salle 2008; Möller 2010). Such agenda-setting enables the mobilizer to motivate others to transition from their old logics to seeing the opportunities of the new VCS (Möller & Svahn 2009). To this end, generative learning, to co-construct shared meanings with the emerging network, is required from the mobilizer (Möller & Svahn 2009; Storbacka & Nenonen 2015). Agenda-setting guides actors' recognition of options for action and locks them into a desired investment trajectory (Möller 2010). It also requires trajectories to co-evolve with the network to find common ground on the basis of shared values (Ritvala & Salmi 2010). These trajectories aim to transition actors' logics and incentivize them by using intermediaries (Hermes & Mainela 2014).

This finally opens the path to tackle the convergence of the diverse actors to collaborate in an increasingly committed way (i.e. from jointly acquiring a common resource pool or developing joint rules and standards to more vertical, specialized and hierarchic joint development of actual commercial applications (Brito, 2001; Möller & Rajala 2007)). The task of convergence revolves around bringing the interests, priorities and goals for the interaction of the wide set of actors closer to each other, for an increased impact toward the shared goal (Öberg & Shih 2014). It entails specifying actors' contributions in a stratified manner, according to their intentionality and (in)direct nature (Aarikka-Stenroos et al. 2014; Story, O'Malley, & Hart 2011). This should reveal differences in actors' eagerness and capabilities to contribute to the mobilization process. The

task of active mobilization hinges on the settlement of collaborative coordination rules and structures – often steered by a hub organization – to negotiate the risk, effort and reward shared between network members (Mouzas & Naude 2007; Partanen & Möller 2012). This hub approach helps to manage participants' satisfaction, and it positively influences performance especially of complex networks (Heidenreich, Landsperger, & Spieth 2016).

4. Toward a Business Actor's Analytical Tool Kit for Network Mobilization to Develop a Field

In terms of a mobilization analysis framework for field development by business actors, the strategic nets perspective helps in the sense-making of the new VCS. However, it could be extended with a more elaborate capability for sense-making of the actor dynamics. At the least, it could encompass having to move cross-sector actors to take up a role in the VCS (Araujo & Brito 1998; Moller & Svahn 2006). When it involves business actors co-creating a joint product or service innovation, or like-minded militants who find it rewarding to identify with an interest group, mobilization can be based on a shared interest (Rowley & Moldoveanu 2003). However, when mobilization aims for change at the field-level and thereby spans societal sectors, each with distinct interests and meaning systems, alignment becomes problematic (Polsky 2000; Ritvala & Salmi 2010). Hence, a mobilization analysis framework for business actors should empower the mobilizer to design a mobilization strategy that looks beyond the VCS and cognitions.

Literature Review of Service Ecosystem

The ecosystem perspective, drawing originally on biological eco- systems to describe differences in the nature of industries and also seen as a third mode of economic organizations besides markets and hierarchies (Moore 1993, 1996), has rapidly gained currency in describing collaborative forms of constructing innovations and business coalitions (Adner & Kapoor 2010; Autio & Thomas 2014; Frow, McColl-Kennedy, & Payne 2016). The drawback with the ecosystem's popularity is, as Aarikka-Stenroos and Ritala (this issue) argue is that the term.

"... has become a buzzword, sometimes adding very little to the analysis. Indeed, a critical look at the rapid expansion of B2B studies using the concept reveals that it is used in a variety of ways, ranging from a synonym for business networks to an analogy for interconnected environments, and even to describe a full-fledged theoretical and empirical approach". Aarikka-Stenroos and Ritala (2017) offer an extensive analysis of how different disciplines use the ecosystem perspective. They distinguish business ecosystem, innovation ecosystem, entrepreneurial and start-up ecosystems, platform ecosystem, and service ecosystem literatures, and their sub-categories. Based on a comprehensive literature analysis, the authors suggest two approaches to ecosystems from the network management perspective: "ecosystem as a new layer" to be managed, adding to Möller and Halinen's (1999) framework of network management levels, and "ecosystem as a novel perspective to business networks, which involves providing an update to current business network frameworks."

We see that most authors using the ecosystem term combine the "layer" or domain view and the "perspective" view. When treated as a domain, we should ask what are the differences between "sector/ cluster", "field", "network environment", and "ecosystem"? What new dimensions or characteristics does the ecosystem description provide? It seems that the broad ecosystem applications (ecosystem as a metaphor for industries, sectors, and clusters) assume that the focal domain is composed of interrelated actors having competitive and collaborative relationships and various aims for influencing and even directing the co-evolution of the focal domain. These larger "ecologies" can comprise several interrelated and competing "business

ecosystems" often driven by a hub firm (e.g., Apple's iPhone/iTunes ecosystem, Google's Android ecosystem), and constituting, with an array of technology providers "platform ecosystems" and with even other, non-business actors "mobile phone/services ecosystems". The mobile phone/services ecosystem may be depicted as part of a more extensive ecosystem comprising all electronic and software fields (and their science and research extensions). This simplified example raises the following observations.

First, all domain-type of ecosystem applications can be described through the actors-resources-activities metalanguage, meaning that the IMP network theory can describe ecosystems. Second, the different views on ecosystems overlap with the other labels; more expansive ecosystem applications (ecologies) seem very similar to the business field conceptualization (DiMaggio & Powell 1991; Kenis & Knoke 2002), while most of the more limited applications are analogous to the strategic nets proposed by Möller et al. (2005). This is clear from Adner's (2006, 98) definition of ecosystems as "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution." This is a neat way to describe a strategic net. Underlying our hint of irony is the worry that those ecosystem enthusiasts that are not familiar with business and innovation network research (or institutional studies) are reinventing the wheel, a serious problem in social sciences and one that is especially pertinent to the silos of business studies.

This does not mean the ecosystem approach is without merit – quite the contrary. The perspective forces us to develop theoretical tools for deeper understanding of the processes and mechanisms that drive the construction and change of business fields, noting both institutions and technologies as part of them (Adner 2017). Institutional theory and evolutionary economics, together with cognitive and learning theory seem useful sources for more advanced studies. The broad ecosystem studies can contribute to the innovation network orchestration research and vice versa, and it seems clear that the more focal-, hub- or coalition- centered ecosystem researchers would benefit from interaction with strategic nets scholars.

Literature Review of Service-Dominant Logic

Previous Research Streams of Service-Dominant Logic

Vargo & Lusch(2004) outlined a framework that has become known as "S-D logic". The core ideas were rather simple and straightforward. First, marketing activity (and economic activity in general) is best understood in terms of service-for-service exchange, rather than exchange in terms of goods- for-goods or goods-for-money. Second, value is co-created, rather than created by one actor and subsequently delivered. As with all "new" ideas, neither of these was entirely new (c.f. Arthur 2009). For example, Bastiat (1848/1964) had declared that "services are exchanged for services" over 150 years ago. Likewise, Prahalad and Ramaswamy (2000) had been advocating value co-creation for several years prior to Vargo and Lusch (2004) and before them Ramirez (1999) had traced its recognition back at least 300 years. In fact, S-D logic was, from its beginning, more about the identification and extension of apparent coalescence in the ongoing development of marketing thought, as reflected in the title "Evolving Toward a New Dominant Logic for Mar- keting" (Vargo & Lusch 2004; Akaka, Vargo, & Lusch 2012), than a radically new idea. That is, it has been grounded on a foundation built by many others, as has been its progress.

Since its introduction, the development of this integrated framework has continued, first by inclusion of the other (than service exchange) primary activity involved in value co-creation—resource integration—and then by explication of the idiosyncratic and experiential nature of

value (e.g., Vargo & Lusch 2008). More recently, in elaborating this framework, the consideration of the role of institutions in value co-creation has moved to the forefront. All of these developments have been captured in five core foundational premises (FPs, of which there are now a total of 11), which have more recently (Vargo & Lusch 2016) been identified as axioms (see Table 1).

There have been other "turns" that have been somewhat more subtle or at least not fully captured in separate FPs/ axioms—though some have resulted in the rewording of existing FPs—and others are currently in more formative stages. Examples of these are the move to a generic-actor (A2A) orientation and the identification of a service ecosystem as the "unit" of analysis for value co-creation (Vargo & Lusch, 2011). There are others.

Vargo & Lusch (2017) pointed out that S-D logic represents a dynamic, continuing narrative of value co-creation through resource integration and service exchange that has been constructed by an increasingly large number of academics from various disciplines and subdisciplines. During the last decade, service-dominant (S-D) logic (1) has taken a series of significant theoretical turns, (2) has had foundational premises modified and added and (3) has been consolidated into a smaller set of core axioms. S-D logic can continue to advance over the next decade by moving toward further development of a general theory of the market and, even more broadly, to a general theory of value co-creation. To support this theory of the market requires developing more midrange theoretical frameworks and concepts of service exchange, resource integration, value co-creation, value determination, and institutions/ecosystems. These midrange theories can be partially informed by theories outside of marketing, including those under the rubrics of practice, evolutionary, complexity, ecological and structuration theories. Evidence-based research is also needed.

Table 1 : The axioms of S-D logic.

	Axiom
Axiom 1/FP1	Service is the fundamental basis of exchange
Axiom 2/FP6	Value is cocreated by multiple actors, always including the beneficiary
Axiom 3/FP9	All social and economic actors are resource integrators
Axiom 4/FP10	Value is always uniquely and phenomenologically determined by the beneficiary
Axiom 5/FP11	Value cocreation is coordinated through actor-generated institutions and institutional arrangements

Foundations, Bifurcations, and Conceptual Turns

At the heart of S-D logic is the identification of service exchange. Vargo & Lusch (2017) especially noted the primary role of operant resources (such as knowledge and skills) that can act on other resources to create a benefit, rather than the role of the relatively static, operand resources (such as natural resources), which are more commonly considered. The S-D logic solution was a transcending conceptualization of service (a process, usually expressed singularly)—i.e. as noted the use of one's resources for another actor's benefit—that depicted service as superordinate to goods and services (units of output, usually plural). In other words, as Gummesson (1995) had noted some years before, "activities render services, things render services." Given that it is redundant to speak of intangible units of output, called "services," as being created to provide service, the former is generally not a concept used in S-D logic.

Instead, the framework suggests that service can be provided either directly or indirectly (e.g., through a good).

Zooming Out: From Resource Application To Resource Integration

Partly due to the editorial focus of the Journal of Marketing (Vargo & Lusch, 2004), as well as to the latent influence of traditional models, the initial perspective was relatively dyadic and micro-level focused and somewhat managerially oriented. A major turn occurred therefore with the attempt to zoom out to reveal the bigger picture. Initially, that zooming out exposed other actors, at first generally seen as other firms (e.g., "competitors" and "suppliers"). It then extended to customer connections (e.g., family, peers, etc.), all involved in service-for-service exchange, thus, at least part of the broader context (Akaka, Vargo, & Lusch 2013). But closer examination revealed that all of these actors exhibited foundational commonalities in addition to service-for-service exchange—resource-integration activities. That is, the (especially operant) resources used in service provision were both the source and the combined outcome of service-for-service exchange. This led to the identification of FP 9, later designated Axiom 4 (Vargo & Lusch 2008), an FP/Axiom that seems to have resonated particularly strongly among S-D logic scholars and others. It also revealed a network structure (Chandler & Vargo 2011), but one that had dynamic, recursive properties beyond those typically attributed to networks. It was becoming increasingly apparent that the key to value co-creation was the ongoing interplay of resource creation and application afforded through reciprocal exchange and differential access and integration.

Full realization of this dynamism, however, required an additional turn. As we argued in Vargo and Lusch (2011), an essential step toward fully grasping the process and extent of value co-creation is the "need to overcome conceptual problems associated with the notion of a 'producer,' as a creator of value, and a 'consumer,' as a destroyer of value. Briefly stated, all actors (e.g. businesses, individual customers, households, etc.) engaged in economic exchange are 'similarly', resource-integrating, service- providing enterprises that have the common purpose of value (co)creation. This had been partially reflected in the wording of FP9: "all social and economic actors are resource integrators" (Vargo & Lusch 2008) but more fully captured in the somewhat tongue-in-cheek proclamation that "it's all B2B" (Vargo & Lusch 2011), which was subsequently rephrased 'more neutrally' to "A2A" (actor to actor). In addition, it also moved the network orientation to at least a rudimentary conceptualization of a service ecosystem, as will be discussed.

Service Ecosystems

As one zooms out from dyadic interactions and discreet transactions, the first thing noticed is that these dyadic interactions do not take place in isolation, but rather within networks of actors, of which the dyad is just a part. These networks can be seen at various levels of aggregation (e.g., macro, meso, micro). Structurally then, these networks reflect what S-D logic captures axiomatically in the resource-integration specification of Axiom 3. Likewise, they emphasize that the benefit (value) realized by a beneficiary (e.g., a "customer") does not occur in isolation either, but rather through integration of the resources from many sources, thus best understood as holistic experiences (FP9/Axiom3 and FP10/Axiom4).

At first glance, it might appear that there is little new here, just the acknowledgement that service provision, value co-creation and value realization take place in networks, as sociologists Granovetter (1973), Burt (1992) and various scholars in marketing (e.g., Achrol & Kotler 1999) have been telling us for some time. Partially, this would be a correct evaluation. However, the S-D logic framework adds several key characteristics that are not in all cases typical of these

network conceptualizations. Most obvious among these is that the connections represent service-for-service exchange, rather than just connections of resources, people, or product flows; thus, in S-D logic, network actors are linked by common, dynamic processes (service provision). Second, the actors are defined not only in terms of this service provision (resources applied for benefit) but also in terms of the resource-integration activities that the service exchange affords. Finally, the network has a purpose, not in the sense of collective intent but rather in the sense of individual survival/wellbeing, as a partial function of collective wellbeing. The study of purpose or purposeful behavior has a long history in philosophical thought concerning concepts of teleology and, more contemporarily, teleonomy (Pittendrigh 1958). The latter focuses more on complexity, emergence and self-organizing systems (Christensen, Anthony Scott, Berstell, & Nitterhouse 2007), which are crucial characteristics of service ecosystems. This literature fits well as we try to understand how wellbeing of individuals is both contingent on and contributes to a dynamic network, in which the resources of the actors are being continually updated. It also indicates the need for a subtle but significant shift in orientation among actors, away from the primacy of conflict and toward the primacy of cooperation and coordination. Unpacking how this "purposeful," cooperative activity leads to value co-creation will be a major underlying theme for the next 10 years, as will be discussed below.

Institutions

This coordination for value co-creation implies mechanisms for the facilitation of these resource integration and service-for-service exchange activities. As partially discussed in Vargo and Lusch (2016), this is the role of institutions and institutional arrangements. Institutions are the humanly devised rules, norms, and beliefs that enable and constrain action and make social life at least somewhat predictable and meaningful (Scott 2008), what North (1990) calls "rules of the game." Institutional arrangements refer to higher-order assemblages of interrelated institutions (sometimes referred to as "institutional logics"). Thus, S-D logic has recently identified the service ecosystem, partially conceptualized in terms of institutions, as the unit of analysis for value co-creation. Service ecosystems are defined as "relatively self-contained, self-adjusting system of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange" (Vargo & Lusch, 2016, p. 161).

With the addition of institutions and service ecosystems to S-D logic's foundational concepts, we believe S-D logic can begin to be something more than the lens, framework, and perspective, as we have characterized it up to now. That "something more" can take several forms, each with its own potential impact. At a minimum, it affords the completion of a relatively coherent narrative of value co-creation through resource integration and service exchange, coordinated by shared institutional arrangements that de- fine nested and overlapping service ecosystems (see Fig. 1).

Figure 1 : The narrative and process of S-D logic. Note: Vargo and Lusch (2016)

METHOD

Qualitative Research Method

This study employs qualitative research method and uses multi-case study as the research method. The reason why this study applies qualitative research is to explore the questions of "how" and "why". Doing qualitative research depends on researchers' observation on phenomenon and deep interaction with facts so that the meanings of problem will be comprehensively and deeply analyzed and examined to conclude applicable implications. In addition, this research studies "process" which focuses on actors' experiences and developing process of the cases.

Multi-case Study

This research also utilizes multi-case study method by adopting 3 cases including the service ecosystems of the inward investment agencies of Taiwan, Singapore, and Korea to make comparisons. As a result, it helps to do detailed and deep investigation to make comprehensive explanation.

Data Collection

The data that this study collects is from two parts: interviews and secondary data. Six interviews have been conducted, which takes around 7.5 hours in total. The interviewees are from different organizations and different positions. On the other hand, the secondary data includes actors' social network sites, speeches, videos, articles, community newspaper, media and academic reports. All these materials are used to help form thorough understanding of the case and know its developing process and operation clearly.

FINDINGS

1. Taiwan

1.1 Taiwan's Inward Investment Agency- the InvesTaiwan Service Center (ITSC)

In order to provide more business-friendly investment services and attract international firms to invest in Taiwan, the InvesTaiwan Service Center (ITSC) has been established since the year of 2010 under the Ministry of Economic Affairs (MOEA) to offer a single-window for investment services, and uses a "project-oriented, dedicated case manager with specific responsibilities, and customized start-to-finish services" approach to assist investing firms. After understanding the needs of investing companies, the ITSC provides services before, during, and after the investment process, while also taking governments to jointly assist firms in eliminating obstacles to investment, thereby accelerating the completion of investment projects in Taiwan.

The ITSC provides fully customized services to meet companies' investment needs, takes advantages of links to specialized resources, and actively serves as a communication platform between government units, facilitating the joint resolution of investment issues. If a major impediment to investment is encountered, the ITSC will activate its coordination mechanisms and hold a working group conference. If the problem still cannot be resolved, the ITSC will notify the MOEA and Executive Yuan to hold an inter-agency coordination conference. The ITSC aims to swiftly respond to problems, and actively reports back to investors on the progress of its assisting actions; as a result, its service spirit has made it an optimal partner for companies planning to invest in Taiwan.

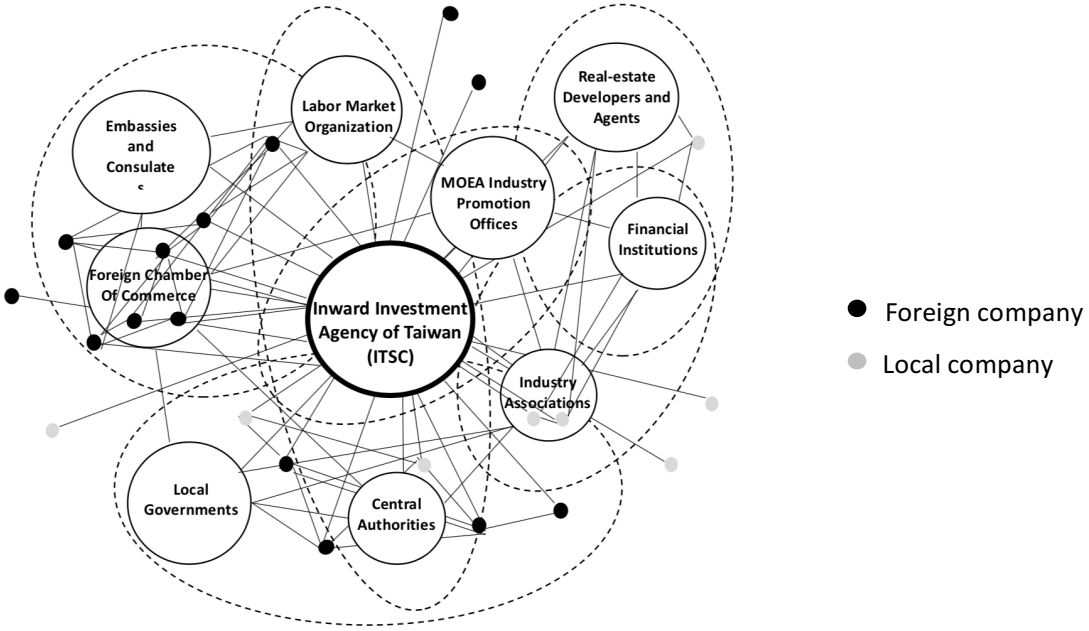
1.2 Investigation into the Service Ecosystem

1.2.1 Stakeholder Analysis

In order to implement the above-mentioned tasks, the ITSC links with various professional resources and related government departments, including actors of 20 MOEA industry promotion committees/offices, 7 industry associations, competent authorities, local governments, foreign and domestic leading enterprises, real-estate developers and agents, financial institutions, foreign and domestic chamber of commerce, Labor market organizations, Embassies and consulates, naturally forming an service ecosystem.

Within the service ecosystem, the main focused actor, the inward investment agency, the ITSC, declaims the value proposition of helping companies to invest successfully in Taiwan, which attracts other actors to participate in the ecosystem.

Figure 2 : The Ecosystem of the Inward Investment Agency of Taiwan



1.2.2 Social Movement Mobilization

Since 2015, the MOEA, the supervisory authority of the ITSC, together with other government agencies, have announced new industrial policies (such as the “5 plus 2 Industrial Innovation” and the “ Forward-looking Infrastructure Construction” projects) to encourage the investment in specific innovative industries including internet of things(IoT), smart machinery, green energy, biomedicine, defense technology, circular economy, new agriculture, and railway vehicles. Through government budget support, business opportunities with a total of USD 45.5 million is expected to be created, which has paved the way for the recruitment of foreign investment.

Taiwan government also provides certain incentives to attract investment, including the exemption of import duty, commodity tax, and business tax for investment in special zones (such as science industrial park, free trade zones, export processing zones, etc.), the 1-3 year deduction with annual rates of 10%-15% from business income tax for R&D expenditure of investment in specific industries. All of these industrial policies and investment incentives are not only the driving forces to attract foreign investments, but also act as rules of the game that shape the service ecosystem.

In order to create better investment environment and form relationships with other countries, Taiwan government has signed 7 free trade agreements, mainly with countries in central and south America and Asia. In this regard, due to special factors, Taiwan has faced certain difficulties in expending its outreach in signing FTAs, but within current constraint it still takes the best advantage of the relationship and resources of the existed signing counter parties and incorporate them as important partners and actors to the service ecosystem of the inward investment agency.

The focused actor, the inward investment agency, the ITSC, also provides complementary measures such as free services for investment plan consulting, assessment, and tax/legal/regulatory consultation, response to questions within 24 hours, match-making service for lands and spaces, etc., to attract other actors to participate and contribute more in the ecosystem.

Since Taiwan has an advantage in ICT manufacturing and is using it as a base to develop IoT industries, it is found that internet of things technology is also applied to the platform of inward investment agency. For example, an Investment Situation Room which uses IoT technology to collect and analyze updated investment information and statistics from actors in the ecosystem was just established. It allows more actors to be willing to join and engage in the ecosystem by using cutting-edge new technologies.

1.2.3 Strategic Nets

In the ecosystem of Taiwan's inward investment agency, the ITSC uses the value proposition of helping companies to invest successfully in Taiwan to reduce uncertainty and attracts sympathy from other actors. It also developed up a standardized operation procedure for investment service which outlines how value will be created by the entire ecosystem to incentivize relevant actors. However, the other actors in the ecosystem, like foreign chambers of commerce, may time to time express their different requirements for the ecosystem, which also foster the ITSC to tackle the convergence of the diverse actors so that every actor can play a role in value co-creation in the ecosystem and to collaborate in an increasingly committed way.

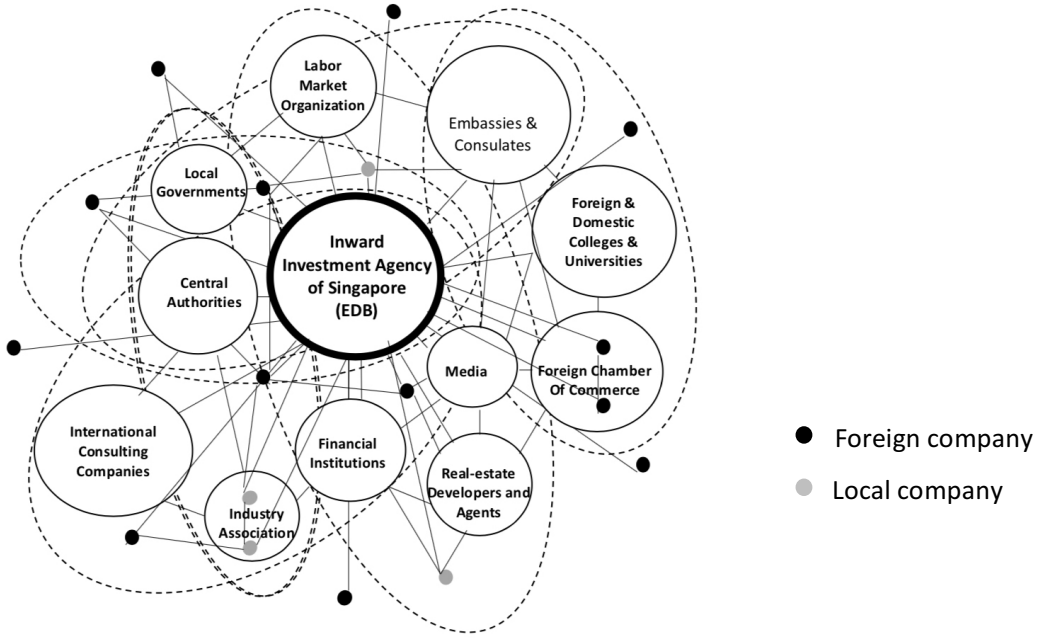
2. Singapore

2.1 Singapore's Inward Investment Agency- Economic Development Board (EDB)

The Singapore Economic Development Board (EDB), a government agency under the Ministry of Trade and Industry, is responsible for strategies that enhance Singapore's position as a global center for business, innovation, and talent. The EDB is selective in engaging and promoting investments which meet the resource profile and the aspirations of Singaporeans, with commitment to ensuring that activities in Singapore are fit for the future and sustainable in the medium to long term. Its core values are care, integrity, team, imagination, courage, excellence, nation (CITICEN). Shared by one and all at EDB, these core values shape and guide the organization in what it undertakes.

With deep insights and networks into Singapore's various industries, the EDB undertakes investment promotion and industry development in the manufacturing and internationally tradeable services sectors. Besides facilitating investments, it also engages Singapore's existing base of companies to transform their operations and boost productivity, and to generate growth in adjacent and disruptive areas by growing new businesses out of Singapore.

Figure 3: The Ecosystem of the Inward Investment Agency of Singapore



2.2 Investigation into the Service Ecosystem

2.2.1 Stakeholder Analysis

The EDB connects actors of industry associations, competent authorities, local governments, foreign and domestic leading enterprises, financial institutions, foreign and domestic chamber of commerce, Labor market organizations, media, Embassies and consulates, foreign and domestic colleges and universities, international consulting companies, to carry out the mission and tasks of the promotion of inward investment.

Within the service ecosystem, the main focused actor, the inward investment agency, the EDB, developed the value proposition of creating sustainable economic growth, with vibrant business and good job opportunities for Singapore, which attracts other actors to participate in the ecosystem.

2.2.2 Social Movement Mobilization

The EDB works with companies by providing information, connection to partners and access to government incentives for their investments, as well as their transformation and growth initiatives. It also works closely with other Singapore government agencies to constantly improve their pro-business environment, and ensure that industries are supported by a globally competitive workforce through talent development.

Singapore has signed 31 free trade agreements with countries around the world. In this regard, the EDB actively provides assistance in delivering explanations to its partners on the benefit a

company can gain from tariff deduction and the removal of non-tariff barriers through emails, conference, seminars, or calling on companies. It also provides formulas on its website to help companies calculate how much they can save from tariff deduction to attract more investments.

Singapore government provides the lowest corporate tax rates in Asia. A slew of financial incentives is offered to investors ready to expand their businesses, covering areas from equipment and technology, to business development, R&D and intellectual property, headquarters management, and industry development. Resident companies also enjoy additional benefits including protection from double taxation, tax exemption on foreign-sourced income and tax exemption for new start-up companies. The Global Investor Program (GIP) also accords Singapore Permanent Residence status to investors with substantial business track record and successful entrepreneurial background who intend to drive their business and investment growth from Singapore. An integrated series of incentives and programs has been tailor-made to welcome companies to integrate into both the business community as well as local society. Those efforts have earned Singapore the reputation for being the world's easiest place to do business, as well as the most competitive Asian economy.

With deep insights and networks into Singapore's various industries, the EDB can help investors to assess the advantages of setting up in Singapore as well as to highlight critical regulations that may be relevant to investors' business. It can connect investors with a wider network of government agencies and EDB partners (private companies) who can assist with business incorporation, taxation, legal matters and financial service. New businesses in Singapore may leverage EDB's network of partners in the private sector, who provide a full range of business support services.

2.2.3 Strategic Nets

The value proposition of the EDB is to creating sustainable economic growth, with vibrant business and good job opportunities for Singapore, which provides a broad vision for its partners (also the actors in the ecosystem) to participate in the related activities of the recruitment of foreign investments. With the vision, the country also creates an open platform allowing more partners/actors around the world to be part of the ecosystem with lower boundary limitations. Therefore, all kinds of actors or cluster of actors can express their feedbacks to the ecosystem with similar or opposite thinking and collaboratively co-create the value of the ecosystem.

3. Korea

3.1 Korea's Inward Investment Agency- Invest KOREA, KOTRA

Invest KOREA(IK), composed of Korea Trade-Investment Promotion Agency(KOTRA) employees, specialists and seconded officials from government ministries and agencies, is a Korean investment promotion organization established since 2003 to provide customized services support for the entry and establishment of foreign businesses in Korea. It works closely with its network of 42 overseas branches, known as Korea Business Centers, to provide comprehensive services for foreign businesses. It includes consultations, assistance with investment notification and corporate establishment, support for business activities in Korea and grievance resolution. It provides comprehensive one-stop services to foreign-invested companies to help them develop into global companies.

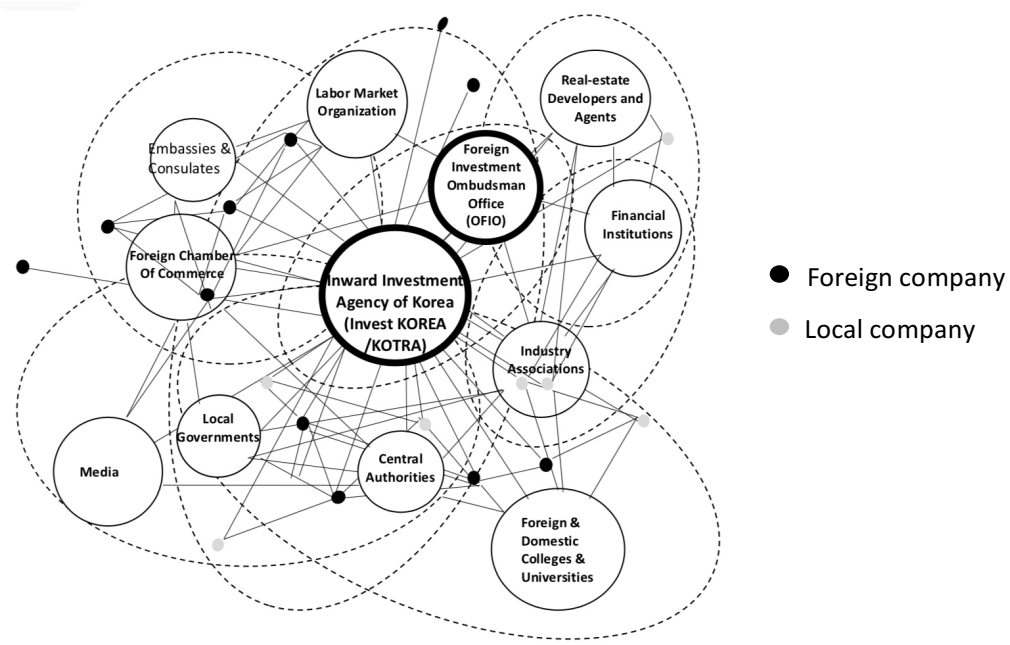
3.2 Investigation into the Service Ecosystem

3.2.1 Stakeholder Analysis

The Invest KOREA connects actors of Foreign Investment Ombudsman Office(OFIO), industry associations, competent authorities, local governments, foreign and domestic leading enterprises, financial institutions, foreign and domestic chamber of commerce, Labor market organizations, media, Embassies and consulates, foreign and domestic colleges and universities, international consulting companies, to carry out the mission and tasks of the promotion of inward investment.

The Value proposition of Invest KOREA is to contribute to the wellbeing of the Korean people and the development of human race by facilitating global business.

Figure 4 : The Ecosystem of the Inward Investment Agency of Korea



3.2.2 Social Movement Mobilization

In order to make the leap to a more attractive investment destination, Korea government is devoted to improving industrial structure by developing key industries, fostering convergence-based new industries, and nurturing high value-added service industries. It also endeavored to reduce economic uncertainty by Increasing flexibility of the labor market and developing the financial market.

Korea has signed 15 free trade agreements with countries around the world and is the first country in the world to complete the all FTAs signature with of the U.S, E.U., ASEAN, and China, with the FTAs effect to cover 49 countries.

The Invest KOREA carries out various activities to attract foreign investment, including finding potential investors, supporting investment projects, providing after care services and building cooperation with related agencies. Invest Korea Plaza, the first international business incubation center in Korea, also offers business consultation, administration support, investment and efficient one-stop services to foreign investors.

The Invest KOREA also employs one office to back-up it investment promotion mission. The Office of the Foreign Investment Ombudsman (OFIO) provides aftercare services to resolve a variety of grievances faced by foreign-invested companies doing business in Korea. The Ombudsman makes recommendations to the government and other organizations to improve the investment environment on behalf of investors, thereby helping resolve their grievances. The Investment Aftercare Division offers “home doctors” (experts in foreign investment) to provide one-on-one services for clients and rapidly identify and resolve problems.

3.2.3 Strategic Nets

In the ecosystem of Korea’s inward investment agency uses the value proposition of contributing to the wellbeing of the Korean people and the development of human race by facilitating global business to attract the other actors in the ecosystem. In spite of providing one-on-one investment services, the Invest KOREA also employs the Office of the Foreign Investment Ombudsman (OFIO) to provide aftercare services. The OFIO makes recommendations to the government and other organizations to improve the investment environment on behalf of investors, thereby helping resolve their grievances.

With the OFIO acting as intermediate between investors and the inward investment agency, it is more convenient for actors to exchange views on how to make a better ecosystem and therefore more easy to co-create value.

4. Analysis

4.1 Stakeholder Analysis

Past Researches on inward investment promotion mostly were conducted from the perspective of traditional merchandise-dominant logic, such as place marketing (Kolter 2002). They tended to consider value creation as a concept of value chain from a one-way and linear thinking. This paper takes a modern perspective from service-dominant logic to review the service ecosystems of the inward investment agency of Taiwan, Singapore, and Korea. It is found that all of the ecosystems of the 3 countries not only contain the major actors pointed out by traditional research (such as industry associations, competent authorities, local governments, foreign and domestic leading enterprises, financial institutions, foreign and domestic chamber of commerce, Labor market organizations, media, Embassies and consulates), but even also involve a larger coverage of actors such as domestic colleges and universities and international consulting companies, and the resources behind them, making the networks more complicated ecosystems which are more coherent with the reality.

4.2 Social Movement Mobilization

According to the observation and comparison to the 3 cases of ecosystems of the inward investment agencies, from the perspective of mobilization, it is found that institution, relations, beneficiary incentives, and application of new technology are all critical driving forces in

mobilization of ecosystems.

(1) Institutions

The governments of the 3 countries all initiates highlighted industrial policies and investment incentives to foster the investment and development of innovative and strategic industries, which can be seen as rules of the games to shape communications and interactions among actors and to reach purposeful goals in the ecosystems. Government of Singapore even owns greater authority in providing Taylor-made investment incentive packages to fit the diverse needs of specific investors. This kind of flexibility also allow the process of institutionalization to be with more opportunities for deinstitutionalization and reinstitutionalization. It turns out to be helpful to value innovation and sustained mobilization in an ecosystem.

(2) Beneficiary Incentives

All of inward investment agencies in the 3 cases provides complimentary services as incentives to attract existed and new actors to involve in and contribute to the ecosystems. These complimentary services include Investment plan consulting, assessment, and tax/legal/regulatory consultation. Taiwan even provide more services as response to questions within 24 hours, match-making service for lands and spaces, while Singapore takes extra care of business transformation and long-term growth for investing companies, and Korea highlights aftercare investment services. All of the above turn out to become important driving forces for actor mobilization and coordination in the ecosystems.

(3) Relations

To provide an investment-friendly economic environment, a lot of countries have endeavored to sign multilateral, plurilateral, and bilateral free trade agreements (FTAs). Through the signing of FTAs, a country not only can get better trade terms especially in the deduction of tariff or non-tariff trade barriers which in the end contribute to investment, but also can outreach to the singing counter parties and utilize their resources from mutual relationship to make the service ecosystems of inward investment agencies more international and comprehensive.

In the multi-case study of this research, it is found that Singapore and Korea both have good outreach in signing FTAs, while Taiwan, due to specific reasons, has less accomplishments.

(4) Application of New Technology

From the multi-case study, it is found that all of the 3 inward investment agencies take different level advantages of new technology in providing their services. Each of the agencies basically has its own portal website providing thorough information to investors, and offer on-line consulting assistance. It allows investors and other actors to require services, communicate, and interact with lower costs in time and money, therefore drive them to participate more in the ecosystems.

Taiwan’s inward investment agency, the ITSC, recently has also established the Investment Situation Room and employed IoT technology in collecting investment data, statistics, and files from actors, including related departments and agencies of central authorities, local governments, and investing companies for Big Data Analysis and AI applications. Through the effect of new technology, actors are more easily steered and mobilized to commit to the ecosystem because of the cost-down and facilitation of the participation process.

4.3 Strategic Nets

All of the 3 cases showed that through creating open and communicable environments for the service ecosystems, the focused actor of inward investment agencies can use their value propositions to reduce uncertainty and attracts sympathy from other actors and also require feedbacks from various stakeholders in the ecosystems. The accumulation of different ideas, opinions, and feedback persistently constitutes the value co-creation of the ecosystems.

The methods the 3 inward investment agencies use to shape open and communicable environments for the ecosystems may differ, however all contribute to value co-creation. For example, Singapore proclaims its value proposition with clear core values of care, integrity, team, imagination, courage, excellence, nation (CITICEN), allowing all actors more actively connect to each other and share resources. Taiwan developed up a standardized operation procedure for investment service and welcome the other actors such as foreign chambers of commerce to express opposite opinions. Korea even hires the Office of the Foreign Investment Ombudsman (OFIO) to act an intermediate to enhance the exchange of view among actors. All of the above help the facilitation of value co-creation of ecosystems.

DISCUSSIONS AND IMPLICATION

Theoretical Implication

Past researches of service-dominant logic have mentioned actors, through services exchange in the process of resource integration, gradually form a service ecosystem under the arrangement and impact of institution (Vargo & Lusch 2017). However, how actors in a service ecosystem are appealed and how they are mobilized to participate in the interaction and resource integration have seldom been explored. This paper borrowed the research stream of mobilization, through linking with the theories of service-dominant logic and service ecosystems, to investigate how key actors were motivated by the inward investment agencies, and how the emergent systems were mobilized and coordinated, evolving towards mature service ecosystems.

In this research, evidences are found to point that the following 4 factors are critical driving forces in the mobilization of service ecosystems: 1) Institutions- acting as rules of the game in service ecosystems, institutions shape interaction of actors and generate agency which strengthen the mobilization of services ecosystems. 2) relations- the breadth and depth of the relations among the actors effects on sustained mobilization, and the broader and deeper the relations are, the easier to have sustained mobilization in service ecosystems. 3) beneficiary incentives- the providing of preferential measures and the flexibility in use are important attraction to actors when services ecosystem need to mobilize them. 4) application of new technology- through the effect of new technology, actors are more easily steered and mobilized to commit to the ecosystem because of the cost-down and facilitation of the participation process.

Managerial Implication

In recent years, as the rise of discussions on the theory of value co-creation, the conceptual thinking of ecosystem has also been highly emphasized theoretically and practically (that means it has not only been explored from the perspective of service-dominant logic). However, the participants of a service ecosystem (in other word, the stakeholders/actors) usually possess different goals and value thinking, and how to mobilize them to participate in collective

construction to create an agency which power and strengthen a service ecosystem to evolve toward a mature one becomes a very important issue. Therefore, mobilization is an essential tool for the management of service ecosystems.

The managerial contributes of this research are on the 2 aspects: 1) knowing the theoretical findings of the 4 critical driving factors influencing mobilization of service ecosystems is also helpful to the practice of the management of services ecosystems. 2) The findings on the comparison of stakeholders/actors, mobilization measures, and the ways of value co-creation of the 3 cases of ecosystems of inward investment agencies of Taiwan, Singapore, and Korea can serve as helpful reference for policymakers in decision making.

LIMITATION AND IMPLICATION FOR FUTURE STUDY

The lack of data on the performance of the 3 ecosystems of inward investment agencies in this paper constituted the limitations of research. Future studies can further explore the relation between Mobilization and performance of service ecosystems.

CONCLUSION

(Vargo & Lusch 2017) pointed out that to support service-dominant logic theory of the market requires developing more midrange theoretical frameworks and concepts. These midrange theories can be partially informed by theories outside of marketing, including those under the rubrics of practice, evolutionary, complexity, ecological and structuration theories. Evidence-based research is also needed. To bridge the gap in the research of service-dominant logic, this paper borrowed the research stream of mobilization, through linking with the theories of service-dominant logic and service ecosystems, to investigate how key actors were motivated by the inward investment agencies, and how the emergent systems were mobilized and coordinated, evolving towards mature service ecosystems.

In Summary, this evidence-based research reached the finds that institutions, relations, beneficiary incentives, and the application of new technology are 4 critical driving factors in mobilization of service ecosystems. These findings may serve as midrange theoretical frameworks and concepts to the theory of service-dominant logic and pave ways for it toward a more comprehensive theory of the market. Additionally, mobilization is an essential tool for the management of service ecosystems. The findings on the comparison in actors, mobilization, and value co-creation of the 3 cases of ecosystems of inward investment agencies of Taiwan, Singapore, and Korea can also serve as helpful reference for investment policymakers to make decisions more correctly and precisely.

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The Knowledge Spectrum and Cognitive Force – Several Emerging Tools of Knowledge Micro Analysis

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ABSTRACT

The first tool of knowledge chemistry was the knowledge spectrum describing the knowledge component of the knowledge-information-data hierarchy. The knowledge spectrum provides much information about knowledge describing the knowledge types which interact to permit intelligent behavior. Based the relationship between insight and Dretske's three knowledge types, a conceptual framework for the development of the force equations is used to create the force equations. The cognitive force calculated by the force equations are compared to the force which is obtained through moment models, and the force equations are refined as the graphic and mathematical techniques for determining cognitive force.

KEYWORDS: Knowledge Creation, Knowledge Management, Knowledge Chemistry

INTRODUCTION

Like chemistry's table of elements, the knowledge spectrum organizes information about knowledge and supports the decomposition of intelligent behavior into its cognitive elements. Building on the knowledge combustion analogy, the knowledge spectrum places seven knowledge types on a continuum and helps to explain the relationship between information, pragmatic knowledge, and semantic knowledge.

Randles, Blades, and Fadlalla (2012) stated that based on its spectrum location, a knowledge type's cognitive force could be determined. Furthermore, they stated that cognitive force was approximated by the shape of the semantic wall in Figure 1. These equations will provide a short-hand method for determining the cognitive force which is generated by the six pragmatic knowledge types: declarative, rules, triggering causes, maps, technical knowledge, and structuring causes. In this book chapter, the knowledge spectrum is reviewed, a deeper look at the knowledge spectrum is provided, and a conceptual framework for the development of the force equations is provided.

Development of a measure of cognitive force began with an attempt to understand increases in diagnostic confidence obtained from telemedicine consultations between specialists and physicians. Knowledge requirements, knowledge gaps, and diagnostic confidence were studied. The cornerstone of this telemedicine research was Dretske's (1988) definition of knowledge which described three knowledge types that control intelligent behavior. The knowledge requirements of the medical diagnostic process were described, and physicians' diagnostic confidence was inversely related to the size of their knowledge gap. Furthermore, the processing of diagnostic information and the provision of explanations by the specialist were found to increase the physician's diagnostic confidence.

Subsequently, the vacuum formed in the cylinder of the combustion engine was related to a knowledge gap. The knowledge combustion and vehicle analogy and the knowledge chemistry approach were developed, and an appreciation of knowledge's moderation and balance was gained. The knowledge spectrum in Figure 1 shows that external information passes through a window into the mind. Ushered through the window by a small number of sensory devices, this external information becomes declarative knowledge. Semantic knowledge is internal. According to the knowledge spectrum, this semantic knowledge is linked to the external environment through six pragmatic knowledge types: declarative, rules, signals, maps, technical skills, and structuring causes. These pragmatic knowledge types generate cognitive force while semantic knowledge generates no force. Instead, its contribution to cognitive force is attributed to the pragmatic knowledge types it serves. Furthermore, individually, a pragmatic knowledge type cannot generate cognitive force. They only have a potential force. Even the simplest knowledge types, rules and signals, must have small amounts of declarative knowledge embedded in them. The knowledge types of the knowledge spectrum must interact to generate cognitive force, and the objective of the knowledge chemistry approach is to study theses interactions.

The tools of knowledge micro analysis should enable organizations to optimize their use of knowledge resources by modelling their business processes using moment models. According to the composition property of knowledge, the knowledge spectrum's higher order knowledge types are composed of lower order ones. For example, a map is composed of declarative knowledge, rules, and signals. Seven components of cognitive force have been described. These components can be graphically portrayed using a moment model, which is the base element of an emerging modelling methodology.

Each knowledge type has a potential cognitive force that is released through interaction with other simple knowledge types. Describing the characteristics of the pragmatic knowledge types requires decomposing the interactions that occur to achieve a specific form of insight or knowledge combustion. This is made easier by Randles and Thachenkary (2002) who described the relationship between insight and Dretske's three knowledge types, and each

knowledge type is viewed as a means to an end. Based on the aforementioned research a conceptual framework for the development of the force equations is provided.

BACKGROUND

Beginning with a telemedicine study in the 1990s, this research has led to a deeper understanding of knowledge and yielded the knowledge chemistry approach, the knowledge spectrum, and the notion of cognitive force. This research supports the provision of a conceptual framework for the cognitive force equations and is provided to support the reader's understanding of this framework which will be developed in the near future.

Pragmatics

The role of pragmatic knowledge is to interpret information in a particular context and to relate it to events and action (Stamper, 1973; Penzias, 1989). According to Randles and Fadlalla (2004), Dretske's definition of knowledge provides a better understanding of the pragmatic process. Dretske (1988) stated that behavior is a causal chain governed by three types of knowledge. The first of these knowledge types is the triggering cause which is a summary form of knowledge that signals the presence of an external event. The second knowledge type is the structuring cause which explains the relation between the signal (triggering cause) and the external event. The third knowledge type is described as a map attached to a belief that guides one's actions (Dretske, 1988).

Determining how telemedicine impacted the fulfillment of medical diagnostic knowledge requirements and influenced diagnostic confidence was the focus of telemedicine research by Randles and Thachenkary (2002). An analysis of knowledge requirements, knowledge gaps, and diagnostic confidence was undertaken. In 1977 Conrath et al. proposed that changes in diagnostic confidence would correspond to bandwidth with higher bandwidth resulting in greater increases in diagnostic confidence. However, both phone supported teleconsultations and teleconsultations supported by audio and video communication technologies had similar influences on diagnostic confidence. Rather than an information/telecommunications perspective, Randles and Thachenkary (2002) took a cognitive one. They found that physicians' diagnostic confidence was based on their ability to fulfill knowledge requirements. Diagnostic confidence was inversely related to the size of the knowledge gap and the successful processing of information and provision of explanations was found to increase diagnostic confidence.

The telemedicine research of Randles and Thachenkary (2002) described the relationship between insight and Dretske's three knowledge types. This research was extended through the knowledge combustion and vehicle analogy of Randles and Fadlalla (2004). Their knowledge combustion specifications described how a number of different knowledge types interacted to permit intelligent action introducing the knowledge chemistry approach and cognitive force.

In describing the knowledge combustion analogy, Randles and Fadlalla stated that pragmatics formed one part of the knowledge combustion equation providing the perspective from the engine. Their first proposition of knowledge chemistry was based on Dretske's (1988) three knowledge types and Sternberg's (1987) forms of insight. Their second proposition of knowledge chemistry stated that there are three primary forms of knowledge combustion, or insight, required for intelligent behavior. Their third proposition extended the second one,

proposing the existence of a fourth form of knowledge combustion (formulation), a planning process that is guided by the insight attained in a previous stage.

To describe what occurs between insight and action, the view from the vehicle was adopted. For the **vehicle analogy,** the vehicle embodies action, and there are devices that are engaged when the engine performs such as the tachometer, which indicates when to shift gears, and the speedometer that measures the speed of the vehicle. Knowledge combustion requires similar devices. According to the **knowledge combustion analogy**, action is controlled by two sets of cognitive processes that precede two emotions concerning knowledge and risk, to establish an **action threshold.** Although these control mechanisms do not contribute any force, in concert, they regulate action (Randles and Fadlalla, 2004). For example, after the problem is framed, a map is formulated. Simultaneously, at a deeper level, there is a subjective assessment of the map's adequacy as well as an assessment of one's ability to follow the map (diagnostic confidence). The second emotion emerges when the map is complete, and the next move is recognized. At this juncture, the consequences of the action are known, and a threshold is established. Only when diagnostic confidence is above the action threshold will an action be performed.

Knowledge Micro Analysis

Knowledge micro analysis focuses on the knowledge interactions that occur **in a moment's time**, in order to show how cognitive force is generated (Randles, Polin, and Abney, 2018). The links between the various knowledge types are analyzed, and these links represent seven components of cognitive force. The first three components: cohesion, coherence, and synergy form a summary measure. The other four components: complement, initiate, promote, and strengthen provide detail and permit a more in-depth description of how cognitive force is generated.

The work of Randles, Polin, and Abney (2018) extends the knowledge chemistry approach providing several propositions of knowledge micro analysis with micro propositions 1, 2, and 3 explaining why knowledge interacts and micro proposition 4 establishing three prerequisites for the generation of cognitive force. Micro proposition 1 is most relevant to this paper and is as follows: each knowledge type only possesses a potential force. Different knowledge types must interact to generate cognitive force.

A moment model is created through the development of a series of panels which depict the knowledge interactions that occur over several minutes of time. Just as data flow and activity diagrams support efforts to improve information flow within an enterprise; the graphical and mathematical techniques of knowledge micro analysis should provide organizations with a closer look at their critical knowledge intensive business processes (Randles, Polin, and Miller, 2019).

THE KNOWLEDGE SPECTRUM AND A MEASURE OF COGNITIVE FORCE

The first tool of knowledge chemistry was the knowledge spectrum which described the knowledge component of the knowledge-information-data hierarchy. As depicted in Figure 1, six knowledge types were placed on an explicit-to-tacit continuum. Randles, Blades, and Fadlalla (2012) stated that based on its spectrum location, a knowledge type's cognitive force could be determined. Furthermore, they stated that cognitive force was approximated by the

shape of the semantic wall in Figure 1. In this paper, a conceptual framework for the development of the force equations is provided. These equations will provide a short-hand method for determining the cognitive force which is generated by the six pragmatic knowledge types: declarative, rules, triggering causes, maps, technical knowledge, and structuring causes.

Knowledge Spectrum

Like chemistry's table of elements, the knowledge spectrum organizes large amounts of information about knowledge and supports the decomposition of intelligent behavior into its cognitive elements. Building on the knowledge combustion analogy, the knowledge spectrum helps to explain the relation between information, pragmatic knowledge, and semantic knowledge. The knowledge chemistry approach is based on a belief that intelligent behavior requires that different knowledge types interact and that more complex knowledge types (technical knowledge, semantic knowledge, and structuring causes) subsume more primitive ones (rules, signals, and maps). The cornerstone of this research was Dretske's definition of knowledge, which described how three knowledge types control intelligent behavior (Dretske, 1988). While proponents of the reverse knowledge management model have stated that knowledge cannot be separated from its tacit meaning structure (Tuomi, 1999), only one of Dretske's three knowledge types is closely related to meaning. The other two can operate independent of the tacit meaning structure, providing additional support for the recursive model.

Such characteristics of knowledge as the semantic wall and the window into the mind were depicted in the knowledge spectrum. Most importantly, characteristics of the spectrum knowledge types were described, and summary descriptions of these knowledge types is now provided. Eysenck and Keane (1990) defined declarative knowledge as the knowledge of knowing that (such as knowing that a specific diagnostic procedure should be conducted). Because of its factual nature, it is similar to information, which is described as a flow of meaningful messages that have the ability to increase, restructure, or change knowledge (Machlup, 1983).

The cognitive component of tacit knowledge is represented by the notion of internal mental models (Polanyi, 1966), and many descriptions of these internal mental models appear in the literature. There are numerous descriptions of rule-based knowledge. For example, semiotics identifies a number of transformations in which stimuli are transformed, such as letters to words and words to sentences (Ramaprasad and Rai, 1996). In addition, Weick and Bougon (1986) stated that predictive and associative knowledge were a collection of rules for processing information, and Covington (1998) described pragmatic rules, as rules of knowing what to say when.

Dretske (1988) defined the triggering cause as a summary form of knowledge that signals the presence of an external event. These signals, alarms, or indicators represent another type of internal mental model. This knowledge type analyzes a large amount of information and determines which information is relevant or irrelevant in a particular situation. The aforementioned knowledge types are ordinarily found at the machine level (Spiegler, 2003). As depicted in Figure 1, this machine-like knowledge falls between declarative and technical knowledge on the knowledge spectrum.

Randles and Fadlalla's (2004) fuel specifications suggest that map-like knowledge is necessary to frame problems and test hypotheses. Each of these different forms of knowledge combustion

has a different role and each requires a different map. For example, framing provides context and narrows a problem. This requires a map that is similar to a globe of the earth and provides a broad perspective. Conversely, hypothesis testing is an iterative process that requires more detailed information. This information is provided through a number of sub-state maps that are more like city street maps than a globe of the earth. These sub-state maps provide procedures for determining which path to take from a specific problem sub-state and provide specific directions like the ones provided in a cookbook.

Knowledge has a technical component which is the knowledge of how to do something (Nonaka, 1994) and is also referred to as procedural knowledge (Fetzer and Almeder, 1993). Technical knowledge resides in the mind and the body (Polanyi, 1966), and is placed in the middle of the knowledge spectrum establishing a broad boundary between tacit and explicit knowledge types. In describing the "new management science," Herbert Simon (1985) understood that the coordinated use of only a small set of simple motor skills became a complex mental task. While simple cognitive tasks require little coordination and limited semantics, more complex tasks require greater coordination and/or semantics. Figure 1 shows that there are different types of technical knowledge which vary with respect to whether they reside more in the body or the mind.

Semantic knowledge attaches meaning to data to create information (Ramaprasad and Rai, 1996). The subsidiary component of semantic knowledge processes cues captured by one's sensory devices and invokes a specific part of the meaning structure (Polanyi, 1998). Meaning representations are described as a background. This background is a tacit knowledge type, and the way these meaning representations are created and maintained is not well understood (Prosch, 1986). As shown in Figure 1, this background knowledge is represented by the semantic wall and semantic knowledge is most prominent in the upper bound on the knowledge spectrum where it is closely related to the structuring cause.

Dretske (1988) stated that the structuring cause was the most important knowledge type, and, as depicted in figure 1, the structuring cause is the most tacit knowledge type. The structuring cause is a deep network of facts, and many of its connections are hidden deep inside the structure. The role of the structuring cause is to generate an explanation that motivates action. This requires the identification of relevant strings of thought that may seem unrelated (on the surface) but are connected at a deeper level.

A Deeper Look at the Knowledge Spectrum

The knowledge spectrum illustrates that simple knowledge types have a dual role with one being internal and semantic and the other being external and pragmatic. As depicted in Figure 1, information passes through a window into the mind and is inspected by myriad triggering causes. These triggering causes signal the occurrences of external events and initiate rules that invoke maps to guide subsequent actions. These simple knowledge types also interact with the internal, semantic processes delivering peripheral data for processing. The semantic processes reciprocate this sharing of external information by activating specific parts of the meaning structure so a map can be formulated. The continual, intermittent interaction between the pragmatic and the semantic processes amplifies the declarative knowledge embedded in the rules and signals, enabling rules and signals to retain their message. Consequently, this embedded declarative knowledge can be located by the appropriate sensory input device.

Repetition and practice results in an intense interaction between pragmatic and semantic processes. When a new concept is established in the semantic wall, rules and signals are created to look for this specific incoming information. These distributed knowledge types transmit the peripheral information to specific parts of the semantic wall, giving knowledge an adhesive quality. This adhesive quality of knowledge allows additional knowledge to be obtained about myriad topics with little cognitive effort.

The dual role of rules and signals and the adhesive quality of knowledge illustrate the importance of balance and complement with respect to the interaction of different knowledge types and different forms of the same knowledge types. The knowledge combustion and vehicle analogy of Randles and Fadlalla (2004) revealed that each form of knowledge combustion uses seven knowledge types in a different way. For framing, the pre-semantic processes are intense while the semantic, pragmatic, and technical ones are simple. Alternately, the technical and pre-semantic knowledge requirements are minimal for formulation, while the semantic and pragmatic requirements are moderately complex.

Through diversity of form and function, knowledge is able to do myriad things using only four forms of knowledge combustion and seven knowledge types. The cognitive force of the each of the pragmatic knowledge types is based on their particular characteristics, and each knowledge type is viewed as a means to an end. Rules are the means to the selective comparison form of insight. The triggering cause is the means to the selective encoding form of insight, and the structuring cause is the means to the selective combination form. This relationship was first described by Randles and Thachenkary (2002), and by treating a knowledge type as a means to an end, a better description and understanding of these knowledge types can be attained.

After the creation of the knowledge spectrum, it became increasingly clear that even the simplest knowledge types (rules and signals) must have small amounts of declarative knowledge embedded in them. This embedded knowledge serves as a label or code, which is compared to incoming sensory data. According to the composition property of knowledge (Randles, Blades, and Fadlalla, 2012), the knowledge spectrum's higher order knowledge types are composed of lower order ones. For example, a map is composed of declarative knowledge, rules, and signals, and the aspect of technical knowledge that is in the mind (as opposed to the body) is composed of maps, rules, and signals.

With respect to cognitive force, knowledge must interact to generate cognitive force and each knowledge type only has a potential force. Furthermore, semantic knowledge is internal and generates no cognitive force. Instead, semantic knowledge is linked to action through the aforementioned five pragmatic knowledge types which interact with the external environment (the other side of the window) and generate cognitive force. Furthermore, the formulation form of knowledge combustion is based on the insight attained in a previous stage. It is a prelude to action and generates no cognitive force. Instead, the forces of the formulated maps are attributed to the processes they support. For example, in medical diagnosis the hypothesis testing stage subsumes the problem space map produced in the formulation stage.

To explain how cognitive force is generated, a study of the interaction of knowledge began, and moment models emerged as an approach for studying these interactions. Moment models depict the interactions between different knowledge types and between different forms of the same knowledge type providing an in depth look at seven components of cognitive force (Randles, Polin, and Abney, 2018). The ring links and base nodes presented in the static model

represent the cohesion, coherence, and synergy components of cognitive force. The static model also presents the links between similar knowledge type nodes (SKT links). The SKT links connect similar knowledge type forms to their base nodes and represent the complement component of cognitive force. The dynamic model presents the links between different knowledge type nodes (DKT links) over several minutes of time. These links represent the initiation, promotion and depth components of cognitive force.

Conceptual Framework for the Cognitive Force Equations

Knowledge is compact and neat and will often take the following course. The triggering cause will frame the situation and invoke a map. The requested map is formulated and is subsumed by hypothesis testing, serving as the basis of more detailed sub-state maps. These sub-state maps are formulated during hypothesis testing, which is an iterative, step-by-step process. The process moves from framing, to formulation, and then to hypothesis testing. It is first guided by simple, standard operating procedures. After the situation is framed, a map of a narrow piece of a vast problem space is formulated. Finally, sub-state maps are formulated, when needed, during hypothesis testing.

While maps provide guidance, it is technical knowledge that is most important during hypothesis testing. Technical knowledge permits the collection and interpretation of required information. However, these skills have little value until the collected (current) information is compared to an expected pattern of facts. Based on a small to moderate number of rules, the next action is determined.

Describing the characteristics of the pragmatic knowledge types (rules, signals, maps, technical knowledge, and structuring causes) requires decomposing the interactions that occur to achieve a specific form of insight or knowledge combustion. This is made easier by Randles and Thachenkary (2002) who described the relationship between insight and Dretske's three knowledge types, and each knowledge type is viewed as a means to an end.

As the basis of all intelligent action, there are many forms of rules performing myriad cognitive functions. A rule serves as a means to the selective comparison form of insight with current information being compared to an expected pattern of facts. It also relates to the hypothesis testing form of knowledge combustion which is an iterative, step-by-step process. In considering the cognitive force that rules generate, the number of rules that must be processed and the number of conditions that must be analyzed to achieve the aforementioned form of insight determines its cognitive force. However, underlying the pragmatic rules that guide action are pre-semantic rules that transform stimuli to letters, words, and sentences. Their force is minimal and is captured by the rules that guide action.

A rule's semantics must also be considered in determining the contribution of rules to cognitive force, as hypothesis testing is involved in a diverse range of activities. However, semantics' influence on a rule's cognitive force is minimal. Rules only possess a small amount of declarative knowledge and are a distributed knowledge type that exists separate from semantic knowledge. Rules are a simple, low energy knowledge type, and a factor of 3 (low, moderate, or high) should suffice in calculating the semantic influence on a rule's cognitive force. Consequently, for rules, cognitive force is a function of the number of rules and conditions that must be processed and analyzed with the sum of these numbers multiplied by a semantic factor of 1, 2, or 3.

The triggering cause rapidly analyzes a stream of external information to identify its salient part. It serves as a means to the selective encoding form of insight which requires distinguishing between relevant and irrelevant information. Like a rule, a signal is a distributed knowledge type that exists separate from semantic knowledge. Because of its dual role as liaison between external and internal processes, the signal is also self-sustaining. The map that guides framing is simple because framing relies on an analysis of readily available information. Standard operating procedures are followed, and the role of the structuring cause, which is to motivate action, is minimal.

The cognitive force that is generated by a triggering cause is determined by the number of variables that must be analyzed to achieve the selective encoding form of insight. The semantics of a signal must also be considered in determining a signal's force. However, like a rule, the influence of semantics on a signal's cognitive force is minimal because a signal only possesses a small amount of declarative knowledge. A factor of 2 (low or moderate) should suffice in calculating a signal's cognitive force. Hence, the cognitive force of a signal is a function of the number of variables that must be analyzed to achieve the selective encoding form of insight multiplied by a semantic factor of 1 or 2.

Intricate atlases of the world and elaborate production schedules are recorded maps, and creating these maps and schedules required great effort. They are valuable sources of information and are studied and learned by many intelligent agents, serving as the basis of their internal maps. However, the maps that are in the mind are small composed of a small number of rules and signals, each with a small amount of embedded declarative knowledge.

Hypothesis testing uses maps more extensively than any of the other three forms of knowledge combustion. The hypothesis testing task provides an excellent glimpse at the kinds of maps that guide intelligent action. Initially, an internal, problem space map composed primarily of triggering causes is provided. These triggering causes serve as beacons marking positions (sub-states) in a narrow problem space, and each of these beacons is identified by a specific pattern of facts. At each juncture of a problem space (a sub-state), there are several alternate branches, and each step of hypothesis testing requires a detailed sub-state map to determine which branch to take. The previously formulated narrow problem space map is subsumed by hypothesis testing. This narrow map of beacons and labels serves as the basis of the more detailed sub-state maps. These sub-state maps are only formulated when required and are primarily composed of a small number of rules that compare current information to an expected pattern of facts.

Because hypothesis testing is a step-by-step process, the breadth of these internal maps is narrow. For example, a map composed of 7 rules and 7 signals, each with a label of 25 characters would require the recall of 2 pages of information. For a label of 50 characters, 4 pages would be required, and the ability to recall maps that are ten to twenty pages in length with 30 rules and 30 signals seems realistic. However, this would require many years of study and practice.

Except for rules and signals, maps are devoid of other knowledge types. The formulation of a map delays action, and the role of the structuring cause (to motivate action) is not significant. Composed of only a small number of signals and rules, their cognitive force is approximately the sum of the forces of seven rules and seven signals. Furthermore, the number of conditions for the seven rules is either: small (2), medium (4), or large (6). The number of variables required

to identify a location in a problem space is either: small (5 or less), medium (6 to 10), or large (greater than 10 and less than 20).

Only if a map is novel and complex would the structuring cause have a significant role. In this case, an explanation would have to be developed to motivate the conduct of a novel action. Hence, the risk of the prescribed action is another variable influencing a map's complexity and force. To determine a map's cognitive force, the sum of the force of each of the rules and signals would be multiplied on a scale from 1 to 5 by a factor of: 1 for little risk and 5 for very risky actions.

Technical knowledge is the knowledge of how to do something and resides in the mind and body. According to Randles, Blades, and Fadlalla (2012), it is the level of control and semantics which determines what is low, moderate, or exceptional with respect to the intellectual (of the mind) aspect of a technical skill. With respect to technical skills that are more of the body, control is the key, and this requires maps. Through practice these maps are distributed to the body and performed with little thought. The internal map in the mind directs messages to the maps distributed in the body. In a thousandth of a second, these signals invoke physical actions that range from simple, mechanical operations to quite elaborate movements. However, these movements only occur if a small number of rules and signals, operating in the mind and body, interact in a millionth of a second. Finally, with respect to the body/mind dichotomy of technical knowledge, exceptional skill in one is usually coupled with less than exceptional skill in the other. This suggests that there is a cognitive limit with respect to the attainment of technical skills and reinforces how important practice is in the attainment of these skills.

With respect to technical skills of the mind, which is the focus of this research, the maps that guide action and the semantic richness of the endeavor are most important. As previously discussed, there are many types of internal maps that guide intelligent action, and the mind only works with several pages at a time. To reduce cognitive burden, even the most intellectual (of the mind) skills, distribute some of this how to knowledge to the body. For example, writers almost effortlessly type in their work as they wrestle for just the right word, and accountants use spreadsheet technology, without barely thinking, to solve the business problems they must attend.

It is the level of semantics that determines what is low, moderate, or exceptional with respect to the intellectual aspect of a technical skill. For example, it is the composer's rich semantics that distinguishes the composer from most musicians, and differences in semantic richness distinguish teachers from professors, bookkeepers from accountants, and nurses from doctors. To determine the cognitive force of a technical skill, the force of each of the maps that is utilized would be multiplied on a scale from 1 to 5 by a factor of: 1 for moderate semantic richness and 5 for extreme semantic richness, and these products would be summed. To factor in the force of the explanation which the structuring cause must generate to motivate action, the sum of the previous calculations would be multiplied by a risk factor on a scale from 1 to 5 (1 for little risk and 5 for extremely risky).

The knowledge requirements of the first three forms of knowledge combustion are moderate. But, this changes with the fourth form of knowledge combustion, which is depicted by the confirmation stage of medical diagnosis. Confirmation is introspective focusing on a few discordant facts. There is little need for a map to guide action. Confirmation is consumed with

thought, requiring recognition of the relationship between seemingly unrelated things. Attaining this form of insight is dependent on the structuring cause.

By identifying relevant facts that may seem unrelated (on the surface) but are connected at a deeper level the structuring cause can generate profound insights. All professions have members who reach beyond the routine to obtain some novel, perhaps, grand insight (creative thinkers). This creativity and grand insight corresponds to the upper sectors of the knowledge spectrum and the beginning of the structuring cause. Based on the semantics of the discipline which is based on a scale of 1 to 3 (1 for difficult semantics, 2 for very difficult semantics, and 3 for extremely difficult semantics), the cognitive force of the structuring cause is the cognitive force of a high-level technical skill multiplied by its semantic factor.

Further along the knowledge spectrum, beyond these creative thinkers are the geniuses that have emerged in myriad arts and sciences such as Bacon (philosophy), Da Vinci (science), Wagner (music), Picasso (painting), Einstein (physics), and Hayek (economics). This creativity and genius corresponds to the upper sector of the structuring cause and is measured on a scale of 1 to 3 with 1 being lowest level genius and 3 highest level genius. The cognitive force of the structuring cause is the cognitive force of a high-level technical skill multiplied by a semantic factor and then multiplied by a genius factor.

FUTURE RESEARCH

Using the conceptual framework provided in this paper, the force equations will soon be developed. Using moment models, moderately complex technical skills will be studied. The cognitive force calculated by the force equations will be compared to the cognitive force which is obtained through a moment model which depicts the interactions between different knowledges. The force equations will be refined as the graphic and mathematical techniques for determining cognitive force are calibrated. These techniques should enable organizations to determine the cognitive force which is generated by their knowledge intense business processes and knowledge-based technologies. Then the relationship between cognitive force and organization success will be studied.

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APPENDIX

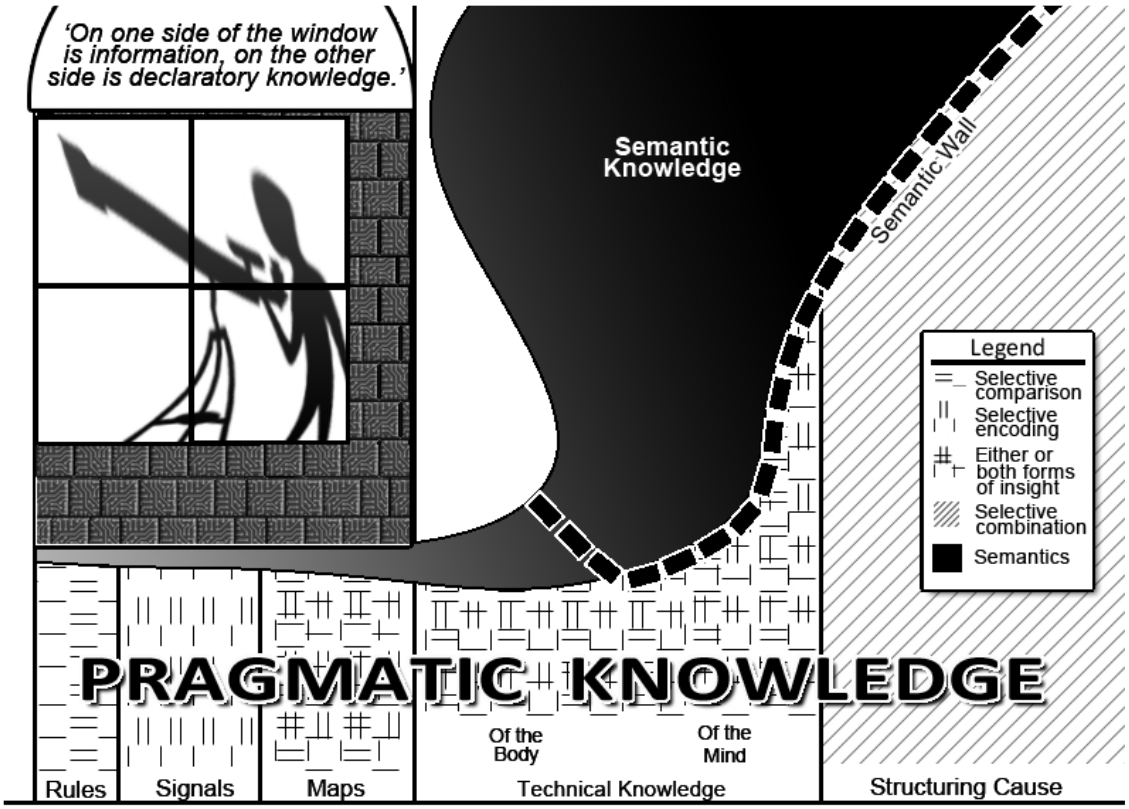

Figure 1: Knowledge Spectrum

DECISION SCIENCES INSTITUTE

The Relationship of Risk Management Integration to Counterfeit Mitigation and Supply Chain Performance in the United States: A Preliminary Empirical Study

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ABSTRACT

This research develops a model for characterizing the relationship of risk management practices with counterfeit prevention efforts and supply chain (SC) performance. A structural equation model is proposed that examines the relationships among SC counterfeit mitigation (CM), SC risk management integration (RMI), firm SC cost performance (CP) and service performance (SP), and overall firm performance (FP). Based on the participation of over 100 managers, greater maturity in CM appears to be associated with greater RMI, while greater RMI is associated with better CP and SP. Better SC performance is, in turn, associated with improved overall FP. Our findings suggest that RMI fully mediates the relationship between CM and SC performance.

KEYWORDS: counterfeiting, supply chain integration, risk mitigation, firm performance

INTRODUCTION

Counterfeiting is a serious issue for supply chain managers as they experience challenges in preventing inferior products from impacting their organizations and from reaching customers (D'Amato and Papadimitriou, 2013). It has the potential to disrupt the operations of suppliers, manufacturers, and downstream stakeholders in the SC. Therefore, the supply chain represents an important nexus for counterfeit research because of the effect counterfeiting disruptions have on SC cost, profitability and the ability to meet service expectations (Zhang and Zhang, 2015; Jeong, et al., 2012). However, empirical research on SC efforts to mitigate the effects of counterfeit infiltration, and the impact on firm performance is very limited.

Many organizations have developed approaches for avoiding or mitigating risk, including counterfeit risk. However, only recently has there been movement toward a standard for supply

chain risk management. The ISO 9001:2015 standard, for example, requires certified organizations to demonstrate risk-based thinking (Kymal and Reid, 2015).

While global interest in quality programs such as TQM and ISO 9001 has been increasing for some time, there are many recent notable examples of the increasing incidence of counterfeiting penetrations into supply chains that impact on quality and the bottom line. Therefore, standards such as ISO 9001:2015, with its focus on risk management, have the potential to be a standard for the active management of both supply chain quality and risk. The present study examines if superior risk-based thinking, such as is required in the latest ISO 9001 standard, is associated with positive performance outcomes in US supply chains. Therefore, this research adds to the literature by exploring the value of risk management integration in mitigating supply chain risk in general, and counterfeit risk in particular.

Next, we provide background on supply chain risk, counterfeiting, and related supply chain performance. We then develop our model and propose a set of hypotheses, explain the study methodology, and present our findings. We conclude by offering theoretical and managerial implications for scholars and supply chain managers.

LITERATURE REVIEW

Interest in the impact and mitigation of risk in the supply chain has recently experienced significant growth in the research literature. There has been a pronounced and sustained rise in the number of articles on the subject (Ho et al., 2015). Classifications of supply chain risks among researchers have included: controllable and uncontrollable risks, environmental risks, financial, information, intellectual property, and reputation risks, process and technology risks, logistics, supply and demand risks (Punniyamoorthy et al., 2013; Samvedi et al., 2013; Zhao et al., 2013; Wildgoose et al., 2012; Tang and Musa, 2011; Blackhurst et al., 2008; Tang and Tomlin, 2008; Wu et al., 2006; Chopra and Sodhi, 2004; Harland et al., 2003).

Counterfeiting, as a supply chain risk, can occur in a variety of ways. D'Amato and Papadimitriou (2013) characterize counterfeiting by the LISC (legitimate-illegitimate supply chain) model that describes interaction between legitimate and illegitimate supply chains. Their study of counterfeiting in the luxury industry identifies six types of supply chain risk related to counterfeiting. These include: pure counterfeiting (demand for counterfeit goods fulfilled with counterfeits from an illegitimate retailer), infiltration (demand for original goods fulfilled with counterfeit by a legitimate retailer), product diversion (demand for counterfeit goods fulfilled with legitimate goods from an illegitimate retailer), factory overrun (extra product sold by a legitimate or illegitimate retailer), retail service copycatting (demand for original goods fulfilled by an illegitimate retailer but known to the legitimate customer with varying product types), and shoplifting (demand for original goods fulfilled through theft at a legitimate retailer with varying product types and then resold). Berman (2008) classifies counterfeits into four groups, including: copies that look like the authentic product and consumers know they are buying fakes; third-shift products, made by suppliers outside of the legitimate contract, and sold under the brand name; non-conforming product that is intentionally identified as such and sold through regular channels; and reverse-engineered products that pose deceptively as authentic.

The costs associated with counterfeiting are substantial. It has been estimated that counterfeiting costs companies anywhere from 10-20% of sales (Shultz and Saporito 1996). The formation of the World Trade Organization (WTO) was a significant step toward better regulation

of counterfeiting related to intellectual property theft through the Uruguay Round strengthening of the General Agreement on Tariffs and Trade. However, there have been problems with enforcement and some economies still waiver on the agreement. For example, even though China joined the WTO in 2001, its share of counterfeits has continued to be much greater than that of any other US trading partner (Krause 2006).

It is clear from the literature that counterfeiting is a complex risk that can present in different ways and is very costly to the supply chain when it occurs. Therefore, effective mitigation of such risks is critical to the bottom line. The simplest generic approach for risk management described in the literature involves several steps, including: identification of potential risks, estimating their likelihood of occurrence, assessing the severity of impact on the supply chain should they do occur, engaging a real-time response when the risk event occurs, and then monitoring the effectiveness of the mitigation action (Ho et al. 2015; Kouvelis et al., 2011). A mature risk management process is characterized by organizational actions taken to avoid the occurrence of a risk event and effective mitigation of risk events that are difficult to avoid, so as to minimize the negative impact on supply chain service and cost. In relation to this, researchers have proposed effective ways to detect and reduce counterfeiting activity. Bush et al. (1989) proposed actions such as adding unique identifiers to products, informing the public about counterfeit risks, rewarding forward channel members for detecting and rejecting counterfeits, and monitoring channel distribution. Shultz and Saporito (1996) suggest co-opting offenders by purchasing them, educating stakeholders in transition economies, doing a better job marketing the brand, improving international surveillance, using high-tech labeling, and evolving the product more quickly. Berman (2008) recommends educating customers, using authentication technology, exercising better control of outsourced supply, monitoring websites, and taking legal action. Hoecht and Trott (2014) identified ten general anti-counterfeiting strategies from the risk literature. These strategies included: co-opting offenders, industry coalitions, internal/external guanxi, educating in-company decision-makers, raising awareness with advertising, surveillance, high-tech labeling, product/process innovation, legal enforcement of legislation, and withdrawal from high-risk markets.

The literature reports that organizational structure and characteristics may also contribute to risk management success. Organizations characterized by agility and flexibility, in addition to systematic contingency planning, are better able to manage risks in general (Ghadge 2012). A total quality management (TQM) culture has been associated in the literature with innovative, change-oriented and adhocratic organizations (Dellana and Hauser, 2000**).** These organizations have an external orientation on the well-being of the organization and a structure of flexibility and change, that may contribute, by extension, to more successful management of supply chain risk. Florio (2017) found that TQM practice is positively associated with risk management maturity. ISO 9001 certification, a standard for meeting quality management system requirements, incorporates the principles of TQM into its certification criteria. Thus, one would expect TQM principles and practices to be present in organizations that have achieved ISO 9001 certification. Hence, ISO 9001 certification may be able to signal risk management capabilities because of the attention the standard brings to improving process management through the principles of TQM. This is particularly true for the latest iteration of the standard, ISO 9001:2015. The 2015 version of the ISO 9001 standard explicitly incorporates risk management in the quality management system to overcome this weakness in the prior standards. This new emphasis on risk-based thinking recognizes that disruptions due to realized risk events impact negatively on customer satisfaction and must be proactively managed.

In the literature we find that firms can be better prepared to manage supply chain disruption by reducing the complexity of supply chain interactions and by becoming more agile and flexible by adopting a culture of innovation, (Ghadge et al., 2012; Scholten et al., 2014). But it is more efficient for supply chain members to proactively avoid such risks in an integrated fashion (Ho et al., 2015). As previously noted, organizations with more mature process monitoring and improvement practices appear to also have more mature risk management programs (Florio, 2017). Risk management maturity is also associated with better integration of supply chain members because it facilitates more rapid identification and better mitigation of risk events. Zhao et al. (2013) report that supply chain integration is an important driver for schedule attainment, competitive performance, and customer satisfaction; supply chain risks decreases as supply chain integration increases, (Zhao et al., 2013). By extension, organizations that exhibit a greater level of supply chain risk integration are likely to be more focused on risks in general, including counterfeit risk.

The occurrence of counterfeiting events in the supply chain increases uncertainty, which can logically result in decreased service performance and increased supply chain related costs. Organizations act in response to uncertainty by specializing and standardizing different tasks (Drazin and Van de Ven, 1985). Standardization improves consistency, providing superior visibility into inventory and service issues. Greater consistency results in lower supply chain costs and increased supply chain service performance (Li et al., 2005). According to Matthew and Mee (2008), as global markets grow increasingly more consistent (i.e., less variable and more efficient), competition occurs between entire value chains. Therefore, top managers seek to reduce costs and improve service performance so that the overall supply chain may gain competitive advantage. This is shown to result in improved overall firm performance (Chapman and Carter, 1990; Akinc, 1993; Agrawal and Nahmias, 1997; Frohlich and Westbrook, 2002).

One aspect that should be considered when comparing organizations in relation to risk management is organization size. Park *et al.* (2007) report that larger firms achieved quality certification compliance monitoring and measurement better than smaller firms. Lee and Palmer (1999) report that smaller organizations are more likely than larger ones to seek a quality certification due to external pressures. Further, larger firms appear to be better able to manage risk events than smaller firms (Kumar, 2011; Aguiar 2011; Skipper et al, 2010). Smaller firms lack the resources to develop a proactive approach, and instead are more apt to simply react to risk events after the fact (Ellegaard, 2008).

MODEL DEVELOPMENT

Counterfeit Mitigation and Risk Management Integration

Firms can be better prepared to absorb the shock of a supply chain disruption by engaging in better risk mitigation practices such as being more innovative or agile, reducing the complexity of supply chain interactions and creating modular/flexible processes, (Ghadge et al., 2012; Golgeci and Ponomarov, 2013; Gualandris and Kalchschmidt, 2013; Scholten et al., 2014). The level of firm's counterfeit mitigation is related to better integration of supply chain members allowing for quickly identifying risks.

As firms better mitigate risks (e.g., counterfeiting) supply chain risk decreases and supply chain integration increases (Zhao et al., 2013). In turn, it would be expected that a firm with enhanced

counterfeit mitigation would have increased risk management integration. Therefore, the following hypothesis is proposed.

H1a. SC counterfeit mitigation efforts positively contribute to SC risk management integration.

Counterfeit Mitigation and SC performance

Uncertainty underlies contingency theory (Venkatraman, 1989) and managers often pursue strategies to lessen the effects or mitigate events as a response to external uncertainty and competitive pressures (Fawcett et al., 2008). Contingency theory explains that managers must recognize the relationship of supply chain performance and their firm's internal structures to become, or remain, competitive (Luthans and Stewart, 1977). From a contingency perspective, managers attempt to eliminate the possibility of a risk occurring, shift the risk or outcome to a third party, and/or reduce the probability and impact of the risk by establishing mitigation strategies.

Such mitigation strategies or plans tend to take the form of avoidance (drop specific products), control (maintaining excess capacity, stockpiling), cooperation (joint efforts to improve supply chain visibility, sharing of risk information), and/or flexibility (multiple sourcing) (Juttner et al., 2003). Individually or used in combination with one another these strategies should improve areas of supply chain performance such as service and cost.

Contingency theory provides the foundation on which firms prepare for and minimize disruptions to their supply chains (i.e., supply chain risk mitigation strategies). In turn, increased efforts at supply chain counterfeit mitigation should have a direct and positive impact on supply chain service and cost performance. Therefore, the following hypotheses are proposed.

H1b. SC counterfeit mitigation efforts positively contribute to SC cost performance.

H1c. SC counterfeit mitigation efforts positively contribute to SC service performance.

The Role of Supply Chain Risk Management Integration as an Enabler of SC Performance

Counterfeiting within the supply chain brings with it higher levels of uncertainty and manifests itself in decreased service levels and increased costs to a firm experiencing it. From a contingency perspective, managers respond to uncertainty through improved risk management integration (Drazin and Van de Ven, 1985). Greater consistency enables supply chain benefits with lower costs and increased service levels (Li et al., 2005). Therefore, improved supply chain risk management integration is expected to lead to increased service and cost benefits. To this point, the following hypotheses are proposed.

H2a. Supply chain risk management integration positively contributes to firm supply chain cost performance.

H2b. Supply chain risk management integration positively contributes to firm supply chain service performance.

Service and Cost Performance as an Enabler of Overall Firm Performance

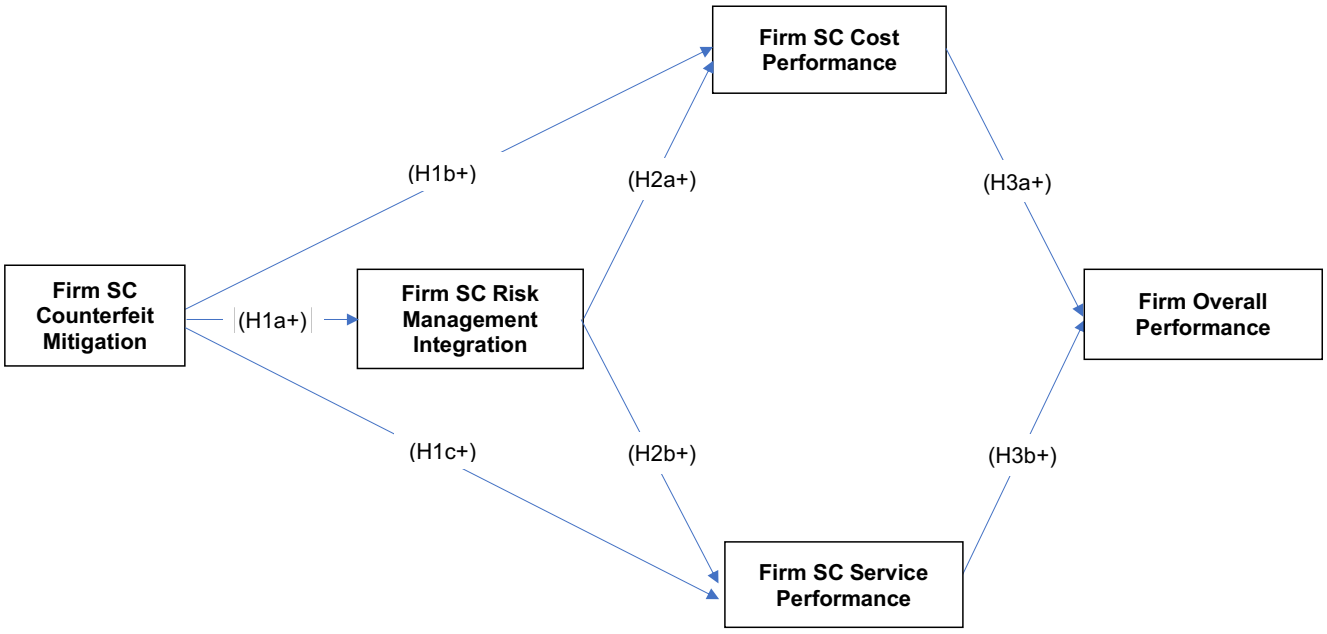
There are numerous studies that link supplier integration and improvements in supply chain cost and service to greater overall firm performance (Chapman and Carter, 1990; Akinc, 1993; Agrawal and Nahmias, 1997; Frohlich and Westbrook, 2002). Therefore, it is logical to posit that as a firm improves supply chain service and/or improves supply chain cost, overall firm performance would improve. From this the following hypotheses are developed.

H3a. Supply chain cost performance positively contributes to overall firm performance.

H3b. Supply chain service performance positively contributes to overall firm performance.

Figure 1 displays the proposed theoretical model. Size of organization (yearly revenues) is included in the model as a control variable.

Figure 1. Proposed theoretical model



METHODOLOGY

Construct Measures and Sample

This research employed an online survey to assess multiple constructs and empirically test a set of hypotheses. All measures were developed using items established in prior studies (Refer to Table II). Specifically, our counterfeiting mitigation measure was adapted from work by Ambulkar et al. (2015) on firm resilience and supply chain disruption. Our measure of risk management integration was developed based on prior work in the area of risk management maturity (Florio 2017). Both measures were completed using a seven-point Likert scale (1 strongly disagree to 7 strongly agree). In order to effectively assess three distinct areas of performance pertinent to our study, a series of previously validated items were used to measure firm SC cost performance, firm SC service performance, and overall firm performance (Chopra and Meindl, 2016; Claassen et al. 2008). All three of the performance measures were considered in relation to the firm's competitors and used a seven-point Likert scale (1 much worse - to 7 much better than competitors).

In an effort to further strengthen our survey instrument, a two-step process was followed to ensure content and face validity of the items and constructs being assessed (Dillman, 2000). In step one, the survey was sent to SC practitioners and experts for item review and feedback. In step two, we completed a pilot study to better assess the survey empirically. Both qualitative feedback and empirical data were collected during this process leading to minimal changes to the final survey.

Next, the survey was sent by email to a list of contacts provided by the Institute for Supply Management (ISM), the Council for Supply Chain Management Professionals (CSCMP), and the Association for Healthcare Resource and Materials Management (AHRMM). In all, the survey was sent to 1,741 SC professionals representing diverse organizations across multiple industries. This effort resulted in 140 completed questionnaires representing a response rate of 8%. Respondents included top-level managers (31.4%), mid-level managers (54.3%), and entry-level managers (12.1%). Participants' organizations were divided across two categories: manufacturing (36.4%) and services (62.9%). Finally, annual revenue was used as an indicator of organization size with small organizations having revenue less than $10 million (13.6%), mid-size organizations with revenue between $10 million and $1 billion (39.3%), and large organizations generating revenue in excess of $1 billion (40.7%). See Table I for a detailed breakdown of the survey participant demographics.

Table I. Survey Demographics

Respondent Job Title	**No.**
Top level manager	44
Mid-level manager	76
Entry level manager	17
Other	3
Total	**140**
Organization's Economic Sector	**No.**
Manufacturing	51
Services	88
n/a	1
Total	**140**
Organization's Yearly Revenue	**No.**
Less than 10 million	19
10 million to 1 billion	55
More than 1 billion	57
n/a	9
Total	**140**

Data Analysis

Descriptive statistics for all constructs and survey items are presented in Table II. Early versus late respondents were compared to evaluate non-response bias (Armstrong and Overton, 1977). The first and last quartiles of survey responses were tested for differences in construct means. The resulting p-values were 0.796 for the CM construct, 0.473 for RMI, 0.141 for CB, 0.177 for SP and 0.524 for the FP construct. The test results indicated that there were no significant differences between the mean construct responses obtained from the two groups across all five constructs, suggesting that non-response bias was not a threat to the integrity of the data.

Table II. Survey Scale Items Descriptive Statistics

Item/*Construct*		Mean	Std. Dev.
Supply Chain Counterfeit Mitigation (CM)		***4.285***	***1.718***
CM1.	We work to identify counterfeiting relationships with suppliers and/or customers.	4.471	2.051
CM2.	We have a person or team dedicated to identifying counterfeits in the supply chain.	3.942	2.224
CM3.	We have developed metrics to assess the risk of counterfeiting in the supply chain.	3.614	1.846
CM4.	After an occurrence of counterfeiting has been detected, it is analyzed thoroughly.	5.179	1.683
CM5.	We have an established counterfeit management process to follow in the event counterfeiting is detected.	4.207	2.082
Supply Chain Risk Management Integration (RMI)		***4.961***	***1.320***
RMI1.	We involve our suppliers in identification and mitigation of potential SC risks.	5.407	1.492
RMI2.	We encourage our suppliers to use a structured risk management process (e.g., ISO 31000).	4.252	1.776
RMI3.	We work with our customers to identify and mitigate potential SC risks.	5.216	1.586
Firm Supply Chain Cost Performance (CP)		***4.737***	***1.120***
	Compared to our major competitors:		
CP1.	Our total inventory cost is lower.	4.650	1.357
CP2.	Our stock-out cost is lower.	4.700	1.274
CP3.	Our emergency actions costs are lower.	4.836	1.228
CP4.	Our returns are lower.	4.743	1.238
CP5.	Our cash-to-cash cycle is shorter.	4.757	1.287
Firm Supply Chain Service Performance (SP)		***5.216***	***1.066***
	Compared to our major competitors:		
SP1.	Our information system is more responsive to our SC needs.	4.885	1.320
SP2.	Our financial transactions with SC partners run more smoothly.	5.007	1.168
SP3.	We have superior service flexibility.	5.400	1.314
SP4.	We are able to better meet our service-level agreements.	5.550	1.244
SP5.	Our SC is more visible.	5.245	1.362
Firm Overall Performance (FP)		***5.402***	***0.958***
	Compared to our major competitors:		
FP1.	Our profit margin is better.	5.080	1.192
FP2.	Our return on investment (ROI) is better.	5.080	1.273
FP3.	Our customer satisfaction is higher.	5.640	1.053
FP4.	Our quality is better.	5.790	1.182

Harman's single factor test was used to assess the potential for common method bias (CMB) (Podsakoff et al., 2003). A factor analysis was performed using all the different survey items included in the study to determine if most of the variance in the model was accounted for by one general factor. Since the percentage of variance explained by a single factor was less than 50 percent (the maximum percentage of variability explained by a single factor was equal to 43%), CMB was not deemed an issue.

The internal consistency, convergent validity and discriminant validity of the constructs as well as the reliability of the individual indicators were analyzed in order to assess the theoretical model. First, outer loadings were examined to evaluate the reliability of the survey items. Table III displays the outer loadings of the different items. The results of this portion of the analysis indicated an acceptable level of reliability for the different survey items since all indicators had loadings above the suggested cutoff of 0.70 (Hair et al., 2016).

Table III. Outer Loadings

Item	Outer Loading	*p*
CM1	0.871	< 0.001
CM2	0.875	< 0.001
CM3	0.876	< 0.001
CM4	0.786	< 0.001
CM5	0.902	< 0.001
RMI1	0.857	< 0.001
RMI2	0.737	< 0.001
RMI3	0.830	< 0.001
CP1	0.887	< 0.001
CP2	0.921	< 0.001
CP3	0.844	< 0.001
CP4	0.828	< 0.001
CP5	0.884	< 0.001
SP1	0.834	< 0.001
SP2	0.786	< 0.001
SP3	0.834	< 0.001
SP4	0.821	< 0.001
SP5	0.867	< 0.001
FP1	0.805	< 0.001
FP2	0.865	< 0.001
FP3	0.778	< 0.001
FP4	0.800	< 0.001

Cronbach's α, reliability coefficient ρ_A and composite reliability estimates were used to evaluate the internal consistency of the research constructs (Dijkstra and Henseler, 2015). All the different estimates were above the 0.70 cut-off recommended by Hair et al. (2016) (Refer to Table IV), suggesting adequate internal consistency across all five constructs. Convergent

validity was established using Average Variance Extracted (AVE) estimates. As shown in Table V, the AVE values were above the 0.50 cut-off recommended by Hair et al. (2016). The results indicate that all model constructs explained over half of the variance of their indicators, suggesting adequate convergent validity for the five research constructs.

Table IV. Construct reliability and validity

Construct	Cronbach's α	ρ_A	Composite Reliability	Average Variance Extracted (AVE)
CM	0.914	0.915	0.936	0.745
RMI	0.740	0.762	0.850	0.655
CP	0.922	0.928	0.941	0.763
SP	0.886	0.888	0.916	0.687
FP	0.829	0.836	0.886	0.661

Cross-loadings, the Fornell-Larcker criterion, and heterotrait-monotrait (HTMT) ratio of correlations approach were used to evaluate the discriminant validity of the model constructs. Cross-loadings were examined first. The loadings of some of the indicators on the different constructs were consistently high. For example, all the RMI1 and RM3 cross-loadings were greater than or equal to 0.40. Similarly, CP2, SP5 and FP2 had loadings at or above 0.60 on the three performance related constructs, confirming the fairly strong correlations among those constructs. While a few cross-loadings were relatively high, the loading on the hypothesized model construct was higher than the loadings on the remaining constructs for each individual indicator (Refer to Table V). Cross-loadings thus provide initial evidence for the constructs' discriminant validity (Hair et al., 2016).

Table V. Discriminant validity: Cross-loadings

	Construct				
Item	**CM**	**RMI**	**CP**	**SP**	**FP**
CM1	**0.871**	0.445	0.286	0.284	0.234
CM2	**0.875**	0.467	0.211	0.236	0.222
CM3	**0.876**	0.493	0.264	0.243	0.262
CM4	**0.786**	0.442	0.285	0.279	0.248
CM5	**0.902**	0.442	0.152	0.171	0.218
RMI1	0.430	**0.857**	0.465	0.437	0.504
RMI2	0.360	**0.737**	0.273	0.305	0.362
RMI3	0.490	**0.830**	0.433	0.432	0.509
CP1	0.224	0.453	**0.887**	0.608	0.592
CP2	0.317	0.463	**0.921**	0.688	0.637
CP3	0.152	0.332	**0.844**	0.597	0.513
CP4	0.255	0.422	**0.828**	0.619	0.546
CP5	0.269	0.471	**0.884**	0.630	0.573
SP1	0.350	0.488	0.573	**0.834**	0.621
SP2	0.083	0.402	0.570	**0.786**	0.617
SP3	0.210	0.368	0.621	**0.834**	0.569
SP4	0.207	0.327	0.572	**0.821**	0.573
SP5	0.315	0.433	0.649	**0.867**	0.605
FP1	0.270	0.453	0.656	0.537	**0.805**
FP2	0.219	0.497	0.668	0.613	**0.865**
FP3	0.186	0.444	0.376	0.600	**0.778**
FP4	0.220	0.475	0.398	0.604	**0.800**

Note: Primary loadings for each indicator are shown in bold.

To further analyze whether the constructs met the conditions for discriminant validity, the Fornell-Larcker method was used next (Fornell and Larcker, 1981). The square roots of the AVEs for each of the five model constructs was higher than the correlations of the construct with the other latent variables included in the theoretical model (Refer to Table VI), further suggesting that all constructs are valid measures of unique concepts.

Table VI. Discriminant validity: Fornell-Larcker criterion

Construct	**CM**	**RMI**	**CP**	**SP**	**FP**
CM	0.863				
RMI	0.532	0.810			
CP	0.283	0.494	0.873		
SP	0.285	0.491	0.720	0.829	
FP	0.276	0.575	0.658	0.722	0.813

Note: Square root of the AVE on diagonal in bold.

Finally, the HTMT ratio of correlations method was used to determine whether the HTMT values were lower than the suggested threshold of 0.85 (Henseler et al., 2015). As displayed in Table VII, for each combination of constructs none of the HTMT estimates were above 0.85, suggesting adequate discriminant validity across constructs (Henseler et al., 2015).

Table VII. Discriminant validity: Heterotrait-Monotrait (HTMT) criterion

Construct	CM	RMI	CP	SP
CM				
RMI	0.638			
CP	0.298	0.578		
SP	0.308	0.591	0.796	
FP	0.315	0.721	0.735	0.843

The model was also checked for collinearity problems. Variance Inflation Factor (VIF) values were calculated for all combinations of exogenous (or predictor) constructs (represented by the rows in Table VIII) and endogenous constructs (represented by the columns in Table VIII). Collinearity was not deemed an issue since all the resulting VIF estimates were below the threshold of five recommended by Hair et al. (2016).

Table VIII. Variance Inflation Factor (VIF) values

Construct	RMI	CP	SP	CM
CM	1.000	1.396	1.396	
RMI		1.396	1.396	
CP				2.081
SP				2.084

RESULTS

Hypotheses Testing

Next, the proposed structural equation model was tested. A summary of the test results is presented in Table IX. The research hypotheses were simultaneously tested in SmartPLS (Ringle et al., 2015). A bootstrap resampling method with 5,000 resamples was used to assess the level of significance of the standardized path coefficients estimated. Organization size, which was included as control variable in the model, was not significant at the 0.05 level (p-value of 0.223).

Table IX. Summary of hypotheses testing

Path		St. Weight	p	Conclusion
H1a:	CM → RMI	0.532	< 0.001	Supported
H1b:	CM → CP	0.027	0.778	Not Supported
H1c:	CM → SP	0.033	0.711	Not Supported
H2a:	RMI → CP	0.480	< 0.001	Supported
H2b:	RMI → SP	0.474	< 0.001	Supported
H3a:	CP → FP	0.282	0.002	Supported
H3b:	SP → FP	0.521	< 0.001	Supported

SC counterfeit mitigation was found to have a significant direct positive effect on SC risk management integration. The findings therefore provide support for H1a at the 0.001 level of significance. On the other hand, SC counterfeit mitigation was found to have an insignificant direct positive effect on both SC cost performance and SC service performance. Thus, H1b and H1c are not supported.

SC risk management integration was found to have a significant positive effect on both SC cost performance and SC service performance. The findings thus provide support for both H2a and H2b at the 0.001 level of significance.

With respect to firm overall performance, both SC cost performance and SC service performance were found to have a significant positive effect. H3a is therefore supported at the 0.01 level of significance, while H3b is supported at the 0.001 level of significance.

Mediation Analyses

The role of SC risk management integration in the link between SC counterfeit mitigation and SC performance was examined in more detail, based on the results of hypothesis H1b and H1c. Table X displays the results of the mediation analysis.

Table X. Summary of mediation analysis

Effect	Direct	Indirect	Total	VAF	Conclusion
CM → CP	0.027	0.256***	0.283**	90.46%	Full Mediation
CM → SP	0.033	0.252***	0.285**	88.42%	Full Mediation

Notes: ** p < 0.01, *** p < 0.001, VAF: Variance Accounted For

The mediation analysis results suggest that SC risk management integration fully mediates the relationship between SC counterfeit mitigation and SC performance. Variance Accounted For (VAF) values of 90% and 88% indicate that SC risk management integration explains most of the effect of SC counterfeit mitigation on both SC cost performance and SC service performance and, ultimately, on firm overall performance. The study findings therefore confirm the critical mediating role of SC risk management integration.

DISCUSSION, LIMITATIONS, AND FUTURE RESEARCH

Counterfeiting continues to be a complex issue facing supply chain managers tasked with preventing inferior products from impacting their organizations and reaching downstream channel partners and end users. A review of the literature reveals that counterfeiting is viewed as a significant risk that can impact the SC in different ways. For example, the proliferation of counterfeiting has the potential to disrupt the SC's of suppliers, manufacturers, and other stakeholders. Additionally, the occurrence of counterfeiting disruptions can have a substantial negative impact on SC cost, profitability and the ability to meet service expectations (Zhang and Zhang, 2015; Jeong, et al., 2012). As a result, the SC represents an important point of focus for counterfeit research and understanding how firms can mitigate this risk. Even still, empirical research on mitigating counterfeiting effects in the SC is quite limited. The current research aims to address this shortcoming in the literature.

Our study considers the role of risk management practices within counterfeit mitigation efforts and the subsequent impact on critical areas of SC performance. Specifically, a structural equation model that examines the relationships among SC counterfeit mitigation (CM), SC risk management integration (RMI), SC service performance, SC cost performance and overall firm performance was developed and empirically tested. Our findings indicate a higher level of CM is associated with greater RMI. Further, RMI appears to fully mediate the relationship between CM efforts and SC cost and service performance.

Our research makes the following contributions. First, interest in standards that incorporate risk-based thinking (such as ISO 9001:2015) is increasing as the importance of global supply chains grows. Therefore, this research contributes to the literature by exploring the value of risk management practices in mitigating supply chain risk in general and counterfeit risk in particular. Second, the literature has recently seen an increase in interest among scholars toward understanding the impact of risk and how to mitigate risk in the SC (Ho et al., 2015). Our study considers counterfeit mitigation efforts in relation to risk and therefore contributes to the extant literature on risk management in the SC.

Our study has a number of limitations to be addressed in future research. First, our survey data called for the subjective perceptions of managers in relation to RMI, CM, and the three performance measures. Although we used an approach well established in prior studies, future research should consider more objective measures such as cost, secondary data from customer satisfaction surveys, and other relevant firm metrics. Second, our study assesses a dynamic process at a single point in time. A more complete understanding of the relationships among the constructs may be accomplished using a longitudinal approach. Finally, research on counterfeit mitigation in the SC literature is largely underdeveloped. While our study makes an effort to illuminate this issue, future research should consider cost, service and firm performance in relation to the prevalence of counterfeiting at the industry- and firm-level. For example, would a firm with more counterfeit exposure at the industry-level have an increased focus on RMI? Would an organization with more experience dealing with counterfeiting at the firm-level have more extensive mitigation efforts in place and how might this impact cost and service performance? We call on scholars to explore these issues and many others in the emerging research stream of counterfeiting in the SC.

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The Relationships between Economic Orientation, Sustainable Product Design and Innovative Performance: An Empirical Evidence from US Manufacturing Firms

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ABSTRACT

The goal of a firm is to make money. For this reason, firms show economic orientation in pursuit of long-term financial benefits and operational effectiveness. Recently than ever, manufacturing organizations are inclined towards designing and producing products using sustainable means. The purpose is to bring new products to the market that are environmentally sustainable and socially responsible. To study how economic priorities affect sustainability initiatives in new product development and innovations outcomes, this research presents a model with relationship between organization's economic orientation, sustainable product design activities and innovations performance of the firm. The empirical evidence is drawn from a panel survey of 282 US manufacturing firms. The results suggest strong relationships among the three constructs under investigation.

KEYWORDS: Sustainability, Economic orientation, Sustainable product design, Innovations performance, Theory of constraints, Theory of firm

DECISION SCIENCES INSTITUTE
The Role of Business Analytics on Organizational Resilience

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ABSTRACT

Aiming to investigate the role of Analytical Capabilities on Organizational Resilience this paper reports the results of a survey developed in companies located in the state of Espirito Santo/Brazil. Data analysis used structural equation modeling. The results show that the analytical capabilities positively influence organizational resilience.

KEYWORDS: Business Analytics, Analytical Capabilities, Resilience, Performance.

INTRODUCTION

Over the last three decades, the business environment has undergone radical changes driven by a series of breakthroughs and innovations that have also brought a variety of strategic and operational challenges to modern organizations in both public and private sectors (Doumpos & Zopounidis, 2016). One of the most fundamental challenges involves the design of resilient processes and the improvement of procedures for the planning and decision, which can provide a superior competitive advantage by improving operational efficiency, promote innovation and create added value for all parties. In this context, business analytics emerges as a powerful alternative to intelligibly reprogram organizational strategies and support the decision-making process based on facts and data (Doumpos & Zopounidis, 2016; Seddon, Constantinidis, Tamm, & Dod, 2016; Vidgen, Shaw, & Grant, 2017), especially in situations related to ruptures and vulnerabilities in the supply chain.

With the proliferation of Internet of Things (IoT) and IT systems like Enterprise Resource Planning (ERP), more and more data is generated, captured and stored. In this context, the survival and growth of many organizations nowadays are linked to their capabilities to effectively utilize large amount of data from different sources to drive their strategic and operational decisions. Thus, data analysis is becoming a critical factor of success (Barbosa, Vicente, Ladeira, & Oliveira, 2017).

Benefits of business analytics adoption are increasingly evident and robust. Business Analytics (BA) is a comprehensive term that comes from the industry. BA refers to the application of a wide range of data-driven analytical techniques and methods in different business domains (Chae, Yang, Olson, & Sheu, 2014). It is a relatively new term whose focus is on improving organizations' performance through a decision-making process based on fact and data (Appelbaum, Kogan, Vasarhelyi, & Yan, 2017; Bayrak, 2015; Bronzo et al., 2013; Cosic, Shanks, & Maynard, 2015; T. H. Davenport & Harris, 2007b; Holsapple, Lee-Post, & Pakath, 2014; Mortenson, Doherty, & Robinson, 2015; Seddon et al., 2016; Vidgen et al., 2017).

Organizations such as the Boston Red Sox, Netflix, Amazon.com, CEMEX, Capital One, Harrah's Entertainment, Procter & Gamble, Best Buy, amongst others, use business analytics to build their competitive strategies, guide their decision-making, and beat the competition. By applying their analytical capabilities to the data, these organizations identify the most profitable customers, accelerate product innovation, optimize supply chains, and manage to work with more competitive prices (Davenport & Harris, 2007).

This work explores the organizational analytical capabilities, identified as one of the five formative dimensions of BA (analytical capabilities, information quality, analytical technology, leadership commitment and analytical strategy) (T. Davenport, Cohen, & Jacobson, 2005). Such choice is justified by the fact that organizations continually need to make high quality decisions, quickly and clearly due to the dynamics involved in their operations. It is observed that it becomes easier for those who develop a set of capabilities to collect, aggregate, synthesize and analyze large volumes of data to support the decision-making process (Strategy & Leadership, 2009). Moreover, it is understood that analytical capabilities, once present in the organizational structure, can impact and interact with different resources and capabilities (J. B. Barney & Clark, 2007) and, consequently, influence organizational performance.

Thus, considering the interaction of such capabilities with the different resources and variables, it becomes relevant to analyze how organizational analytical capabilities relates to performance results in terms of resilience. The organizational resilience (Fiksel, Polyviou, Croxton, & Pettit, 2015; Pettit, Croxton, & Fiksel, 2013; Pettit, Fiksel, & Croxton, 2010) has currently received attention and emphasis from companies due to the continuous increase of vulnerabilities of its supply chains (Ambulkar, Blackhurst, & Grawe, 2015). In addition, the World Economic Forum indicated that more than 80% of the companies are now concerned with the development of supply chain resilience (Bhatia, Lane, & Wain, 2013) due to their harmful effects on operations.

Therefore, considering that organizational analytical capabilities are in a position to positively influence performance results, it is understood that they are hypothetically related to organizational resilience. It is based on such argument that this research effort will be directed to answer the following research question: *What is the impact of organizational analytical capabilities on organizational resilience?*

The article is structured in five main sections. After this introduction, it is presented in section two the definition and the theoretical relations between constructs, the research hypothesis and the proposed conceptual model. In section three, the methodological path is presented. In the fourth section the results are pointed out and the discussion developed in light of the researched theory. And in the fifth and last section, it summarizes the findings and final considerations of

the study along with the research limitations, proposing questions that may guide future research endeavors.

THEORETICAL BASIS, CONCEPTUAL MODEL AND RESEARCH HYPOTHESIS

Organizational Analytical Capabilities

Davenport, Cohen and Jacobson (2005) emphasize that analytical capabilities is one of the formative dimensions of BA in the organizational context, pointing out that although analytical software becomes increasingly popular and easy to use, companies that are beginning to become analytical oriented or are already competing on analytics still require substantial analytical capabilities from its members.

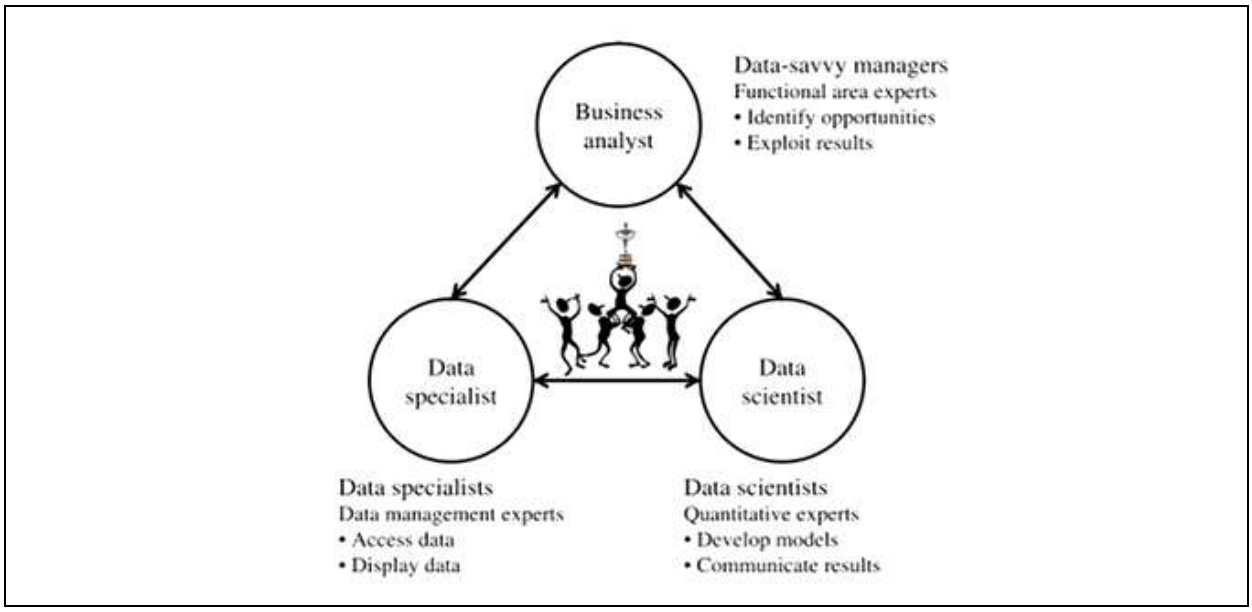
Analytical capabilities, according to Acito and Khatri (2014), refers to the use of a portfolio of analytical methods and tools, including those that support traditional ad hoc queries, inferential statistics, predictive analysis, simulation and optimization, aiming to support inquisitive, descriptive, predictive and prescriptive analysis at the managerial level, supporting the decision-making process (Acito & Khatri, 2014).

Delen and Demirkan (2013) brought another connotation for the respective dimension by considering the abilities to understand the needs of the business, to deal with large data – big data – usually complex and unstructured, and provide meaning to support the decision-making process.

Corroborating with the ideas of Delen and Demirkan (2013) and Acito and Khatri (2014), Holsapple, Lee-Post and Pakath (2014) argue that the key set of analytical capabilities is based on the combination of skills to manage evidence (facts/data) through models and logical and systemic reasoning. In this portfolio of competences lies the respective abilities: the use of quantitative and qualitative techniques and their combinations; the use of statistical techniques; systematic use of reasoning; management models of descriptive, explanatory, and predictive nature; and effective work based on evidence (eg, reports, databases, click- streams, documents, sensors, maps, etc.) (Holsapple et al., 2014).

Therefore, based on explained above and the definitions and a set of works on the subject (Acito & Khatri, 2014; Bayrak, 2015; Bronzo et al., 2013; Delen & Demirkan, 2013; Doumpos & Zopounidis, 2016; Gorman & Klimberg, 2014; Holsapple et al., 2014; Mortenson et al., 2015; Oliveira, McCormack, & Trkman, 2012; Sincorá, Carneiro, & Oliveira, 2015; Trkman, McCormack, Oliveira, & Ladeira, 2010; Troilo, Bouchet, Urban, & Sutton, 2015; Wagner, Brandt, & Neumann, 2016; Wilder & Ozgur, 2015), the conceptual and operational domain of the Organizational Analytical Capabilities construct is based on the synergistic inter-relationship amongst: i) Statistical Capabilities (referring to the ability to develop logical, critical and analytical reasoning about organizational reality from quantitative data); ii) Business Capabilities (inherent in the ability to identify problems, formulate and implement solutions, conduct decision making from facts and data, develop expression and communication compatible with the business environment); and iii) Capabilities in Information Technology (related to the competence to operate machines, information systems, and work with computational modeling), as represented in Figure 1.

Figure 1: Synergistic flow between the skills of the multidisciplinary teams of an organization oriented by data analysis



Source: Adapted from Wilder and Ozgur (2015).

Organizational Resilience

In today's turbulent and uncertain environment, every organization in a supply chain is susceptible to disruption (Ambulkar et al., 2015; Ponomarov & Holcomb, 2009). The global reach of supply chains, products with shorter life cycles, and increasing customer requirements have made organizations aware that disruptions can cause undesirable operational and financial impact. In this way, disruptions such as the loss of a critical supplier, a major factory fire, or even an act of terrorism, have the potential to negatively affect revenue and cost. However, even if researchers and practitioners fully agree about its importance, what it is observed is that a vast majority of the companies still give limited attention to manage potential risks and do not have the capabilities to deal with them (Trkman, Oliveira, & McCormack, 2016), acting predominantly more reactive than proactive (Bhatia et al., 2013).

Based on this scenario, companies are now focusing on performance improvement and on the capacity to respond to the contingencies and risks, developing resilience in order to mitigate the effects of ruptures in their operations as they may result in negative consequences for the organization and for the whole supply chain (Ambulkar et al., 2015). Several researchers point out that resilient firms are less vulnerable to risk situations and are more able to deal with supply chain disruptions when they occur in more resilient processes (Blackhurst, Dunn, & Craighead, 2011; Fiksel et al., 2015; Pettit et al., 2013; Ponomarov & Holcomb, 2009; Rice & Caniato, 2003; Sheffi, 2005; Sutcliffe & Vogus, 2003; Weick, Sutcliffe, & Obstfeld, 1999; Wieland & Wallenburg, 2013; Wildavsky, 1988; Zsidisin & Wagner, 2010).

Although the theory about resilience is still in full development and discussion (Ponomarov & Holcomb, 2009; Wieland & Wallenburg, 2013), it was adopted an operational definition for the theme, as well as a set of key elements capable of characterize it in order to enable its measurement. Thus, based on Pettit, Croxton and Fiksel (2013, 2010), the conceptual domain built to delimit the Organizational Resilience construct consisted in the ability to survive, adapt and grow in the face of turbulent change. In other words, operationally, it refers to the abilities to discern and prepare for unexpected events (Anticipation), to respond to disturbances by

modifying processes and operations (Adaptability), and to recover from them, returning to the normal operating state (Recovery), maintaining control over the structure and functions and the continuity of operational processes at the desired level. This is, therefore, the essence of resilience, whether it is analyzed from the perspective of the supply chain or the organizational scope.

Theoretical Relationship Between Organizational Analytic Capabilities And Organizational Resilience

The company's resource-based view (RBV) provides an important basis for understanding how competitive advantage is created and sustained over time, given that firms gain competitive advantage through the accumulation of internal resources and capabilities that are rare, valuable, and difficult to imitate (Barney, 1991). These capabilities consist of attributes, skills, organizational processes, knowledge, and capabilities that enable an organization to achieve superior performance and sustainable competitive advantage over its competitors (Teece, Pisano, & Shuen, 1997).

In formulating the perspective of dynamic capabilities, Teece et al. (1997) argue that the capabilities of an organization can be renewed and developed to achieve congruence with the changing environment, making it possible to adapt, integrate, and reconfigure resources, organizational capacities, and functional competencies to respond to the challenges of the external environment. These dynamic capabilities, when approached in contexts of reaction to unforeseen situations, become important bases for the achievement of good Organizational Resilience performance results since they enable organizations to respond to the challenges imposed by the environment through the reconfiguration of their organizational resources.

Thus, when considering that the data and information generated by the organization also constitute resources (Chae et al., 2014; Cosic et al., 2015), it is assumed that when they are reconfigured based on the application of analytical capabilities, particularly to help the organization to cope with turbulence and uncertainty, such resources become rare, valuable, and difficult to imitate. Thus, the cross-referencing of data and information enabled by Organizational Analytical Capabilities allows the production of knowledge and insights to aid decision-making, envision future scenarios, capture opportunities, and identify problems and other possibilities that help the organization perform satisfactory resource reconfigurations to better respond to environmental challenges and therefore collaborate for better resilience outcomes.

Some of the crucial aspects of resilience are anticipation, adaptability, and recovery (Pettit et al., 2013, 2010), and it is interesting that these dimensions go together. According to Wieland and Wallenburg (2013), resilience can be improved by investing in the routine of sharing knowledge about relevant changes in the environment, in advance or when they occur. In this manner, to anticipate, it is necessary to acquire knowledge about possible changes that may occur in the future (Zsidisin & Wagner, 2010). To adapt to changes, which may or may not be predicted, it is necessary to reconfigure organizational resources, and to enable such reconfiguration, it is pertinent to control and evaluate the results of the implemented actions.

Therefore, the development of skills in anticipation, adaptability, and recovery can be positively supported in organizations that maintain an approach to use and share their data and information among different working groups that can be further used in the most diverse applications and business needs.

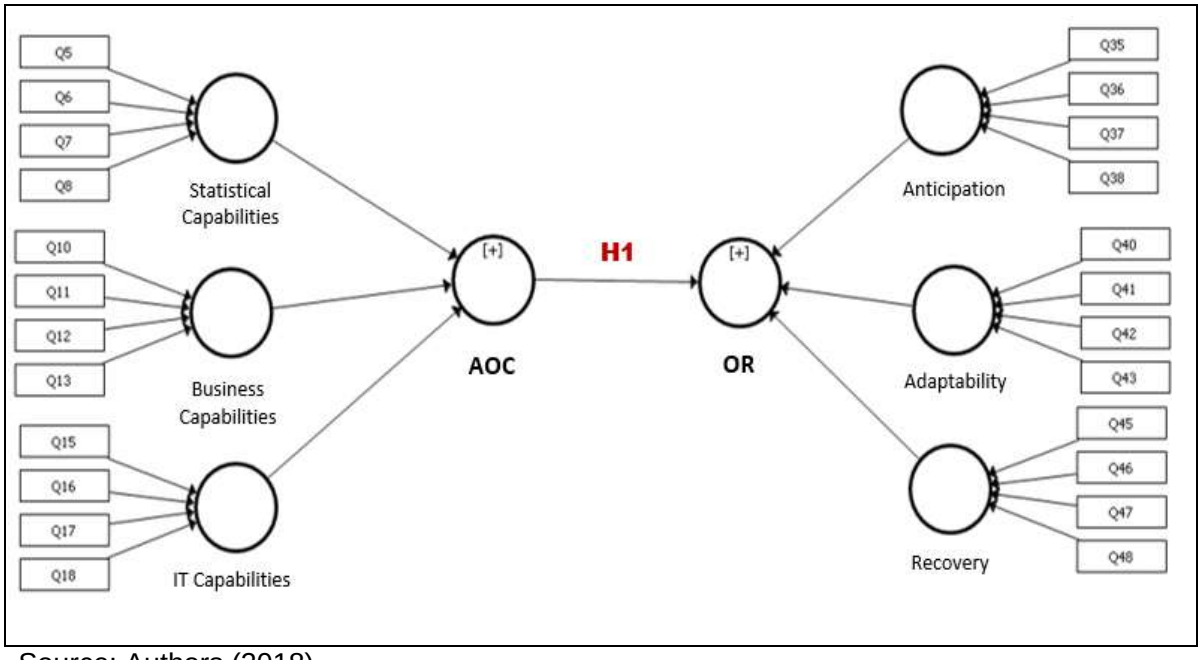
Finally, following these considerations, it is assumed that when Organizational Analytical Capabilities (composed of statistical capabilities, business capabilities, and information

technology capabilities) act in an integrated and coordinated manner, they can have a significant impact on Organizational Resilience. It is therefore argued that the better the integration between Organizational Analytical Capabilities, the greater the possibility of positively influence Organizational Resilience. This assumption results in the central hypothesis of the study: **H1:** Organizational Analytical Capabilities positively impacts Organizational Resilience.

Presentation of the Conceptual Model

The hypothetical model of this study contemplates constructs related to the conceptual domains of Organizational Analytical Capabilities (OAC) and Organizational Resilience (OR). As shown in Figure 2, the conceptual model of this study presents OAC as predictor of OR (the operationalization of each of the constructs of the model is presented in detailed fashion at the Appendix).

Figure 2 - Conceptual Model and related questions



Source: Authors (2018).

METHODOLOGY

Design of the Survey, Source and Data Collection

This research was conducted based on a survey questionnaire. The questions were based on the literature, which served as a theoretical basis for the formulation of 34 measures - 4 related to the profile of the respondent/company and 30 related to the constructs studied -, the questionnaire used the Likert scale from 1 (one) to 5 (five) points.
In order to operationalize the OAC scales, we undertook a bibliometric study in seven databases of the area of Social Sciences (Ebsco, Emerald, Jstor, Sage, Scielo, Science Direct and Web of Science) to identify a set of manifest variables - with a higher incidence in the literature - that could measure the construct studied. The articles were collected searching for the term "business analytics" in the title, abstract and keywords that were published between 2004- 2015. For the measurement of the OR construct, it was adapted from the scale developed by Pettit et al. (2013), titled Supply Chain Resilience Assessment and Management (SCRAM), validated with data from seven global organizations from the industry and services sector.
After structuring the questionnaire, the 34 questions were validated by a group of experts (PhDs and managers) experienced in the conduction and application of surveys. These professionals contributed to the objectivity, clarity and coherence of the instrument, eliminating redundancies, ambiguities and content overlaps.
The data used in the survey was collected from online questionnaires applied to managers of companies associated to FINDES (Federation of Industries of the State of Espírito Santo) and CRA-ES (Regional Council of Administration of the State of Espírito Santo). The managers selected to participate in the survey were those who held positions related to production, logistics, marketing, sales, quality, purchasing and product development. It is worth mentioning that in order to guarantee the participation of key informants, contacts were made via telephone before sending of survey link to the email address informed by the respondent.
Espírito Santo is one of the states located in the Southeast region of Brazil. The state's economy is essentially based on traditional activities such as construction, extraction and processing of marble and granite, coffee agriculture, the garment industry, and tourism. In addition, the state has a solid position in the steel, furniture, mining, pulp, and fruit growing sectors, also emerging in new economic sectors such as oil and gas production and agro-tourism (Ferrari & Arthmar, 2011).
However, with the worsening of the current economic crisis in the country, the state has been forced to rethink alternatives for the readjustment of its development model. The changes imposed by the current political and economic situation generated turbulence and marked the trajectory of the sectors of industry, commerce, and service of Espírito Santo, compelling these sectors to incorporate into their operations and strategies technological and managerial innovations that are able to cope with the modifications that have been occurring in the internal and external markets.
This context provides the study with information about how the use of data and information by companies in Espírito Santo has been impacted their performances, based on the evaluation of their OAC and their supposed impact on the organizational resilience. Therefore, through the data collected in this scenario, it becomes possible to identify viable paths to generate a competitive advantage sustained through informational resources and the application of analytical capabilities.
Having that said, the criteria used to calculate the sample were recommended by Hair, Hult, Ringle and Sarstedt (2017) for the use of Structural Equation Modeling (SEM), based on the partial least squares (PLS) algorithm, which consisted of the following conditions:

a) The value of the sample should be 10 times ≥ the number of indicators of the construct that has the highest number of formative indicators of the measurement model; or

b) The sample value should be 10 times ≥ the number of the greatest number of paths directed to a particular construct of the structural model.

Therefore, based on the respective criteria, a minimum sample size of 50 respondents was identified. However, 83 questionnaires answered were collected from FINDES respondents, and the remaining 211 respondents were collected from CRA-ES. After performing a preliminary analysis to identify equivalence issues and avoid sample problems with the data collected, the final sample consisted of 288 valid cases.

Data Processing

According to Knoppern et al. (2015), interviewee data from heterogeneous groups should not be grouped and/or compared without first examining whether they are equivalent, since ignoring questions of equivalence can lead to ambiguous and erroneous conclusions.
In order to check the equivalence between those two groups (FINDES and CRA-ES), a multi-group analysis was performed (Ringle, Wende, & Becker, 2014). The equivalence test consisted of three steps: the tests of configural equivalence, metric and scalar. The configural equivalence was verified with all loads of the indicators demonstrating significant to the same factors between the groups. Similarly, the metric equivalence test showed no statistical difference between the factor loads of each group, with all p-values of the confidence interval between 0.025 to 0.975 (Sarstedt, Henseler, & Ringle, 2011). Finally, through the data obtained by the bootstrapping technique ran with 5,000 sub-samples (Hair, Sarstedt, Ringle, & Gudergan, 2018), the scalar equivalence test revealed that all p-values of the difference between groups are not significant at a 95% confidence level (Table 1). This result shows that there is no statistically significant difference between groups, thus indicating the possibility of grouping the data.

Table 1 – Scalar equivalence Test using PLS-MGA technique

PLS-MGA	**Path Coefficients-diff (GROUP (1.0) vs GROUP (2.0) |)**	***p*-Value (GROUP (1.0) vs GROUP (2.0))**
OAC → OR	0,002	0,503
Statistical Capabilities → OAC	0,024	0,550
Business Capabilities → OAC	0,231	0,220
IT Capabilities → AOC	0,242	0,787

Source: Authors (2018).

PRESENTATION AND DISCUSSION OF RESULTS

Results of Descriptive Statistics

The descriptive statistics for the profile of the respondent and companies that composed the sample was based basically on the frequency distribution and the graphical representation of these variables. Related to the “Position of the Respondent” in the company, half of the respondents belong to strategic positions (sum of the functions of president 4%, director 16% and manager 29%), followed by analyst 16%, assistant 13% and other positions 22%. This sample composition is beneficial for the study, since they denote greater knowledge about fundamental questions of the study and capture greater understanding of the organizational functioning due to the position they occupy, above all, positioned in areas related to operations. Regarding the variable “Business Sector”, it was possible to observe that 69% of the sample came from the service sector, followed by commercial companies (19%) and industrial (12%) respectively and more than 70% of the companies have more than 5 years age. Considering the “Size”, following the definition given by the National Bank for Economic and Social Development of Brazil (BNDES) based on annual revenues, 32% of the companies participating in the study are micro-sized, followed respectively by small companies (30%) and the minority, represented by 10%, refer to medium-large and large-sized companies.

Results of the Structural Equation Modeling

The structural equation modeling analysis technique was used to validate the proposed conceptual model, as well as verify the hypothesized relationship. Initially, based on Smart software PLS-SEM 3.0 (Ringle et al., 2014), it was possible to carry out the validation tests of the measurement model (convergent validity test, collinearity test, and significance and relevance test). Thus, after removing the indicator q6 - referring to the Statistical Capabilities -, since it presented high collinearity within the set of indicators in which it belonged, the results showed that all relations between indicators and constructs were considered valid within the quality criteria.

With the measurement models validated, we proceeded to validate the structural model of the research (the direct and indirect relations between the constructs of the model). Initially, when carrying out the multicollinearity test, which evaluates whether the constructs are highly intercorrelated, it was identified that there are no problems of this nature, which indicates a good quality measure for the general adjustment of the theoretical model, since they were adequately defined, having a robust conceptual coverage and without shadowing with other theoretical concepts.

The Significance and Relevance *t* test, with 287 degrees of freedom and 5% significance level, using data from Bootstrapping, demonstrated that the hypothesis **H1**: Organizational Analytic Capabilities positively impacts Organizational Resilience was accepted since it is statistically significant, as can be seen in Table 2.

Table 2 - Total effects

Direction of the Path of Coefficient			Path Coefficients Values	*p-value**
Statistics Capabilities	→	OAC	0,071	0,477
Business Capabilities	→	OAC	0,520	0,000
IT Capabilities	→	OAC	0,466	0,000
OAC	→	OR	0,785	0,000

* The path coefficients significance of the 1st and 2nd order constructs, at the p-value level <0.05, when submitted to the t-test with the Bootstrapping technique.

Source: Prepared by the authors based on the research data.

Also, through the t test, it is possible to emphasize that only the paths coefficient of Business Capabilities (0.520) and Capabilities in Information Technology (0.466) have been shown to maintain statistical significance in relation to OACs, thus revealing that first-order constructs are the ones that contribute the most to indirectly impact OR behavior.

This conclusion reinforces the assumptions of Wieland and Wallenburg (2013) and Zsidisin and Wagner (2010) that organizational resilience can be improved by investing in the routine of sharing knowledge about relevant changes in the business environment, in advance or when change happens. Corroborating this discussion, experts from different regions and sectors of the economy, invited by the World Economic Forum (Bhatia et al., 2013) to discuss measures to build resilience, recognized that priority number one was to improve the sharing of information among the different actors in the chain. Such line of thought stresses that the expansion of the use of data sharing platforms to identify and respond to risks can enable the visibility of information, providing early warning of problems and allowing decentralized solutions.

It is also reflected in the Information Technology Capabilities that companies are increasingly targeting constant investments in technology platforms, ERP systems and corporate management solutions. It turns out an incipient paradigm shift, that is, the technological infrastructure has not only served to store data without the effective contribution to the managerial process, but has effectively contributed to the business needs, since it has been identified among the companies researched the organizational competence to operate machines, information systems and work with computer modeling.

The results of the test also point to the importance of Business Capabilities, since their presence in the business structure indicates that the organization is able to understand its business needs, interpret the analyzes performed in large databases and provide meaning supporting the decision making and revealing opportunities that emerge in the business routine, with the potential to communicate and share them whenever they are needed (Acito & Khatri, 2014; Bayrak, 2015; Cosic et al., 2015; Cybulski, Keller, Nguyen, & Saundage, 2013; Delen & Demirkan, 2013; Gorman & Klimberg, 2014; Informs, 2014; Mcclure & Sircar, 2008; Mortenson et al., 2015; Ranyard, Fildes, & Hu, 2015; Rasmussen & Ulrich, 2015; Troilo et al., 2015; Wilder & Ozgur, 2015).

However, the explanation that the Statistical Capabilities did not show a significant antecedent to OR may be in the reality of the organizations researched. Because it does not have all the analytical capabilities that have been developed to fuel the decision-making process, most decisions are based on subjective knowledge of the business rather than on quantitative and numerical data. Possibly, the companies that composed the study are not familiar with the extraction and use of data of quantitative nature due to the lack of skills to work with descriptive, predictive and prescriptive analyzes, thus revealing the need for investments to foster the development of logical reasoning based on critical and analytical information about organization.

Despite of this results, it is important to highlight that Fahimnia et al. (2015) found that quantitative risk analysis is rapidly expanding across studies and research related to the subject, quantitative and analytical models - inherent in statistical skills - (i.e. mathematical models, optimization, simulation, analysis decision-makers and others) are being used to

manage both organizational and supply chain risks, thus strengthening the capabilities of anticipating organizations to identify potential risks and barriers.
Nevertheless, from the Variance Coefficient (R^2) evaluation, it was verified that 61.6% of the variation that occurs in the behavior of the endogenous OR construct can be explained by the variation that occurs in the OAC. Thus, it was concluded that if a manager wants to develop the analytical capabilities of her company, she should make efforts to improve its capabilities, especially in business (inherent in the ability to identify problems, formulate and implement solutions, data and facts, developing expression and communication compatible with the business environment) and in information technology (related to the ability to explore dataset, sanitize data, integrate dataset and build big data environments). In this way, OACs can act as medium- and long-term performance driver, helping companies to design and develop new capabilities, especially in terms of resilience, improving with time, skills and competitiveness standards.
In a managerial decision, for example, the relevance of this data is that the company can choose to invest on the promotion of analytical skills since it will benefit the company's performance, especially regarding its capacity to respond to its stakeholders in situations of turbulence, challenges and uncertainties, thus contributing to deliver satisfactory results to both its clients and shareholders.
It is understood that the advantages obtained by the organization from the continuous use of its data and information, which are successively generated and circulated in the organizational environment, support business operations and decision-making processes and help to leverage resilience levels achieving satisfactory and meaningful performance results.
Therefore, organizations that understand the value of analytical orientation through the development of their analytical capabilities, will better manage their business problems specially when they experience turbulence and disruptions in their operations. In this way, they will be in a better position to build and strengthen their capabilities in resilience and, therefore, to achieve superior performance results (Sheffi, 2005).
The findings are also reinforced by experts who claim that optimization requires discipline, the use of business analytics and the involvement of a broad range of business, technology, and executive work both within and outside the organization (Bhatia et al., 2013). Therefore, to mitigate the risks, vulnerabilities and ruptures, it is necessary to encourage organizations to follow agile and adaptive strategies to improve resilience (Bhatia et al., 2013; Fiksel et al., 2015). This opportunity is verified through the application of analytical practices in the business routine and in the day-to-day chain, given that the analytical approach itself allows actions to intelligibly reprogram organizational strategies and operations, facilitating the development of capabilities to compensate or mitigate vulnerabilities.

CONCLUSIONS

The research results present relevant findings, both from the practical and academic point of view, by presenting that organizational analytical capabilities act as a critical and predictive element to determine organizational resilience.
Thus, the results of the research contributed to clarify the Organizational Analytical Capabilities construct, which has emerged since the last decade as a relevant topic for the scientific community in studies related to Business Analytics. Regarding the managerial context, the effort of this research made it possible for managers to understand what analytical skills are critical to be developed and articulated by the work teams. Moreover, it demonstrated the importance of

valuing and developing capabilities under statistical analysis, given that empirical research has revealed that such capabilities allows leveraging and influencing the behavior of resilience.
In seeking answers to the central problems of the study about the impact of organizational analytical capabilities on organizational resilience, the answer obtained was that the impact for this relationship is positive, therefore, companies that have an orientation focused on the analysis of their data, will be better able to go through situations vulnerabilities. Faced with these findings, we can depict that the analytical approach, besides being able to act as a resource for other organizational variables, it is also an important strategy for the development of resilience, since it allows intelligently reprogramming business activities when potential risks, ruptures or vulnerabilities are detected.
In addition, the study also showed the need to invest not only in software and hardware, but also in the development and recruitment of qualified professionals to undertake the analysis of the vast amount of information that organizations and society today deal with. Thus, without such properly prepared individuals, of course, many economic sectors will be missing the opportunity to improve their performance and take competition in their markets based on data analysis.
Another implication of the research lies in the understanding that business analytics can generate business value from structured and highly analytical decision-making processes (Seddon et al., 2016; Sharma, Mithas, & Kankanhalli, 2014) and not only limited to the treatment and analysis of data and information (Emblemsvåg, 2005). The refinement and use of resilience capabilities can also generate benefits at the organizational and network level, especially when attention and resources are directed to the generation of value over time and not only to protect themselves from risk (Trkman et al., 2016).
In addition, research findings also have clear implications for both academics and practitioners. Over the last few years, disruptive events have significantly increased the internal and external risks of organizations (Hohenstein, Feisel, Hartmann, & Giunipero, 2015). Thus, the proposed conceptual model for measuring analytical capabilities and organizational resilience provides an excellent managerial orientation to build analytical practices and resilience in various business areas. The component elements of the constructs can be used to evaluate the level of use of the data and information by the organization, as well as to measure resilience results in order to implement actions to strengthen its own resilience and to identify the priority areas in which the should be prioritized.
Thus, measuring resilience, whether in organizations or in supply chains, reveals itself a relevant managerial need, since this attitude supports the knowledge and understanding of managing unexpected risk events, as well as helps companies to assess their ability to respond to disruptions. Therefore, measuring the resilience level of business operations influences decision makers in prioritizing the development of resilience capabilities needed (Hohenstein et al., 2015).
An example of a company that is already working on this dynamic response to possible disruptions using different mitigation tactics is Procter & Gamble, which by applying monitoring tools has increased its resilience capabilities, bringing together, updating, and using data and information regarding critical points in its supply chain (Sáenz & Revilla, 2014).
Likewise, at the supply chain level, associations are created around the world to protect themselves against possible vulnerabilities in which they are sensitive. An example is C-TPAT (Customs-Trade Partnership against Terrorism) which is a voluntary initiative that creates joint security protocols for member companies to strengthen and improve US supply chains. TradeXchange, on the other hand, is an association of Singapore that engages business partners to collaborate in logistics activities, allowing flexibility and quick collective response to

the anomalies that emerge from the supply chain. Also, associations such as the Kyohokai were formed aiming at mutual learning at Toyota Motor Company (Bhatia et al., 2013).
Regarding the limitations, because it is an essentially quantitative research, the study presented restrictions on a qualitative analysis of the queried questions. If such an analysis had been possible, more explanatory and detailed results would possibly be obtained. Although this is a recognized restriction, the proposal to carry out a quantitative research was met within the statistical criteria, as well as validation of the proposed conceptual model and verification of the hypothesized relationship.
Despite this set of restrictions, the study of CA (analytical capabilities) represents expressive contours for the field of research, especially in Decision Making. Since only a few years ago the topic was effectively discussed in organizational studies and in management science. Taking root as a new teaching and research arena, publications are increasingly growing and popularizing, contributing for the evolution of the analytic movement. Therefore, the analytical approach that first emerged within the context of consulting and evolved over a short period of time within the applied social sciences has received increasing attention from the scientific community interested in understanding its phenomenon and its impacts and configurations within organizations, thus justifying in part, the validity of the study performed here.
It is necessary to suggest future work on the subject. Thus, it is possible to evaluate the extent that the Process Management construct, for example, may prove significant to positively impact both organizational and supply chain resilience. As well as analyze how its relationship with the analytical capacities improves the development and the reinforcement of the resilience. This investigation is valid, given the suspicion that the analytical capabilities can leverage the influence they exert on the performance of the organization when being undertaken in the business routine, especially supporting the management of business processes and obtaining relevant information about the processes itself (Bronzo et al., 2013; Galbraith, 1974; Muehlen & Shapiro, 2010).
In addition, it is recommended that new studies can be developed based on the validated model in this study by taking a qualitative approach. An alternative approach of qualitative nature can bring new and useful information regarding the relationships between the constructs investigated in the present research, considering, for example, interviews and participant or non-participant observations on decision-making practice in organizations.

APPENDIX

Figure 3 – Research constructs and indicators.

FORMATIVE CONSTRUCTS: SECOND-ORDER	FORMATIVE CONSTRUCTS: FIRST-ORDER	ITEMS/ FORMATIVE INDICATORS *
ORGANIZATIONAL ANALYTICAL CAPABILITIES (OAC)	Statistical Capabilities	▪ inquisitive analysis; ▪ descriptive analysis; ▪ predictive analysis; ▪ prescriptive analysis; ▪ Improving the decision-making process (reflexive indicator).
	Business Capabilities	▪ communication of problems; ▪ data translation; ▪ interpretation of analyses;

FORMATIVE CONSTRUCTS: SECOND-ORDER	FORMATIVE CONSTRUCTS: FIRST-ORDER	ITEMS/ FORMATIVE INDICATORS *
		▪ decision-making; ▪ Improving the decision-making process (reflexive indicator).
	Information Technology Capabilities	▪ data exploration; ▪ data hygiene; ▪ data integration; ▪ creation of environments; ▪ Improving the decision-making process (reflexive indicator).
ORGANIZATIONAL RESILIENCE (OR)	Anticipation	▪ identification of risks; ▪ monitoring deviations; ▪ early recognition of disruptions; ▪ recognition of opportunities; ▪ Good predictive capacity (reflexive indicator).
	Adaptability	▪ modification of processes; ▪ simulation of processes; ▪ development of technology; ▪ use of continuous improvement; ▪ Good capacity for adaptation (reflexive indicator).
	Recovery	▪ organization of response teams; ▪ communication of information; ▪ managing public relations; ▪ mitigation of effects of interruption; ▪ Good capacity for recovery (reflexive indicator).

Source: Prepared by authors based on research data.

*In the research instrument, there are 30 indicators used to measure the second-order constructs of OAC and OR. These indicators were derived from the items presented in this table. Thus, for each item present in the table, there is 1 (one) corresponding question in the research questionnaire.

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The Role of Social Media in the Relationship between CRM, SRM, and Customer Satisfaction

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ABSTRACT

Literature indicates that 42% of U.S. firms have integrated social media in their business strategies. Firms now use social media as a tool to interact with customers for sharing information and responding quickly to their needs. This study explores the role of social media in customer/supplier management and customer satisfaction.

KEYWORDS: Social Media, Customer Relationship Management, Supplier Relationship Management, Customer Satisfaction, Social Networking Perspective

INTRODUCTION

Customer satisfaction is a central tenet of management (Yeung and Ennew, 2000). Every organization strives to achieve great customer satisfaction because it leads to repeat purchase, brand loyalty reduces customer compliant and increases the profitability of organization (Churchill and Surprenant, 1982). In the early 2000s, customer relationship management (CRM) became very popular among managers to help improve customer relationship and satisfaction (Trainor et al., 2014). Today, managers and employees are charged with the exceptional task of combining nascent technologies with existing management systems, processes, and capabilities to foster customer relations and improve customer satisfaction (Trainor et al., 2014). This collaboration has led to a better framework not just to improve customer relations, but to improve customer satisfaction.

CRM is a “system that collects data from a number of customer-facing activities to help an organization better understand its customers so that it can better match its products and services to customer needs and thereby increase sales” (Hill, 2017, p.104). It can be viewed as a “core organizational process that focuses on establishing, maintaining, and enhancing long-term associations with customers” (Jayachandran et al., 2005, p. 3). CRM serves as a fusion of people, processes, and technology working together to understand a company’s customers. Hence, it is an integrated approach to manage customer retention, build customer relationships, and improve customer satisfaction (Chen and Popovich, 2003).

In the last decades, the nature of competition among companies has shifted towards supply management and the struggles management face when choosing and managing the relationships with their suppliers. Thus, the supply chain management is now viewed not just as means of getting products and services to the customers but also as a way of enhancing key outcomes - customer satisfaction (Hult et al., 2007). Researchers have begun to examine supplier relationship

management (SRM) and its effect on firm performance and customer satisfaction (Tan et al., 1998; Li et al., 2006). According to Webb (2017), SRM helps managers plan and manage all interactions with suppliers in an attempt to determine what supply chain categories are essential and what avenues/strategies are necessary to manage them efficiently. Studies (Croom et al., 2000; Choi et al., 2006; Hult et al., 2007) explain the importance of supply chain management in management research as well as in a firm. These studies suggest that in order to sustain competitive advantages in the market, companies must manage their supply base efficiently and with caution so as not to lose their competitive position in the market.

Since the internet revolution in the 1990s, our lives and the way we communicate have been significantly changed. Decades later, with the advent of social media, people can come together, share information, generate ideas, and give feedbacks concerning a company's product or service (Madabushi, 2014). The information shared is almost instantaneous hence, companies have resulted to investing lots of money to preserve their brand by continually communicating with customers, listening to complaints and accepting feedback all in an attempt to satisfy their customers and improve company performance. Reports show that companies are increasingly spending time and resources on their social media technological use. Statistics from eMarketer in 2015 projected companies' spending on social network advertising globally to be $35.98 billion in 2017 (representing an increase of 33.5% from 2014) (Emarketer, 2015, April). Statista projected that social media marketing in the United States would amount to $13.5 billion in 2017(Statista, 2018).

Despite the extant literature (Arsenault, 2014; Parveen et al. 2015; Rossmann et al., 2017) on the importance of social media on business operations, the effect of social media on customer satisfaction remain underexplored. There is a a considerable amount of research (Sousa et al. 2006; Weinberg and Berger, 2011) that show that social media complements a firm's strategy to produce more successful results. However, "whether firms are better off using social media" is still up for debate (Rossmann et al. 2017, p. 3950), so also has the effectiveness of social media on CRM and SRM remained underexplored" (Trainor et al. 2014). Academic research on social media has remained incomplete – not providing discerning analysis on the various objectives of social media and the impact it has on organizations and its customers (Parveen et al. 2015, p. 68). Further, organizational-level research on social media usage and its relationship with CRM and SRM is still in its infancy (Lovejoy and Saxton, 2012; Parveen et al., 2015). Thus, the purpose of this study is to explore the role of social media in the relationship between CRM, SRM, and customer satisfaction.

In the next section, we review the literature on Social Media, CRM, SRM and various studies related to the subject area, followed by hypotheses development and research methodology. Finally we discuss theoretical and managerial implications of this study.

LITERATURE REVIEW

Customer Relationship Management

Studies (Heskett et al., 1990; Blanchard and Galloway, 1994; Hallowell 1996) suggest that customer satisfaction is a reflection of customer's perception of the value obtained from a product or service received. This perception affects customers continued relationship with the company - attachment to a product or service (Fornier, 1994), and product recommendation (Yi, 1990). This also reduces customer acquisition cost and increases company revenue (Reicheld and Sasser, 1990). In a survey of 200 top managers, 142 of them agree that customer satisfaction is a very effective tool that helps manage and monitor their business (Farris et al., 2010). Customer

Relationship Management (CRM) centers on helping managers and employees develop and manage long-term relationships with their customers in other to improve customer satisfaction (Jayachandran et al., 2005). CRM is an all-inclusive approach that combines technology, process, and all business activities around the customer (Anton, 1996; Anton and Hoeck, 2002; Feinberg and Kadam, 2002). It is a management technique that focuses on individual customer, and requires firms be structured around customers, rather than products (Chen and Popovich, 2003). Hill (2012, p. 93), describes CRM as a "system that collects data from a number of customerfacing activities to help an organization better understand its customers so that it can better match its products and services to customer needs". Further, evidenc supports that CRM provides incentives for employees to break down functional barriers and encourages information sharing which helps to improve customer satisfaction (Chen and Popovich, 2003; Day, 2003; Cooper et al., 2008; Trainor et al., 2014). It also supports the coordination of activities with customers, enables a firm to understand its customers better, interact with them, and respond quickly to their needs (Day, 1994). Therefore, a good CRM system helps management develop a deeper understanding of customer buying behavior (Hill, 2012) and as a result, influences customer relationship by building on established long-term customer relationships thereby increasing customer satisfaction.

Supplier Relationship Management

As competition increased and markets became global, so did the challenge of product and service distribution. Companies were faced with the task of getting products and services to customers on time and at an affordable price (Li et al., 2006). Managers began to realize the importance of supply chain management to stay competitive and increase profitability. The effective management of buying raw materials, integral parts, and finished goods to meet the needs of the customer is the very core of competitive supply chain management (Ross, 2004). With supply chain management, the main objective is to create synergy within the supply chain to achieve larger benefits than those achieved by an individual firm in the chain acting independently (Vollmann and Cordon, 1998). The goal of which is to "create distinctive competencies—for the chain—where the whole is greater than the sum of the parts" (Vollmann and Cordon, 1998, p. 687).

Managing these relationships to achieve the maximum potential is a daunting task as the buying/purchasing company is not just faced with the challenge of managing single purchases with different suppliers instead, it is faced with the challenge managing several purchases from multiple suppliers (Moeller et al., 2006). The goal of SRM is to ensure that both information and material, flow seamlessly throughout the supply chain in an effective competitive manner (Feldmann and Müller, 2003; Childhouse and Towill, 2003). SRM involves taking on activities that set up, develop, stabilize and dissolve relationships with suppliers in other to create and enhance value for the company and its customers (Moeller et al., 2006). It strives to enhance relationships with suppliers to increase collaboration, reduce cost, improve quality, reduce inventory, increase value and reduce risk (Hill, 2012). Paparoidamis et al. (2017) found that suppliers benefit from maintaining and building a strong, loyal customer base. For the suppliers, they can maintain a stable stream of revenue; it reduces customer acquisition cost, and ultimately increases profitability. The benefits of using SRM are enormous; reduces cost, increase efficiency, minimizes price volatility, consolidates supply chain, and also helps in the continual improvement of operations (Shin et al. 2000; Davies 2018). With SRM, managers can plan and manage all interactions with suppliers in an attempt to determine what supply chain categories are important and what avenues/strategies are necessary to manage them efficiently (Webb, 2017). Jap (1999)

found that active collaboration with suppliers can help the purchasing company reduce unnecessary inventories, reduce cost, increase business and information flow about competitors for suppliers and increase customer satisfaction. Beamon (1999) found that on-time delivery was an essential variable that affected customer satisfaction. Also, Heikkilä, (2002) found the delivering products to customers on time increases customer satisfaction.

Social Media

Social media has become a critical concept for many business practitioners (Kaplan et al., 2010). Managers now use social media as a tool to improve company profitability as well as a way to interact with customers - to meet their needs and respond quickly to their wants. Social media can be described as an “online resource that people use to share ‘content’: video, photos, images, text, ideas, insight, humor, opinion, gossip, news — the list goes on” (Drury, 2008, p. 274). Table 1 summarizes articles that show how social media has been used in various fields and in numerous capacity to improve business operations. Studies suggest that social media enhances business operations by improving customer satisfaction and facilitates the use of these management systems.

Table 1: Major Studies on Social Media, Customer Relationship Management, and Customer Satisfaction			
Study	**Objective**	**Type & Sample**	**Key Findings**
Gallaugher and Ransbotham, (2010)	How social media facilitates customer dialog	Empirical/ meetings and interviews with Starbucks social media team and secondary sources – newspapers	Using social media helps identify problems and foster innovation
Heller and Parasnis (2011)	Argue for the use of social media in conjunction with customer relationship management (CRM).	Empirical/ 1000 customers worldwide and 350 executives	Consumers have a vested interest in getting tangible value. However, businesses may confuse their need for customer engagement with what motivates a customer to engage
Sashi (2012)	Describes how social media can help practitioners develop close relationships with customers	Conceptual	Designed a model to help improve our understanding of customer engagement and gives strategies that can form the foundation
Rishika et al. (2013)	Studies the result of customers' involvement in a firm's social media endeavors and its effects on firm activities	Empirical/ 394 customers from the customer base of a large specialty firm in northeastern United States	Customer involvement in firm's social media endeavors increases customer visits
Rapp et al., (2013)	Develop a framework that provides insight into how social media affects sellers, retailers and customers.	Empirical/ 3 level data set from suppliers, retail managers, and consumers	Social media affects brand performance and customer loyalty
Hajli (2014)	How social media facilitates customer engagement, influences buying intention and trust	Empirical/ 237 members of social networking sites in London and UK	Social media had a positive effect on trust which in turn influences consumer buying intention

Sano (2014)	How social media use in the tourism industry increases customer satisfaction and affects behavior intentions	Empirical/ 4,731 respondents accessing or using travel agencies' social media	Social media affects customer satisfaction stronger than it does behavior intention
Della Corte et al., (2015)	Describe how social media facilitates customer engagement and promotes service innovation	Empirical/ secondary web data	Social media allows companies monitor customers' comments and their level of commitment to a product.
Agnihotri et al. (2016)	To examine how salesperson's information dissemination behaviors affect the relationship between social media and customer satisfaction	Empirical/ 111 salesperson-reported data, within a business-to-business (B2B) context	Social media influences communication behaviors, and strengthens responsiveness/customer satisfaction.
Maecker et al. (2016)	Examines how social media channels affects customer relationship management.	Empirical/ 334,111 customers from a mobile phone service provider in a major European country	Social media facilitates upselling efforts and reduces customer attrition
Elena (2016)	Examines how social media promotes the growth of customer relationship management	Empirical/ case studies and survey of 87 business executives/managers from Romania.	With social CRM, organizations can build better relationships with customers, gain their trust and increase their confidence
Liang et al. (2016)	Examine how social media influences customer satisfaction	Conceptual	Social media affects buying behavior and customer satisfaction
Khan et al. (2017)	Examine the approach used by Bank Muscat customers to make suggestions and complaints; and to explore the problems these customers face while reaching out the bank via Social Media.	Empirical/ 234 respondents from the branches of Bank of Muscat in Oman	The Bank uses social media to disperse important information to customers. Suggestions and complaints made through Social Media received a quick response. Trustworthy information and Responsiveness affect Customer Satisfaction.

HYPOTHESES

The Effect of Social Media on CRM and Customer Satisfaction

Technological changes gave rise to the use of social media which is changing the world on a daily basis. Social media is used for information sharing and seeking, entertainment, and expressing an opinion about a product or an issue (Whiting et al. 2013). Never before have companies come so close to engaging with their customers in such a timely manner (Woodcock et al., 2011). Agnihotri, et al., (2016, p. 1) describes how customers are 'asked to 'like' companies on Facebook, to 'follow' companies on Twitter, or to 'connect' via LinkedIn". Hence, he suggests that customers have become more connected to companies and more knowledgeable about company products making them powerful agents in the buyer and supplier relationships. With the emergence and versatility of social media, "many businesses began to determine how to reap the potential benefits of this resource which includes building better relationships with customers, promoting their company brand as well as improving customer satisfaction" (Sano, 2014, p. 46). Social media has become a crucial communication tool for people to communicate with friends and families, and for companies to communicate with customers (Sano et al., 2016). A study by Insites Consulting (2011) on 399 randomly selected European and U.S. companies found that 80% of the companies have adopted some social media initiatives and 42% of these companies had fully integrated the use of social media in their business strategies. Another study by (Nielsen, 2010) found that consumers spend 25% of their internet time of social networking sites and more than half of online shoppers interact with retailers online (Rapp et al., 2013).

Based on the social networking perspective, which can be described as "a set of nodes (e.g., persons, organizations) linked by a set of social relationships (e.g., friendship, transfer of funds, overlapping membership) of a specified type" (Laumann et al. 1978, p. 458), we now have social customers - who are able to share reviews and give feedback about a company's product or service. Hence, companies are forced to deal with the continuous growth of social media where customers share their experiences and opinions on a much larger scale and where company reputations can be ruined very quickly. To do this, they now have to find ways to navigate the market effectively and come up with strategies that build better relationships with the customer (Acker et al., 2011). With the constantly changing business environment, companies are faced with the influential power of social media and are now using the social media platforms in various fields such as CRM (Sano et al., 2016). Social media impacts an organization's CRM capability because it establishes an environment that fosters customer engagement, collaborates and enhance customer relationships (Trusov et al., 2009). Companies that use social media can increase their product or service awareness, accentuate their plan to engage in interactive dialogue, thereby augmenting the effect of CRM capabilities. Also, companies that adapt quickly to technological innovations tend to have higher performance (Han et al., 1998). The study by Agnihotri et al., (2016) on the impact of social media on customer satisfaction found that social media does plays a vital role in communicating with customers. However, it does not have a direct effect on customer satisfaction; rather, it is an antecedent that enhances a salesperson behavior to increase customer satisfaction. They emphasize setting clear boundaries on what can be shared and how employees interact with the company customers.

Using social media platforms, companies have been able to reduce customer complaints (Acker et al., 2011). The online community that Best Buy has is a perfect example of the impact social media has on customer satisfaction. In the last decade, Best Buy online community (made up of staffers and other community members) had 2.5 million visitors and approximately 80 million messages on questions they had about a product or service. Only 5% of customers questions

were answered by Best Buy staffers, most of which were answered by the online community. As a result, Best Buys saved $5m (Acker et al., 2011). iPhone call centers also experienced fewer calls as a result of their FAQ page viewed more than 84,000 times. Hence, if social media is effectively managed, and used in conjunction with CRM, it can generate not only financial rewards but improve customer satisfaction (Acker et al., 2011). The study by Wang and Kim (2017, p. 15) shows that social media has more "direct impact on brand communities, produces higher response rates and customer engagement levels than traditional marketing methodologies that focus only on the firm–consumer relationship." According to Trainor et al., (2014) social media use increases firm effectiveness by providing a better understanding into the underlying relationships between the social networks existing customers and new prospects and also by facilitating internal and external collaborations which lead to improved customer solutions (Trainor, 2012). In the light of all arguments above, it is rationalized that the use of social media will positively moderate a company's CRM capability of interacting with customers in collaborative conversations and enhancing customer relationships. As such, we suggest that the relationship between CRM and customer satisfaction would be stronger especially for firms that use social media technology extensively. Therefore, the following hypothesis is proposed to empirically test in this study:

H1: *Social media positively moderates the relationship between CRM and customer satisfaction*

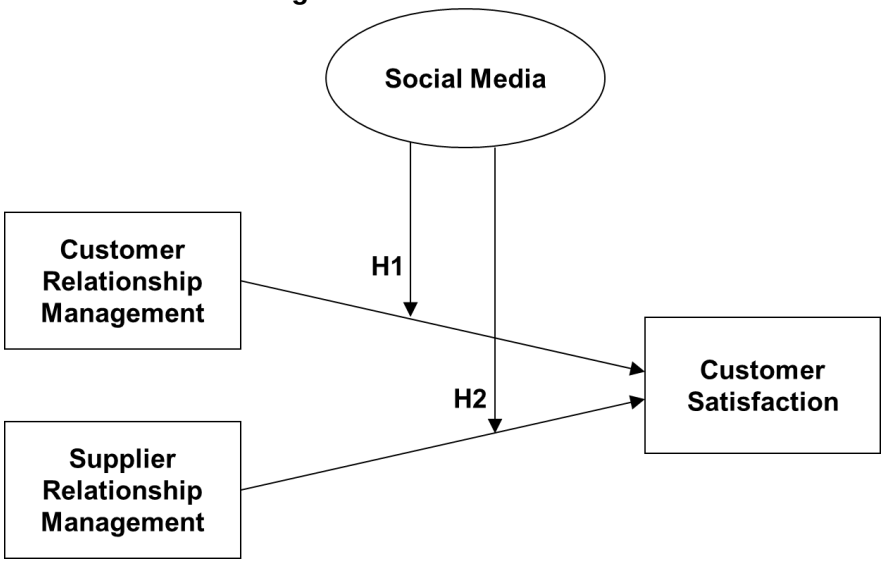
The Effect of Social Media on SRM and Customer Satisfaction

Studies on the relationship between social media and SRM show that "the goal must be to create distinctive competencies—for the chain—where the whole is greater than the sum of the parts" (Vollmann and Cordon, 1998, p. 687). The use of social media has become more paramount than ever and it has raised a lot of interest. Many companies now use social media as a strategic marketing tool in order to increase their brand visibility and awareness. However, what about using this new trend in conjunction with "Supplier Relationship Management"? (The Social Media becomes, 2010). The literature on SRM and its impact on customer satisfaction is very scant. Based on the few studies done on this topic (Rapp et al., 2013), the use of social media with SRM should increase customer satisfaction. This is because, managers and suppliers are able to collect information and give feedback to customers in a timely manner, while also allowing companies adapt to the changing needs and taste of customers (Brin, 2011). The effective management of a firm's suppliers thus has a tremendous effect on its competitive position, as well as its ability to fulfill its customers' needs (Song et al., 2014; Omoruyi et al., 2016). Zappos, one of the online retailers uses social media to interact constantly with customers, thereby developing real relationships and increasing customer satisfaction (Porterfield, 2011). T-Mobile, one of the large wireless tech giant, is known for its use of social media to interact constantly with customers and as of 2014, its Facebook page had a response rate of 91.13% (Patel, 2015). Gil Saura et al. (2008) found customer satisfaction to be positively related to timeliness-a factor of effective supply management.

The increasing use of social media in management means that social media is relevant in the purchasing perspective as well as in the aspect of increasing consumer satisfaction (Ylimaula and Ulkuniemi, 2013). With social media, companies can improve their communication strategy, exchange ideas with customers who can participate in product development and then create products based on customer need (Bughin et al. 2009). This in turn, helps to increase customer satisfaction. For Partridge (2011, March), "Any supply chain is only as strong as its weakest link. A company can move a product from China to the United States, clear it through Customs, move

it to a distribution center, and fulfill it in record time. But if it doesn't deliver the product to consumers quickly enough, they are not happy, and the company's supply chain has failed."
In a case study by Ylimaula and Ulkuniemi (2013) on a telecommunication company, they found out that social media was used by employees on a minimal level. Some employees did not even know they were using social media. Even though some admitted to the use of social media tools such Skype and LinkedIn to communicate with suppliers, they were oblivious to the idea that it was social media that was been incorporated in their strategy probably because it is a relatively new concept. Previous studies (Rapp et al., 2013; Brin, 2011; Ylimaula and Ulkuniemi, 2013) show that social media use increases customer loyalty and satisfaction. Brown (2016) emphasizes the importance of supply management because it determines if a company retains or loses its customers. Barve (2011) talks about market instability and that speed and flexibility from suppliers is essential for companies to keep abreast and respond to the unique and changing needs of customers. As earlier stated, social media allows companies to engage consistently with its customers; consequently, they remain well informed about their changing tastes and needs. Namely, this constant engagement with customer enables the firms to remain competitive and allows them to relay this information to suppliers promptly to keep customers satisfied. Thus, considering all arguments above, we propose the following hypothesis. In addition, the conceptualized research model of this study is demonstrated below in Figure 1.
H2: *Social media positively moderates the relationship between SRM and customer satisfaction*

Figure 1: Research Model



RESEARCH METHODOLOGY

Sample

Based on the study of Dillman et al. (2014), we design our survey. The data for this study will be collected by sending out surveys to managers of service companies in the United States. The reason for using these respondents is based on previous research (Ghobadian et al., 1994; Akbaba, 2006). These studies show the importance of service quality to the survival of any firm in today's competitive environment. Berry et al. (1989) show that service quality increases employee

and customer satisfaction, reduces cost, and increases business performance. Survey respondents will be offered a summary of the research results from this study in return for responding to the surveys. The responses will be collected over an eight-week period and reminders will be sent out bi-weekly. A sample size of 200 companies will be adequate for this research.

Measures

All measurement items used in this research will be adopted from previous research studies. The scale items will be slightly modified to capture the data needed to carry out this research. The responses are rated on a 7-point Likert scale, anchored by 1 being "strongly disagree" and 7 being "strongly agree". Specifically, social media-related items are adopted from Trainor et al. (2014). Respondents will be asked if they use any form of social media to sell their products/services or use it as way of keeping in touch with their customers. If they respond by clicking “YES”, they will proceed to the corresponding social media questions. Scales developed by Reinartz et al. (2004) will be used to assess CRM usage in the company. These measures include how the company uses CRM to initiate, acquire, and maintain customer information to better respond customer needs and expectations. Scales developed by Swink et al. (2005) will be used to measure SRM. Their measure captures cost, technology, and long-term relationships with suppliers. To measure customer satisfaction, scales developed by (Samson and Tezriovski, 1999; Das et al., 2000; Zu, 2009, Cho et al., 2017) will be adopted. These measure items were slightly revised to suit our research purpose. All scale items used in this study are found in the Appendix

DATA ANALYSIS

Testing of Scale Reliability and Validity

- Scale Reliability is the extent to which an observed variable is consistent, measures the true value of what it is supposed to measure and is error free (Hair et al., 1998 p. 9 and 92). Scale validity is the extent to which the test measures gauge what it is supposed to (Brown, 1996). The Cronbach alpha coefficients will be computed to test the reliabilities of the scales (Powell, 1995). Typically, the coefficients should fall within a range of 0.70 to 0.90 for narrow constructs, and 0.55 to 0.70 for moderately broad constructs (Van de Ven and Ferry, 1979; Powell, 1995).

- Construct Validity is the extent to which the sample accurately represents the objectives or stipulations of the study (Brown, 2000). With construct validity, the researcher’s goal is to analyze the instrument chosen and to make sure it catches the latent variable (Zaiţ and Bertea, 2011, p. 217). To test if there is a relationship between the variables, we use Confirmatory Factor Analysis (CFA) which is “a statistical tool that verifies the factor structure of the observed variables and checks if there is a correlation between the observed variables and the latent constructs” (Suhr, 2006, p. 1).

- Convergent Validity is used to test whether “the scale is measuring the intended concept” (Hair et al., 1998, p.125). To analyze convergent validity, we will use Average Variance Extracted (AVE) (Fornell and Larcker, 1981). AVE is “average variance shared between a given construct and its indicators” (Dean et al. 2008, p.11). If the value of AVE is bigger than

the construct's correlation of other constructs, we assume that convergent validity is confirmed (Gefen et al., 2000; Alumran et al. 2014)

- Discriminant Validity is used to test whether the scales are sufficiently different from each other (Hair et al., 1998). One way to test discriminant validity is to carry out a Chi-square difference test (Segars, 1997). Here, we will collate two models, one of which is correlated and the other which is not. If the statistical test is significant, then we will condluce that there is discriminant validity (Zaiţ and Bertea, 2011).

Testing of Common Method Variance

Since data for this study will be collected using the survey method, and the data from respondents is self-reported, common method variance (CMV) is a major concern (Chang et al., 2010). CMV is ''variance that is attributable to the measurement method rather than to the constructs the measures represent'' (Podsakoff et al., 2003, p. 879). CMV can cause a researcher to make erroneous conclusions about the association between variables either by inflating or deflating the research findings (Craighead et al., 2011). To test if CMA augments the relationships between the variables, we will employ Harman's single factor test with CFA (Harman 1976; Jansen et al., 2005).

Testing of Non-Response Bias

Non-response error is the error that "occurs when a significant number people in a survey sample do not respond to the questionnaire and are different from those who do in a way that is important to the study" (Salant and Dillman, 1994, p. 20). Miller and Smith (1983) emphasize the importance of paying attention to non-response error and suggest that even though the response rate received from a questionnaire is high, non-response error still needs to be considered because certain important information may be missing from the questionnaire, all of which may affect the validity of the study. Non-response error can be assessed by comparing the early and late respondents (Armstrong and Overton, 1977; Hausman and Siekpe, 2009). This is referred to as 'wave analysis'. Respondents who completed and returned their survey before the first deadline are compared to those who returned theirs later (Halbesleben and Whitman, 2013). To compare these two groups, "a random sample of the non-respondents are selected and the researcher collects data from these subjects. The data collected from the non-respondents is compared to data collected from the respondents. If no difference is found, the data can be pooled and inferences made to the population" (Collier and Bienstock, 2007, p.165)

Hierarchical Regression Analysis

To examine the hypotheses developed in this study, we will conduct a three-step hierarchical regression analysis. This analysis allows us to add a set of independent variables to the regression equation and determine how much contribution these variables makes or adds to the dependent variables (Cohen et al., 2013, p.144). In this case, our interest is to determine whether newly added variables show a significant improvement in R^2 (the proportion of explained variance in DV by the model) and the F-ratio (Kim, 2016). To control for the possibility of variance across the two different industries and firm size, we will enter the type of industry and firm size as a control variable. Particularly, our hypotheses are tested based on the following hierarchical regression model:

$Y = \alpha + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X3X5 + \beta7X4X5 + \varepsilon$ where Y = customer satisfaction, X1 = industry type, X2 = company size, X3 = customer relationship management (CRM), X4 = supplier relationship management (SRM), X5 = social media (SM), and ε = random disturbance terms.

Step 1: Y = Intercept + Industry type + company size

Step 2: Y = Intercept + Industry type + company size + CRM + SRM + SM

Step 3: Y = Intercept + industry type + company size + CRM + SRM + SM + CRM*SM + SRM*SM

DISCUSSION AND CONCLUSION

Theoretical Implication

The study would investigate social media use by analyzing the use of social media in 200 service firms in the United States. The social networking perspective (Scott,1988) provide a basis for which this study is designed and that when resources are effectively used in conjunction with nascent technology can increase customer satisfaction. This study also provides a better insight into the how organizations use social media to improve customer satisfaction, identifies the various forms and ways social media is used in companies. Hence, the results of this study can serve as a guide for other organizations and top management teams who have not incorporate social media in their organization (Trainor et al., 2014; Parveen et al., 2015).

This study suggests that SRM and CRM make a synergic effect with social media on a firm's competitive advantages. This finding is also consistent with the information system literature that indicates using technology alone is not be enough to gain competitive advantage. Instead, our study supports that the use of social media facilitates other organizational capabilities that allow companies better understand their customers and meet their needs (Trainor et al., 2014)

Managerial Implication

The evidence from previous research shows that CRM and SRM have positive effects on customer satisfaction. However, our study suggests that the effects can be significantly improved by incorporating other nascent technology like social media. This is beneficial not only to the company because it increases revenue but it also increases customer satisfaction. Further, this study presents that using social media allows companies to better serve their customers by affording them the opportunity to respond quickly to customer needs and get feedback concerning a product or service. Therefore, managers should consider investing in social media technology and integrate it with other existing systems to enhance their company's capabilities and increase customer satisfaction. However, it is also important to note that there are many regulatory and legal risk associated with using social media (Moorcroft, 2008; Parveen et al., 2015).

Limitation and Future Research

It is well known that retaining a firm's current client base is more profitable than developing new relationships. An understanding of a firm's customers can help companies better tailor their products to maximize customer satisfaction (Chen and Popovich, 2003). However, managing customer relationship is difficult especially in today's dynamic and competitive environment. Even though this study is diverse, the relationships may be less applicable to specific industries that may not see much potential or whose customer demand for social media use is minute (Trainor et al., 2014). Future research can also look at the position of the firm in the industry and if using social media is necessary.

APPENDIX: Survey Measure Items

Social Media Scale Items (Trainor et al., 2014)
Does your organization use any form of Social Media? YES □ NO □
If yes, which of the following represents the reason why you use social media technology**.** Please check all that apply *Conversation support*

□ Blogging (e.g. Blogger, Wordpress, TypePad)
□ Instant messaging (e.g. Google Instant Messenger, MSN, Yahoo)
□ Micro-blogging (e.g. Twitter, Tumblr)
□ Online conferencing/webinar (e.g. Adobe Connect, Go-to-Meeting, Yugma)
□ Live interactive Broadcasting (e.g. UStream.tv)

In this company, we use social media for
Information generation

- We use social media to conduct market research.
- We use social media to detect changes in our customers' product preferences.
- We use social media to detect fundamental shifts in our industry (e.g., competition).

Responsiveness

- We use social media to respond to our competitor's price changes.
- We pay attention to changes in our customers' products or service needs using social media.
- If a major competitor launched an intensive campaign targeting our customers, we would respond immediately using social media.
- The social media activities of the different departments are well coordinated.
- Customer complaints can be filed and tracked using social media in our firm.
- When our customers want us to modify a product or service, we announce that change using social media.

CRM Scale Items (Reinartz et al., 2004)
Technology

- We invest in technology to acquire and manage "real time" customer information and feedback.
- Relative to our competitors the quality of our information technology resources is larger

Initiation

- We have a formal system for identifying potential customers
- We have a systematic process for assessing the value of past customers with whom we no longer have a relationship.

Acquisition

With regard to your SBU, to what extent do you agree to the following statements?

- We made attempts to attract prospects in order to coordinate messages across media channels.
- We have a formal system in place that differentiates targeting of our communications based on the prospect's value.

Maintaining

- We have a formal system for determining which of our current customers are of the highest value.
- We continuously track customer information in order to assess customer value

SRM Measures (Swink et al., 2005)

- We provide technological assistance to suppliers.
- We share our cost information with our major suppliers.
- We require cost information sharing by our suppliers.
- We establish long-term contracts with suppliers.
- We pursue joint investments with suppliers.

Customer Satisfaction measures

- Customer retention about our products and services has increased over the past three years (Das et al., 2000)
- Customer satisfaction about our products and services has increased over the past three years (Zu, 2009; Cho et al., 2017)
- Customer satisfaction with the quality of our products and services has increased over the past three years (Zu, 2009)
- Please choose among one of the followings as the best description of your company's customer satisfaction level (Samson and Tezriovski, 1999; Cho et al., 2017).

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Never meets expectations	Sometimes meets expectations	Often meets expectations	Generally meets expectations	Consistently meets expectations	Always meets expectations	Exceeds expectations

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DECISION SCIENCES INSTITUTE

The underlying impact of supplier participation on manufacturer green innovation

Full Paper Submission

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ABSTRACT

Drawing on social network and capabilities theories, this study examines how supplier participation in new green product development influences a manufacturing firm's new green product creativity. The results from a longitudinal survey of 328 manufacturing firms and their suppliers reveal that novel green knowledge sharing mediates the effect of supplier participation on manufacturing firms' new green product creativity. In particular, the effect of supplier participation on novel green knowledge sharing is enhanced by knowledge sharing capability, while the effect of novel green knowledge sharing on new green product creativity is enhanced by joint learning capability.

KEYWORDS: Supplier participation, Manufacturing firm, Green innovation

INTRODUCTION

Manufacturers intending to adopt green innovation often proactively involve suppliers in their new green product development (NGPD) process (Govindan et al., 2015). The existing literature has also acknowledged the benefit of engaging suppliers in the NGPD process (e.g., Chatterjee et al., 2018; Katsikeas et al., 2016; Dou et al., 2014). While existing studies provide rich insights into how suppliers can contribute to a manufacturer's green product innovation, the results of studies in this research stream are mixed.

Some studies find a strong relationship between supplier participation in NGPD (hereinafter 'supplier participation') and NGPD performance. That is, manufacturers with effective supplier participation will perform better than those that do not adopt supplier participation (e.g., Chatterjee et al., 2018; Katsikeas et al., 2016; Dou et al., 2014). Conversely, other studies report lower or even no significant correlations between supplier participation and NGPD-related performance (e.g., Kumar et al., 2016; Leonidou et al., 2013; Azevedo et al., 2011). Kumar et al. (2016) report that short run green adoption is a costly process for NGPD. Leonidou et al. (2013) find that managers are expected to perceive greening efforts as risky for NGPD performance. Azevedo et al. (2011) reveal that green practices have negative effects on the performance of supplier involvement.

Most studies attribute these inconsistencies to factors that potentially influence the supplier participation–NGPD performance relationship, such that the time necessary to understand the knowledge of the green supplier may be too costly (Blome et al., 2014), involving suppliers in NGPD may lead to deterioration of manufacturing firm NPD capabilities (Huo et al., 2018), and manufacturing firm employees may reject suppliers' knowledge (Dou et al., 2014). Although supplier participation has been identified in the literature as a key driver of manufacturer green

innovation, the process through which it affects manufacturers' NGPD is apparently still not well understood.

The primary objective of the present study, therefore, is to explain why some manufacturing firms are more successful than others in converting their supplier participation into superior NGPD performance. Building on social network theory (Burt, 1997), we examine the role of supplier participation on the manufacturers' new green product creativity. Based on previous work of Moorman and Miner (1997), Dean et al. (2016), and Dayan et al. (2017), new green product creativity refers to the degree to which a new green product is perceived to provide unique and meaningful differences to manufacturers' customers. Since new product creativity is a necessary condition for successful innovation, by providing meaningful differences from rivals, creativity leads to product differentiation and competitive advantage for manufacturers (Dayan et al., 2017). However, while supplier participation has a potential value for manufacturer innovation, the actual impact is achieved when the manufacturing firm can detect and assimilate information from its suppliers. Because suppliers' knowledge is implicit in nature (Luzzini et al., 2015), knowledge sharing between the manufacturing firm and its supplier reflects a key relational process for successful knowledge assimilation (Gao et al., 2015). Therefore, extending previous research, we propose novel green knowledge sharing as a critical process through which supplier participation affects manufacturer new green product creativity.

Furthermore, according to capabilities theory (Eisenhardt and Martin, 2000; Teece, 2014) and relevant studies (e.g., Dai et al., 2017; Handfield et al., 2015; Menguc et al., 2014), an important driver of a manufacturing firm's ability to translate supplier participation into superior NPD performance is its organizational capabilities. This proposition is based on the premise that how supplier participation is deployed to capture, share, and exploit novel knowledge resources amid competitive pressures, and the quality of deployment of supplier participation, will depend on the strength of a manufacturing firm's organizational capabilities (Kozlenkova et al., 2014). Accordingly, drawing on capabilities theory, we propose two green organizational capabilities that help with deployment of supplier participation: knowledge sharing capability and joint learning capability. Knowledge sharing capability refers to a manufacturing firm's ability to develop mechanisms that promote the exchange of novel green knowledge among suppliers participating in NGPD activities (Cai et al., 2010). Joint learning capability refers to a manufacturing firm's ability to learn collectively with its suppliers in creating green innovation value through novel green knowledge for both parties during the NGPD process (Fang and Zou, 2010; Foss et al., 2010).

HYPOTHESES

In this study, supplier participation is defined as the extent to which manufacturers incorporate their suppliers into NGPD and continuously improve new product projects (Yan et al., 2018). Specifically, supplier participation includes both the breadth and depth of supplier participation in the NGPD process. Breadth captures the scope of participation across the NGPD process, while depth represents the green supplier level of participation in a stage of the NGPD process.

Researchers have proposed that supplier participation affects a manufacturer's NGPD process by increasing the level of knowledge shared during the NGPD process, and by improving how well two firms coordinate their actions during the NGPD process (Albort-Morant et al., 2018). Novel green knowledge sharing refers to the extent of the exchange of novel green knowledge about the green product idea, market, and competition, among other issues, during the NGPD process that facilitates inter-firm collaboration among supply chain members (Li et al., 2014). This implies that supplier participation enhances the ability of both manufacturers and suppliers to identify what knowledge needs to be shared and how to work more cooperatively.

When a green supplier participates in a manufacturer's NGPD process, each party knows the pertinent green knowledge possessed by the other, which helps them evaluate and recognize what knowledge to share, and increases the efficiency of their coordination effort (Jean et al., 2014). Researchers have also found that suppliers' early participation in the NGPD process and higher levels of social interaction between the parties improve the knowledge intensity, frequency, and breadth (Katsikeas et al., 2016).

While most research argues for the positive effects of supplier participation on NGPD performance (e.g., Dai et al., 2017; Govindan et al., 2015; Lee and Kim, 2011), it is possible that, if the interaction is dysfunctional or leads to conflict, higher levels of participation could be detrimental and offset some of the expected benefits. Therefore, we expect that higher levels of supplier participation improve communication and help both the suppliers and manufacturers specify the behaviors desirable in the relationship, which enhances the effectiveness of novel green knowledge sharing. Thus, we hypothesize that:

H1: Supplier participation positively affects novel green knowledge sharing.

Jean et al. (2010) have identified communication between the supplier and manufacturer regarding manufacturers' new product preferences as a key prerequisite for new product creation. Research on the formation of manufacturers' new product preferences suggests that these preferences and needs evolve through supplier participation in specific new product ideas, concepts, and prototypes across the NPD stages (Yeniyurt et al., 2014). As such, constant novel green knowledge sharing should help suppliers probe and learn how manufacturer needs evolve and emerge during the NGPD process. Moreover, novel knowledge shared by the supplier with the manufacturer about cost structure and production and engineering options helps manufacturers realize constraints and, thereby, make appropriate adjustments in their preferences for NPD (Yang et al., 2016). Following this line of reasoning, due to novel green knowledge sharing, manufacturers and suppliers should be better able to discover unique opportunities for new green product creativity.

In particular, green innovation requires the manufacturing firm to assimilate and recombine novel knowledge perspectives from various sources (Behnam et al., 2018). Supplier participation exposes the manufacturing firm to dissimilar green knowledge, which increases the number and variety of potential combinations and novel solutions (Watson et al., 2018). In addition, exposure to diverse green knowledge and perspectives also stimulates the manufacturing firm to blend different knowledge elements, which represents a key cognitive process for generating novel insights (He et al., 2018). Further, supplier participation can stimulate the manufacturing firm to develop flexible, outside-the-box thinking. As a result, because supplier participation offers the manufacturing firm an approach to observe how a problem could be solved differently, it challenges the manufacturing firm's existing cognitive structures, including its premises and beliefs about cause-and-effect relationships (Behnam et al., 2018). The manufacturing firm, thus, is more likely to develop multiple conceptualizations of problems and find novel solutions.

At the same time, supplier participation can provide the manufacturing firm with brokerage advantages through rich connections (Potter and Lawson, 2013). In such connections, the manufacturing firm can observe and access diverse expertise, perspectives, and knowledge in various fields. In turn, novel green knowledge can be applied, modified, and experimented with in new areas and then achieve green innovative outputs (He et al., 2018). As Gao et al. (2015) find, suppliers embedded in supply chain networks with high levels of knowledge heterogeneity are good sources of creative ideas. Accordingly, in the NGPD process, novel green knowledge sharing between suppliers and manufacturers should increase the level of manufacturers' new green product creativity. Thus, we hypothesize that:

H2: New green product creativity is positively affected by novel green knowledge sharing.

While supplier participation likely stimulates manufacturer green innovation, little is known about the underlying process linking supplier participation and manufacturer new green product creativity. We propose that novel green knowledge sharing is a critical relational process that mediates the effect of supplier participation on manufacturer new green product creativity.

The knowledge-based view argues that suppliers are a key element in creating new knowledge, but if this knowledge is not shared with other supply chain members, it will have very little impact on the performance of the supply chain network (Grant, 1996; Handfield et al., 2015). Thus, when the green knowledge possessed by the suppliers is shared and transferred from one to another within a supply chain network, synergy occurs (Ghali et al., 2016). Especially, supplier participation typically performs project-based work of a non-routine and complex nature, so such work requires effective coordination and the integration of novel knowledge (Lee, 2015). In addition, in order to take advantage of each party's individual competencies, suppliers and manufacturers must coordinate their efforts to increase the effectiveness of their novel green knowledge sharing across the different stages in the NGPD process (Pinheiro et al., 2018). The novel green knowledge sharing will, thus, play a key role in manufacturing firms' NGPD process.

However, it is also vital that the novel knowledge is shared in order for innovation to be created (Gao et al., 2015). Suppliers can have diverse and novel knowledge, but the manufacturer may not necessarily benefit from such diversity automatically if the suppliers are unwilling to proactively share their proprietary knowledge. Similarly, in supplier participation where multiple suppliers are involved, competition for the manufacturer's NGPD can stimulate proactive green knowledge sharing from suppliers. In addition, frequent knowledge sharing keeps the manufacturer updated with novel knowledge so that it can detect critical knowledge more easily (Jean et al., 2014). Moreover, knowledge sharing through formal and informal mechanisms, including routine interactions, frequent meetings, and impromptu and random encounters, enhances the manufacturers' ability to assimilate suppliers' knowledge (Yeniyurt et al., 2014). Most importantly, because technological knowledge provided by suppliers is difficult to codify and communicate, effective knowledge sharing between the manufacturer and the suppliers is critical for the manufacturer to fully understand and successfully integrate the acquired knowledge (Martín-de Castro, 2015).

Overall, it is predictable that supplier participation will be more effective when there is effective novel green knowledge sharing between the manufacturer and its suppliers. Based on this assumption, we propose the following hypothesis:

H3: Green novel knowledge sharing mediates the relationship between supplier participation and new green product creativity.

Knowledge sharing capability is a commercial prerequisite for business-network-based structures and is essential in obtaining and processing information and identifying opportunities in these structures (Cavaliere et al., 2015). It can be conceptually disaggregated into a firm's capacity for: knowledge dissemination, distribution, contribution, and transfer. Thus, knowledge sharing capability is an important capability in enhancing organizational innovation performance (Brandon-Jones et al., 2014). As such, we propose that developing knowledge sharing capability should enhance the impact of supplier participation on novel green knowledge sharing for the following reasons.

First, firms with strong knowledge sharing capability can effectively transfer knowledge, so that the recipient of that knowledge can understand it well enough to act on it (Zhou and Li,

2012). Knowledge sharing capability enables firms to increase their understanding of an underserved new knowledge base (Ho and Ganesan, 2013). Such knowledge is the main prerequisite for outcomes related to green innovation (Albort-Morant et al., 2018). Thus, knowledge sharing capability improves manufacturing firms' innovation potential through quicker access to, and processing of, novel green knowledge.

Second, knowledge sharing capability facilitates the achievement of supplier participation and innovation goals through external coordination of a firm's novel knowledge (Jean et al., 2014). This capability to bring supplier participation and new knowledge together and, subsequently, to share such knowledge internally, is likely to improve the quality of novel knowledge sharing (Gao et al., 2015). Thus, strong knowledge sharing capability complements supplier participation and, at the same time, reduces inefficient or excessive knowledge resource allocation.

Third, knowledge sharing capability is considered an enabler in which one unit is affected by the knowledge and expertise of another unit (Lahiri, 2010). In addition, it considers the extent to which such units use and build on each other's knowledge an important part of knowledge sharing which may occur through formal collaboration or in informal everyday interaction. Furthermore, firms with strong knowledge sharing capability can maximize organizational capacity to encourage their external participants to share their novel and unique knowledge, which will help the firms gain a competitive advantage (Foss et al., 2010).

Accordingly, based on the above reasoning, it is logical to assume that, when a manufacturing firm has strong knowledge sharing capability, their outcomes of supplier participation are strengthened, while novel green knowledge sharing is enhanced. Thus, we hypothesize that:

H4: Knowledge sharing capability positively moderates the effect of supplier participation on novel green knowledge sharing, such that the effect is stronger at a higher level of knowledge sharing capability.

Joint learning capability reflects a relational capability that captures the degree of partner cooperation and participation in developing a relationship-specific, inter-organizational process and communication channel aimed at creating and integrating knowledge for value creating (Huikkola et al., 2013). Although supplier participation, enabled by knowledge sharing capability, may generate new green product creativity through novel green knowledge sharing, that creativity must be captured by joint learning (Jean et al., 2016). Although some managers may assume that novel knowledge sharing in itself leads to successful innovation, a recent study by Wang, Noe, and Wang (2014) shows only moderate support for such a relationship, a finding that could be explained by differences in firms' specialized capabilities.

The role of joint learning capability helps firms create new knowledge sets and transform relational ties into better outcomes (Fang and Zou, 2010; Foss et al., 2010). Strong joint learning capability provides two primary advantages. First, innovation generation is a process of knowledge exchange and combination (Grant, 1996). Joint learning capability involves a firm's exchange of different knowledge resources with its partners to exploit complementarities. With the help of knowledge exchange through joint learning capability in novel knowledge sharing, firms are able to refine and extend their existing product innovation knowledge, which consequently triggers more novel ideas (Jean et al., 2014). Second, strong joint learning capability cultivates goodwill-based trust, such that firms rely on the intentions and behaviors of partners in a specific relationship (Beske et al., 2014). The strong joint learning capability, thus, facilitates collaboration among partners.

We posit that strong joint learning capability helps the manufacturing firm enhance the value of novel green knowledge sharing in generating new green product creativity. First,

goodwill-based trust from strong joint learning capability could help the firm overcome difficulties associated with diverse knowledge assimilation and recombination. Sharing exclusive knowledge with partners is inherently risky, because the offering firm could lose its core proprietary assets if the receiving firm behaves opportunistically (Zhou et al., 2014). Trust in strong joint learning capability can enhance suppliers' confidence that the manufacturing firm will not exploit its vulnerabilities (Jean et al., 2014). Therefore, suppliers are more willing to share novel green knowledge with manufacturing firms.

Second, by facilitating implicit knowledge sharing, strong joint learning capability enhances the value of new product creativity for manufacturers' NGPD. Although supplier participation provides novel and unique knowledge, the knowledge is usually complex and implicit, and difficult to assimilate and utilize (Handfield et al., 2015). Because strong joint learning capability enables the partners to learn about each other's NPD and develop mutual knowledge (Jean et al., 2014), this improves the manufacturer's capacity to absorb complex and implicit knowledge from suppliers. Thus, the manufacturer is more likely to explore with various combinations of diversified and novel green knowledge, leading to greater levels of new green product creativity.

Conversely, if a manufacturing firm does not possess adequate joint learning capability its innovation strategies may be weak, hampering its ability to extract novel knowledge from the supplier. As such, manufacturing firms with weak joint learning capability will face challenges in generating new green product creativity that is the potential value hidden in green innovation. Therefore, we hypothesize that:

H5: Joint learning capability positively moderates the effect of novel green knowledge sharing on new green product creativity, such that the effect is stronger at a higher level of joint learning capability.

RESEARCH METHODS

Consistent with previous studies on green innovation (e.g., Cheng et al., 2014; Shang et al., 2010), this research chose manufacturing industries in Taiwan as the research setting. Among the 328 manufacturing firms, average annual sales revenue was $7.2 million US. The average number of employees was 1168. These respondents had a mean industry experience of 11.2 years and a mean firm experience of 9.6 years. The firms in the sample were distributed by sector, as follows: 66 firms were general machinery (20.1%), 63 firms came from electrical and electronic machinery (19.2%), 58 firms were transportation equipment (17.7%), 51 firms were automobiles (15.5%), 46 firms represented plastics (14.1%), 39 firms were pharmaceuticals (11.9%), and 5 firms were in other sectors (1.5%).

DATA ANALYSIS AND RESUTS

For the model estimation, we used average scores across the items of the constructs, mean-centered to increase interpretability and minimize nonessential multi-collinearity (Aiken and West, 1991). Using Mplus (Muthén and Muthén, 2012), estimates show that the effect of supplier participation on novel green knowledge sharing is positive and significant (0.231, $p < 0.01$), and the effect of novel green knowledge sharing on new green product creativity is positive and significant (0.248, $p < 0.01$), supporting H1 and H2, respectively.

We ran an additional model to check for mediation. We excluded both the interaction terms "supplier participation × knowledge sharing capability" and "novel green knowledge sharing × joint learning capability" for the mediation-only model and ran a Bayesian mediation analysis. The indirect effect is significant (supporting H3), while the direct effect is insignificant supporting mediation, or indirect-only mediation, following Zhao et al. (2010).

The interaction term supplier participation × knowledge sharing capability, is positive and significant (0.253, $p < 0.01$), thus supporting H4. The interaction effect of novel green knowledge sharing and joint learning capability is significant and positive (0.267, $p < 0.01$), in support of H5.

DISCUSSION AND CONCLUSIONS

The findings provide several important contributions to existing green manufacturing research. We develop a more comprehensive theoretical model of how manufacturing firms benefit from supplier participation through the process of novel green knowledge sharing. Although researchers have long recognized the importance of suppliers for manufacturer green innovation (Chatterjee et al., 2018; Katsikeas et al., 2016; Dou et al., 2014), few studies have examined the underlying processes for the efficacy of supplier participation from the perspectives of social network and organizational capabilities. Thus, it is critical to examine the underlying mechanism through which supplier participation contributes to manufacturer green product innovation. While supplier participation provides manufacturing firms with access to external and rich green knowledge, its potential value must be achieved using the process through which the manufacturers and suppliers interact and share the novel green knowledge. That is, novel green knowledge sharing mediates the effect of supplier participation on manufacturer new green product creativity. Therefore, manufacturing firms may not necessarily benefit automatically from supplier participation, without suppliers being willing to proactively share the novel green knowledge. Extending previous studies that emphasize the direct benefit of relational embeddedness between manufacturers and suppliers (Gao et al., 2015; Zhou et al., 2014; Day et al., 2013), our findings provide new evidence that novel green knowledge sharing, from a perspective of relational embeddedness, acts as a mediator for manufacturing firms to benefit from supplier participation.

Our findings provide important implications for manufacturing firms to leverage their supplier participation to facilitate NGPD performance. Our findings suggest that the impact of supplier participation on new green product creativity is maximized at higher levels of knowledge sharing and joint learning capabilities. Managers, therefore, need to ensure that resources are allocated to building knowledge sharing and joint learning capabilities when employing supplier participation. Particularly, the results hint at some unintended consequences of low-level joint learning capabilities. At lower levels of joint learning capability, supplier participation has a negative impact on new green product creativity. This result gives pause to the finding of Govindan et al. (2015) that the impact of supplier participation on green innovation performance is strong and positive. Our results show that this may not be the case for all firms, particularly those at the lower end of the continuum in their green organizational capabilities. Overall, these results call for manufacturing firms to focus on supplier participation, but with recognition of the limits of such a focus and an appreciation for the increased success they can achieve if they simultaneously build essential green organizational capabilities.

The results of this study must be viewed in light of its limitations. First, because supplier participation and both knowledge sharing and joint learning capabilities were captured from a survey, there could potentially be a positive or upward bias on these measures. Future research can consider exploring secondary sources for capturing these metrics.

Second, while this study took a supply-side view to focus on new green product creativity generated by the manufacturing firm, examining the demand-side view of the value of green innovation may also be interesting and valid. Future studies could also take a comprehensive view of customer participation and link it to demand-side concepts, such as customer value.

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DECISION SCIENCES INSTITUTE

The Use of a Self-Managed Learning Project to Teach Governmental Accounting Topics

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ABSTRACT

A self-managed learning project was investigated that required the students to actively participate in their learning by organizing information and writing on moderately complex governmental accounting topics (general capital assets and capital projects funds). The short and long-term project effects were assessed. The student perceptions of the benefits of the project in (a) understanding the topics, (b) doing the homework, and (c) preparing for a quiz/exam were examined by obtaining opinions from student surveys. The self-managed learning project was effective in learning selected governmental accounting topics and it appears to be a good alternative teaching method.

KEYWORDS: Self-managed learning, Governmental accounting, Alternative teaching method

INTRODUCTION

Accounting committees over several decades have recommended that the accounting curriculum should be revised. The Pathways Commission (2012) accelerated the discussion when they indicated that the responsibilities of accounting educators should include both curricular dimension (what we teach) and pedagogical scope (how we teach). Under pedagogical scope this committee suggested that approaches or learning experiences should be developed to help students in thinking, performing, and making decisions that are comparable to accounting professionals.

Earlier, Albrecht and Sack (2000) emphasized that accounting educators need to assist students to improve their ability-to-learn skills. The self-managed learning project (self-generated elaboration) used in this research should give students an opportunity to cultivate or expand their ability to "learn to learn."

In November 2015, the Pathways Commission suggested that accountants develop a signature pedagogy for learning the "Accounting Common Body of Knowledge" that will support the learning approaches of a diverse student body. In 2013 Apostolou *et. al.*, indicated that accounting research is needed to ascertain the best ways to teach or to learn core professional competencies (e.g., communication skills). The research in this paper involved an investigation of whether a self-managed learning project in a Governmental Accounting course is a good technique for teaching selected governmental topics.

In 2008 Jackson and Durkee emphasized that the instructor's role must switch from being the presenter of facts to facilitator of active learning in order for the students to achieve the necessary professional skills. According to Helliar (2013) teaching techniques that engage students should be an essential component of accounting education (e.g., role playing, self-managed learning, and group activities). One of the characteristics of signature pedagogy stipulated by Schulman (2005, pp. 56-57) includes learning experiences that ensure students are active and interactive. Our self-managed learning project was created to engage the students and to require them to actively participate in their own learning.

The Pathways Commission in August 2014 asserted that quality education should incorporate various teaching methods that would encourage students to develop their ability to exercise professional judgment in decision making. Also, Bandura and Lyons (2012) suggested that instructors should include different learning approaches (e.g., lecture, problem-solving, or self-managed learning) in their courses. In addition, Wessels (2010) maintained that the instructor's fundamental role is to persuade students to embrace learning activities that will probably result in the students achieving the desired learning outcomes for the course. Our research study used a self-managed learning project to assist Governmental Accounting students in understanding the general capital assets (GCA) and the capital projects funds (CPF) topics.

Previously, the Accounting Education Change Commission [AECC] (1990) asserted that accounting students should actively participate in the learning process and not be just passive recipients of information. Earlier, the American Accounting Association (The Bedford Committee) 1986; American Institute of Certified Public Accountants 1988; and "Big 8" (now Big 4) CPA firms ("Perspectives . . .") 1989 all have advocated change in accounting education. These committees consistently advocated that accounting education should place more emphasis on writing skills and critical thinking skills.

The AECC in 1990 stated that the accounting curriculum "should lay the base on which life-long learning can be built." The Quality Assurance Agency for Higher Education (2002) suggested that accounting students should have the capability for independent and self-managed learning. The project utilized in this research introduced the students to self-managed learning.

One of the proposals of the Pathways Commission in 2012 was to develop the accounting body of knowledge (Action Item 4.1.1). In November 2015 the Pathways Commission's Knowledge and Pedagogy Task Force endorsed a "Common Body of Knowledge Learning Objectives" for accounting (e.g., communication). Previously, the AICPA Core Competency Framework for Entry into the Accounting Profession (Framework) (1999) identified a set of essential competencies (encompassing 100 elements) for students preparing to enter the accounting profession (e.g., organize, communicate). These competencies are comparable to the skills set elaborated by educators and practitioners in Albrecht and Sack (2000), Canadian Institute of Chartered Accountants [CICA] (2010), the Institute of Management Accountants (1994), the Institute of Internal Auditors (1999), and the Accounting Education Change Commission [AECC] (1990). Our self-managed learning project (elaboration) was designed to enable the students in a Governmental Accounting course to utilize organizational and written communication skills recommended by the Pathways Commission's learning objectives and the AICPA Framework elements.

Our study contributes to the existing accounting literature by investigating the effects of a self-managed learning project on moderately complex governmental accounting topics. Also, there was further exploration of the effects of this teaching technique on both short-term and long-

term knowledge retention. In addition, student opinions of the self-managed learning technique were obtained and an analysis was conducted.

THEORY

Learning-to-Learn

The Pathways Commission (2014) stated that high-quality accounting education should prepare students for a lifetime of learning. In addition, Albrecht and Sack (2000) implied that accounting educators need to assist students in the development of their ability-to-learn skills. Further, Gammie and Kirkham (2008) indicated that the ability to "learn to learn" is a key competency needed by accountants to adapt to the rapidly changing business environment. Our self-managed-learning project should permit the students to have an opportunity to develop or expand their ability to "learn to learn."

The role of learners according to the constructive learning theory is to actively participate in activities that construct their knowledge base. Under this theory the learning environment should be aligned with learning outcomes, which should foster independent learning. According to Seifried (2012) and Tan and Ferreira (2012), constructive alignment transpires when learning outcomes, teaching and learning activities, and assessment are carefully coordinated. Students need to "learn to learn" so that in their professional careers they will be able to discover needed tacit knowledge. Our self-managed learning project enabled the students to participate in an activity that should help them construct their knowledge base.

Other cognitive researchers (Anderson 1970; Gage and Berliner 1984; Ross 1983; and Glaser 1984) have implied that learning is an active process, which involves several steps. The first step requires the students to be attentive. Secondly, the students must encode the information into their own words in a meaningful way. Finally, the students must relate the new information with their previously learned related knowledge.

The self-managed learning concept is similar to the "discovery learning" method (Davidson 1990). Davidson found that the learners were able to retain more because they had discovered the knowledge themselves. Accounting researchers (Springer and Borthick 2007; Hermanson 1994; and Cottell and Millis 1993) have found that when the learners generate their own solutions and/or explanations, they experience ownership and are more likely to retain the information. Our project required the students to develop their own explanations thus allowing them to experience ownership of the information generated during preparation of the project, which should help them retain the knowledge acquired.

Elaborations

Annis (1985) suggested that student-generated paragraph summaries seem to help the students in executing the vital encoding process more efficiently than either note-taking or only reading the information. Levin [1988] found that the learning process might be enhanced by utilizing elaborations. Anderson [1983] defined an elaboration as any information that explains or clarifies some to-be-learned (target) information. An elaboration can be thought of as the link that allows the new target information to be integrated into the student's present knowledge. In addition, several cognitive research studies (e.g., Anderson [1983], Stein *et al.* [1984] and Reder *et al.* [1986]) suggested that elaborations can facilitate memory. Types of elaborations include summaries, examples, analogies, and self-explanations.

Past research has indicated that student-generated paragraph summaries tend to be generally superior to externally presented information (Hite and Parry 1994; Schadewald and Limberg 1990; Pressley *et al.* 1987; Jacoby 1978; Slamecka and Graf 1978; and McFarland, Jr., *et al.* 1980). Bransford *et al.* (1982) found that self-explanations tend to facilitate memory because self-generated elaborations assist the memory to reconstruct the target information, which permits later recall. These research studies involved the encoding of topics that were relatively basic or not very complicated. In contrast, our study involved moderately complex governmental accounting topics. The preparation of the project should help the students retain the knowledge acquired. In addition, the students in our study completed a survey to determine their opinions of the usefulness of the project in (1) understanding the topics, (2) doing the homework, and (3) preparing for a quiz and an exam.

Complexity

Various researchers [Anderson (1995), Driscoll (1994), Gagné and Medsker (1996), Gredler (1997), and Schunk (1996)] have suggested that instructors need to establish different learning opportunities to accomplish different types of learning objectives. Boh *et al*. (2001) indicated that lecture-based training may not be an adequate transfer technique when complexity of knowledge is high.

Bonner (1999, p. 11) suggested that "learning objectives involving complex skills require teaching methods that promote active learning on the part of the students, while learning objectives involving simpler skills can be achieved with more passive teaching methods." In our research the students were required to organize moderately complex governmental accounting topics using a self-managed learning elaboration technique.

Writing-to-Learn

The ability of the accounting students to write is important to the profession. As a result, various professional committees over many years have consistently advocated that accounting education should place more emphasis on writing skills and critical thinking skills. More recently, both the Pathways Commission (2015) and the AICPA's Framework (1999) have indicated that beginning accounting professionals should be able to organize and effectively communicate information so that it can be readily understood by the receiving party.

Hite (2001) recommended incorporating writing exercises into accounting courses when large quantities of information need to be taught (as is the situation in a governmental accounting course). Previously, Stocks *et al.* (1992) commented that writing-to-learn is as important as learning-to-write. In another study, Stout *et al.* (1991) examined the effect of writing assignments on course knowledge. Scofield and Combes (1993) implied that written assignments allow the students to individualize the learning process thus creating their own unique versions of the concept. Zinsser (1988) suggested that writing helps students determine what they do know and do not know.

In 2012 the Pathways Commission suggested that accounting students must possess both technical knowledge and professional skills such as the ability to communicate effectively. In a follow-up report, the Pathways Commission (2014) suggested that quality accounting education should result in students improving their oral and written communication skills. Earlier, Bui and Porter (2010) found in a survey that employers considered communication skills to be essential

for accounting graduates. Despite educators best attempts there still appears to be a disparity between practitioners desired communication skills of accounting graduates and what is possessed by the new graduates according to Conrad and Newberry (2012). Considering this disparity, the Pathways Commission (2015) included under "Professional Foundational Competencies" learning objectives related to communication.

Further, the International Federation of Accountants (IFAC) in its International Education Standard 3 (IES3), Professional Skills and General Education (2008) emphasized that entering accountants should have communications skills. In addition, the Institute of Chartered Accountants in Australia (ICAA) and Certified Practicing Accountants of Australia (CPA Australia) in their International Accreditation Guidelines for Accounting Degree Programs (ICAA/CPA Australia, 2009) indicated that cognitive skills (e.g., writing skills and thinking critically) are essential for accounting graduates to succeed. Our self-managed learning project gave the students an opportunity to write on moderately complex governmental accounting topics.

Learning to Organize

The Pathways Commission's Common Body of Knowledge Learning Objectives (2015) stated that accounting students should be able to identify appropriate accounting information. One of the skills sets that the AECC (1990) believed that students should possess is the ability to locate, obtain, and organize information. In 1999 the AICPA in its Framework (Functional Competencies category under Decision Modeling) indicated the need for entry-level accounting professionals to be able to organize and evaluate information.

Our study presented a self-managed learning technique that required the students to actively participate in the learning process by organizing and writing on information related to selected technical governmental accounting topics. The topics utilized were (1) general capital assets (GCA) and (2) capital projects funds (CPF).

In summary, literature suggests that student self-managed learning can enrich the learning process and that writing projects can be utilized as a learning tool. Since the benefit of self-managed learning techniques may have a greater short-term effect than a long-term effect, the following hypotheses were used to test these effects.

H_1: The distribution of Quiz scores on the GCA (CPF) questions are the same for the students who prepared an outside of class project on this topic as the students who did not prepare an outside project for this topic.

H_2: The distribution of Exam II scores on the GCA (CPF) questions are the same for the students who prepared an outside of class project on this topic as the students who did not prepare an outside project for this topic.

Learning from Examples

VanLehn (1996) suggested that learning from worked-out examples is a good source of learning. Thus, working-out (i.e., reviewing) examples in a governmental accounting textbook should be an important source of learning. According to Anzai and Simon (1979) and Sweller and Cooper (1985), it is possible to learn from working-out examples.

In fact, Anderson, *et.al.* (1984) and Recker and Pirolli (1995) indicated that the preferred learning mode of novices is to work-out examples. Zhu and Simon (1987) noted that learning is achieved more quickly using worked-out examples than from lecturing if the examples are appropriate. They also indicated that participants using the worked-out examples acquired not just rote learning but an in-depth understanding of the subject(s). Other cognitive researchers [Anderson (1987), Tarmizi and Sweller (1988), and Ward and Sweller (1990)] have shown that the utilization of worked-out examples is normally a very effective method of learning.

The students in our research study were required to complete a questionnaire to determine their opinions of the usefulness of reviewing the textbook examples related to the general capital assets (GCA) topic and the capital projects funds (CPF) topic in (1) understanding these topics, (2) preparing the homework, and (3) studying for a quiz/exam on these topics. In addition, this research study compared the students' opinions associated with reviewing textbook examples to reading only the text in the textbook.

Like Stone and Shelly (1997), our study used a questionnaire to measure (Likert-scale used) student perceptions of the self-managed learning technique. The following hypotheses were used to test whether the students considered the project, textbook, and the textbook examples to be useful in understanding the appropriate governmental accounting topics:

H_3: In understanding the GCA (CPF) topics, the students will consider the self-managed learning project (Project) to be as useful as reading the textbook.

H_4: In understanding the GCA (CPF) topics, the students will consider the self-managed learning project (Project) to be as useful as reviewing the textbook examples.

H_5: In understanding the GCA (CPF) topics, the students will consider reviewing the textbook examples to be as useful as only reading the text in the textbook.

Students should be able to apply their newly acquired knowledge. A good self-managed learning project should help the students in this process. The preparation of homework assignments is probably the first time the students apply their recently acquired knowledge. When students take a quiz/exam they also are applying their knowledge. The following hypotheses were used to ascertain if the students believed that the Project was most helpful in (1) understanding the topics, (2) doing homework, or (3) preparing for a quiz/exam:

H_6: The students will consider the Project to be as useful in understanding the GCA (CPF) topics as doing the homework on the topics [preparing for the quiz (exam) on the topics].

H_7: The students will consider the Project to be as useful in preparing for the quiz (exam) on the GCA (CPF) topics as doing the homework on the topics.

RESEARCH METHODS

A governmental accounting class taught by one of the researchers was used in the experiment. At the beginning of the semester, the students were requested to complete a personal data sheet (e.g., classification, university GPA, accounting GPA, credit hours enrolled, work hours, number of accounting course(s) enrolled in during that semester, number of previous

accounting courses, and gender). There were no significant differences between the two experimental groups (GCA topics and CPF topics) on the reported demographic information.

Projects

Every other student in the class was assigned to Group A. In Group A the students were asked to prepare a project (Project A) to assist them in learning about general capital assets (GCA). On the same day, the other students in the class (Group B) were asked to prepare a project (Project B) to assist them in learning about capital projects funds (CPF). The students in both groups were told they could use a checklist, chart, graph, grid, flowchart, outline, or other approach that would help them understand the topics. The project was not to be more than 1 1/2 pages in length. The students were given one week to prepare the project. To encourage the students to complete the project, the project was assigned 25 points, which represented about 4 percent of their grade. The students were instructed to make copies of their projects, which were to be used in preparing their homework assignments related to the topics. On the day that Project A was due, Group B was required to read the GCA topics in the textbook (13 pages). On the day that Project B was due, Group A was required to read the CPF topics in the textbook (17 pages). Both groups received the same class discussion and were assigned the same homework problems for these topics.

Testing

In the class period following the discussion of the homework problems on these topics, a common Quiz was given. During the class period prior to the Quiz, the students were reminded to use their projects to help them study for the Quiz. On this Quiz there were 9 points related to GCA topics and 11 points pertaining to the CPF topics. The results of this Quiz were used to measure the short-term effect of this teaching technique.

Two weeks following the Quiz, a common exam (Exam II) was administered. In the class period before Exam II, the instructor suggested that the students use their projects to help them study for this exam. The results of this exam were used to measure the long-term effect of this teaching technique.

Student Surveys

Just prior to the students receiving the results of the Quiz, the students were requested to complete a survey to determine their opinions on the usefulness of the project in (1) understanding the topics, (2) preparing the homework assignments, and (3) studying for the Quiz. In addition, other questions were included, which were related to the usefulness of both the textbook readings and examples in (1) understanding the topics, (2) preparing the homework assignments and (3) studying for the Quiz.

Prior to returning Exam II, the students were requested to complete another survey to determine their opinions on the usefulness of the project in (1) understanding the topics, (2) preparing the homework assignments, and (3) studying for Exam II. Also, the survey included questions related to the usefulness of both the textbook readings and examples in (1) understanding the topics, (2) preparing the homework assignments and (3) studying for Exam II.

RESULTS

A quiz, which was used to measure the short-term effect of the self-managed learning projects, will be discussed first. Next, the long-term effect (Exam II) will be investigated. Also, the student survey results will be analyzed.

Quiz

During the class period following discussion of the problems on the general capital assets (GCA) and capital projects funds (CPF) topics, a common Quiz was administered, which included 9 points related to the GCA topics and 11 points on the CPF topics. The results of this Quiz were used to measure the short-term effect of the self-managed learning technique. For Project A the students with and without the project scored equally well on the GCA topics (see Table 1). The students with Project B scored slightly higher than the students without the project on the CPF topics, but the chi-square test indicated that the effect of the self-managed learning Project B was not statistically significant.

Table 1
Percentage of Correct Answers by Project Type
Quiz

GCA Project		CPF Project	
Project	88.89%	Project	84.42%
No Project	88.89%	No Project	80.81%

Exam II

Two weeks following the Quiz, a common exam (Exam II) was given. There were 11 points related to GCA topics and 12 points related to the CPF topics on this exam. The results of this exam were used to measure the long-term effect of this teaching technique.

The percentage of correct answers for each project is shown in Table 2. There were different results depending on the project given. For Project B the students with the project scored higher than the students without the project on the CPF questions, but for Project A (GCA topics) the students without the project scored higher than the ones with the project. However, the chi-square test indicated that the effects of the self-managed learning projects were not statistically significant for Exam II.

Student Surveys—Quiz

Just prior to returning the Quiz, the students in both Groups A and B were required to complete a survey to determine their opinions on the usefulness of the projects in helping them (1) to understand their project topics, (2) in doing the homework related to their project topics, and (3) in preparing for the Quiz related to their project topics. In addition, six other questions were included on the survey related to the usefulness of both the textbook readings and examples in

(1) understanding the topics, (2) preparing the assigned homework, and (3) studying for the Quiz. The results of the survey and mean scores are shown in Table 3.

Table 2
Percentage of Correct Answers by Project Type
Exam II

GCA Project		CPF Project	
Project	78.79%	Project	73.81%
No Project	96.10%	No Project	66.67%

The researchers considered the topics covered in Projects A and B to be similar in level of complexity. Therefore, as expected, the students in both groups had similar mean scores pertaining to the usefulness of the projects in (1) understanding the project topics, (2) doing related homework, and (3) preparing for the Quiz (see Table 3). Also, as expected, the students in both groups had similar mean scores related to the usefulness of reading the textbook discussion and reviewing textbook examples.

The researchers had hoped that the students would find the self-managed learning projects to be more useful in (1) understanding the topics, (2) doing homework, or (3) preparing for the Quiz than reading the textbook or reviewing the textbook examples. Generally, the students in both groups found that their projects were as helpful or more beneficial than either reading the textbook discussion or reviewing the textbook examples. The only exception was that the Group B (CPF) students felt that reviewing textbook examples was more helpful in completing homework assignments than either reading the text or preparing the project (see Table 3). However, there were no significant differences.

The students in both groups indicated that reading the textbook was more helpful than reviewing textbook examples in understanding the appropriate topics. However, they found that reading the textbook and reviewing the textbook examples were equally beneficial in preparing for the Quiz [see Table 3].

Group A students indicated that the Project was more helpful in understanding the GCA topics than either doing the homework on the topics or preparing for the Quiz [see Table 3]. Group B students also found that the Project was most helpful in understanding the CPF topics. However, there were no significant differences.

Student Surveys—Exam II

Immediately before returning Exam II, the students in both Groups A and B were required to complete a survey to determine their opinions on the usefulness of the projects in (1) understanding the topics, (2) preparing the assigned homework, and (3) studying for Exam II. Also, the survey included questions related to the usefulness of both the textbook readings and textbook examples in (1) understanding the topics, (2) preparing the assigned homework, and (3) studying for Exam II. The results of the survey are shown in Table 4.

Table 3
Student Survey – Quiz
Mean Scores

	Group A (GCA)	Group B (CPF)
Reading the textbook gave me a thorough understanding of GCA (CPF) topics.	3.375	3.875
The **Examples** in the textbook greatly assisted me in obtaining an understanding of GCA (CPF) topics.	3.250	3.571
Preparing **Project** greatly assisted me in understanding GCA (CPF) topics.	4.125	4.286
Reading the textbook was very helpful in doing the homework on GCA (CPF) topics.	4.000	3.857
The **Examples** in the textbook were very helpful in doing the homework on GCA (CPF) topics.	3.750	4.000
My **Project** was very helpful in doing the homework on GCA (CPF) topics.	4.000	3.857
Reading the textbook greatly assisted me in preparing for the quiz on GCA (CPF) topics.	3.250	3.857
The **Examples** in the textbook greatly assisted me in preparing for the quiz on GCA (CPF) topics.	3.250	3.857
My **Project** greatly assisted me in preparing for the quiz on GCA (CPF) topics.	4.000	4.143

The students in Group A (GCA) felt that the project was more helpful than either reading the textbook or reviewing the textbook examples in (1) understanding the GCA topics, (2) preparing the homework, and (3) studying for Exam II [see Table 4]. However, Group B (CPF) students found the project most helpful in understanding the CPF topics. This group changed their opinions as to the usefulness of the project from the first survey after the Quiz. They no longer

felt that the project was more useful than reading the textbook or examples in preparing for a testing situation [see Table 4]. But, there were no significant differences.

Table 4
Student Survey – Exam II
Mean Scores

	Group A (GCA)	Group B (CPF)
Reading the textbook gave me a thorough understanding of GCA (CPF) topics.	4.125	3.429
The **Examples** in the textbook greatly assisted me in obtaining an understanding of GCA (CPF) topics.	3.750	3.714
Preparing **Project** greatly assisted me in understanding GCA (CPF) topics.	4.625	3.857
Reading the textbook was very helpful in doing the homework on GCA (CPF) topics.	4.000	4.000
The **Examples** in the textbook were very helpful in doing the homework on GCA (CPF) topics.	3.375	4.000
My **Project** was very helpful in doing the homework on GCA (CPF) topics.	4.250	3.857
Reading the textbook greatly assisted me in preparing for the Exam II on GCA (CPF) topics.	3.875	3.857
The **Examples** in the textbook greatly assisted me in preparing for the Exam II on GCA (CPF) topics.	4.000	3.857
My **Project** greatly assisted me in preparing for the Exam II on GCA (CPF) topics.	4.250	3.429

The opinions of Group A students as to the usefulness of the project increased between the two surveys [see Tables 3 and 4]. However, the opinions of Group B students as related to the usefulness of the project in understanding the topics and in preparing for a testing situation decreased between the two surveys. Again, there were no significant differences.

When comparing textbook reading to reviewing textbook examples, the students generally found both methods of learning to be equally helpful [see Table 4]. In fact, Group B indicated that reading the textbook and reviewing textbook examples were equally beneficial in doing homework assignments and in preparing for Exam II.

Group A indicated that the Project was more helpful in understanding the GCA topics than either doing the homework on the topics or preparing for Exam II [see Table 4]. However, no significant differences were found. Group B also found that the Project was equally helpful in understanding the CPF topics and in doing the assigned homework.

SUMMARY AND CONCLUSIONS

The results showed that the mean scores on the Quiz and Exam II were higher for the students with Project B (CPF topics) than the students without this project, but the chi-square test indicated that there were no significant differences. However, for the Project A (GCA topics) students, the mean scores on the Quiz and Exam II were equal to or lower than the students obtained without this project but again there were no significant differences.

This result is similar to the Hite and Parry (1994) study for their announced quiz and final exam. They found only major differences between the two treatment groups on the unannounced quiz given immediately after the experiment. The quiz results of our research do differ from Schadewald and Limberg (1990) who found that the students using self-generated explanations had a better recall on a test given six days after the instructional period ($p < .10$). The difference between our research and the Schadewald and Limberg research may be due to the different types of topics that the students were required to organize in the two studies. Our research and the Hite and Parry study required the students to be able to apply specific rules while the Schadewald and Limberg study requested the students to only understand the reasons why a tax law was enacted.

The students were surveyed both after the Quiz and Exam II to obtain their opinions on the usefulness of their projects, the textbook readings, and exams. On the survey following the quiz, both groups felt that the project was more helpful in understanding the topics and in preparing for the Quiz than either reading the text or studying the textbook examples. However, there were no significant differences. The students indicated on the survey after Exam II that they still ranked their projects to be more beneficial in understanding the topics than reading the text or reviewing the textbook examples, but there were no significant differences. The students in Group A felt that the GCA Project was more helpful in studying for Exam II and doing the homework than just reading the text or reviewing the examples, but Group B felt that their projects were least helpful in preparing for Exam II. However, there were no significant differences.

These self-managed learning projects, which required the students to be active participants in the learning process, were generally equally as effective in learning the governmental accounting topics (GCA and CPF) as either reading the textbook or reviewing the textbook examples. Thus, it appears that the self-managed learning project is a good alternative method of teaching moderately complex governmental accounting topics.

Further, our Project introduced the students to self-managed learning as advocated by the Quality Assurance Agency for Higher Education (2002). In addition, in the preparation of this Project, the students were active participants in the learning process as suggested by

Schulman (2005) and the AECC (1990). Also, the self-managed learning Project was beneficial because the Project did give the students experience in organizing information as recommended by the AECC (1990) and the AICPA Framework (1999). Further, the Project gave the students an opportunity to improve their written communication skills as recommended by the Pathways Commission (2012), the International Federation of Accountants in IES3 (2008), the Institute of Chartered Accountants in Australia and Certified Practicing Accountants of Australia in International Accreditation Guidelines for Accounting Degree Programs (2009), the Canadian Institute of Chartered Accountants in CA Skills and Competencies (2010), and PricewaterhouseCoopers in Educating for the Public Trust (2003).

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The Use of French Words in Brand Naming: An Exploratory Analysis of Luxury Versus Non-Luxury Hedonic Brands

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ABSTRACT

This exploratory proposed that a luxury brand of nail polish (a product category that reflects hedonism) would have a higher proportion of brand names utilizing French words (which have been shown to have a hedonic connotation) compared to a non-luxury brand of nail polish. This proposition was supported.

KEYWORDS: Hedonic brands, Luxury, French Words, Content Analysis

INTRODUCTION

Developing appropriate and meaningful names for products is considered an essential element of effective brand management (Kohli and LaBahn, 1997; Ailawadi and Keller, 2004). Research has shown, for example, that consumers tend to draw inferences from brand names (Peterson and Ross, 1972). And, to the extent that the brand name reflects sound evidence, it serves to enhance the image of the brand which, consequently, leads to higher levels of brand equity. (Kohli, Harich, & Leuthesser, 2005)

It is not surprising, therefore, that market researchers have sought to understand the influence of brand name characteristics on consumer perceptions. At the most fundamental level, this research has resulted in the development of a set of general guidelines that include such things as: (1) distinguish the brand from competitive offerings, (2) facilitate learning of brand associations through suggestive names and/or the use of sound symbolism, (3) achieve compatibility with the desired image, and (4) be memorable and easy to pronounce. (Shimp 2010).

Of these, research on sound symbolism has been an enduring area of inquiry in the marketing literature. For example, Klink and Wu (2017) examined the influence of name characteristics on consumers' perceived ethicality of the brand. Among the findings, they showed that names with higher frequency sounds (i.e., commonly used words) convey greater ethicality than lower

frequency sounds (i.e., words that are more uncommon). Yorkston and Menon (2004) examined sound symbolism in an experimental design for hypothetical brands of ice cream and found that names with back vowel sounds (e.g., such as in 'boot') resulted in a greater preference for a hypothetical brand of ice cream than front vowel sounds (e.g., such as in 'beet'). Merskin (2007) content analyzed brand names from a sample of cosmetic companies and suggested that they tend to "optimize women's emotional connections with food, particularly desserts and rich beverages, through lipstick in two ways: (1) by symbolically consuming of the forbidden fruit and (2) by transforming oneself into the consumable." (587)

Sound symbolism has also been applied to studies of luxury brand names versus nonluxury names. In one of the earliest studies, Meyers-Levy (1989) hypothesized that luxury brands are more likely to use words that are relatively uncommon or distinct (what they term 'low frequency' words that have fewer implicit associations). By using terms that are uncommon (and thereby have fewer associations in memory), the luxury brand can facilitate greater *distinctiveness*, a desired characteristic of luxury brands.

In a related study, Pathak, Calvert, and Lim (2017) examined the linguistic structure of luxury versus non-luxury brand names and hypothesized that "the phonetic structures within luxury brand names are distinct from those of basic brand names and that these distinctions help to maintain the perception of exclusivity associated with luxury brands in consumers' minds." In essence, they argued that the objective of luxury brand names is to create a sense of exclusiveness in consumers' minds and thereby distinguish the luxury brand from non-luxury ones. They found luxury brand names differ from basic brands in their use of distinct phonetic features that can be formally identified: (1) luxury brands names have more syllables, (2) luxury brands are more likely to use back vowels, nasal, and affricates, and (3) luxury brands are more likely to use a higher number of stressed vowels.

The current study seeks to contribute to the body of knowledge on sound symbolism by examining an additional characteristic of sound symbolism; namely, the use of foreign brand names. Foundation for the study is provided by Salciuviene, Ghauri, Strider, and De Mattos (2010) who hypothesized that 'French' sounding brand names would be perceived as more *hedonic* relative to non-French sounding brand names. The results of the study supported the hypothesis that French-sounding words were associated with hedonism. This further validated the findings of prior research in this area (i.e., Thacker and Kohli, 1996; Leclerc, Schmitt, and Dubè-Rious, 1989). By implication, therefore, it would appear that the use French words for brand names of hedonic luxury goods might make sense.

First, we reviewed the relationship between hedonic goods and brand naming. As background, hedonic goods are characterized as ones "whose consumption is primarily characterized by an affective and sensory experience of aesthetic or sensual pleasure, fantasy, and fun" (61, Dahr and Wertenbroch, 2000; Hirschman and Holbrook, 1982). Conversely, utilitarian goods are "ones whose consumption is more cognitively driven, instrumental, and goal oriented and accomplishes a functional or practical task." (61, Dahr and Wertenbroch, 2000; Strahilcvitz and Myers, 1998).

Second, we reviewed the relationship between hedonic goods and luxury in order to identify evidence to support the relationship. Specifically, Kurnaz (2017) maintains that "Luxury items contain emotional value, and when consumers perceive a product to be exquisite, glamorous

and stunning, it creates a *hedonistic experience* for the owner and attributes the luxury product personal meanings (Turunen & Laaksonen, 2011, p. 469)." (109) Given: (1) the relationship between luxury and hedonism and (2) the hedonic connotation of French words, we conduct an exploratory analysis of two brands of cosmetic nail polish to determine the extent to which the luxury brand (i.e., Marc Jacobs) utilizes French brand names in greater proportion that the non-luxury brand of nail polish (i.e., Revlon). The cosmetic industry was selected as the unit of analysis based on the argument that cosmetic products have an inherent hedonic component (Hume and Mills, 2013). As such, it is a product category that appears highly suited to the analysis. While we would expect both brands to utilize French words, it is the luxury component that should help explain differences in proportions. That is, both brands are expected to use French words due to the inherent hedonism associated with the product category; however, given that one of the brands is from the luxury sector, we would further expect it to have a higher proportion of French-sounding brand names. The purpose of this study is simply to provide an exploratory analysis of this proposition.

METHOD

The first stage of the research process involved a content analysis of brand of nail polish. Two American brands of nail polish (one luxury and one non-luxury) were examined to identify the frequency of English versus French words in their sub-brand names. The data was then placed into a contingency table and a chi-square test for differences in proportions was conducted.

In the second stage, the French brand names were translated in English to obtain further insights into the sources of uniqueness. If the English translations reflect common words, it would suggest that the uniqueness of the brand name stems, not from the meaning of the word itself, but from the symbolism of the French language itself.

DATA PROFILES

For the comparison, we selected one luxury brand of nail polish and one non-luxury brand. To help avoid country-of-origin issues, we confined the study to nail polish from one country; namely, the United States. *Marc Jacobs* (n=35) is a well-recognized American brand nail polish and represents the luxury market. *Revlon* (n=59) is a well-recognized American brand of nail polish and represents the non-luxury market. The difference between the two brands, therefore, is the luxury component.

RESULTS

The results of the chi-square test for differences in proportions is presented in Table 1. Each data cell contains information on: the observed value (Obs Val), the expected value (Exp Val) and the individual X^2 values for each cell. The sum of the X^2 values is 8.3952 with 1 degree of freedom (p=.0038). Hence, the proposition that there would be differences in proportions was supported: the luxury brand has a higher proportion of French words.

Table 1: Contingency Analysis			
	Luxury Brand (Marc Jacobs)	Non-Luxury Brand (Revlon)	Marginal Row Totals
French Words	Obs Val = 9 Exp Val = 4.47 X^2 = 4.6	Obs Val = 3 Exp Val=7.52 X_2 = 2.73	12
English Words	Obs Val = 26 Exp Val = 30.53 X^2 = .67	Obs Val = 56 Exp Val = 51.47 X^2 = 0.04	82
Marginal Column Totals	35	59	94 (grand total)

In the second stage of the analysis, the French brand names were translated into English using one of the open-source translation programs available online. The results are presented in Table 2 and reveal that the words do not appear to have unique or distinctive meanings.

Table 2: French to English Translations	
Luxury Brand – Marc Jacobs	Non-Luxury Brand – Revlon
Oui! -> Yes	Romantique -> Romantic
Blaquer -> Fake French, similar to bloquer, to block/stop	Crème Brûlée -> Creme Brulee
Le charm -> The charm	Mauve -> Purple
Delphine -> Classic French name, associated with the noun dolphin	
Lux -> Luxury	
Lola -> A female French name	
Madame -> Mrs	
Louise -> A female French name, derived from the meaning "a famous warrior"	
Blanche ->White	

DISCUSSION

Developing an understanding of how branding elements can influence consumer perceptions has been an important component of the common body of knowledge in marketing. The results of the current study support the proposition that luxury brands will utilize French in greater proportion than non-luxury brands. Nonetheless, it was also argued that the inherent hedonic connotation of cosmetic products would suggest that even non-luxury cosmetics would utilize French words, just not in the same proportion and luxury brands. This proposition was also supported.

The analysis subsequently revealed that the French words, when translated to English, reflect relatively common terms. This was true for both the luxury and non-luxury brands. This suggests that it might be the symbolism of French words that help convey a higher image of luxury, rather than the actual meaning of the word itself.

Given the exploratory nature of this study, additional research may be warranted to examine the extent to which brand names reflect the evidence from the scientific literature. For example, it would be helpful to expand this line of research through an examination of other languages and cultures. Since language has been shown to convey a country-of-origin effect (Salciuviene, et al., 2010) and that the effect can differ across cultures (Strebinger & Rusetski, 2016), this might be a viable course of inquiry.

Additionally, this study was confined to only two brands within a single product category. While the results are encouraging, an examination using a larger sample would help establish the validity of these preliminary results. Furthermore, the research should be extended to other product categories to help establish the extent to which the results are generalizable. Finally, it is important to note that while the results are consistent with the evidence presented in the common body of knowledge, we do not know (and we did not test) whether brand managers utilized this knowledge when developing brand names or, instead, relied on other information. That was beyond the scope of this analysis. Further research may help determine the extent to which brand managers rely on scientific knowledge to guide their decision making.

In summary, the results are encouraging, but remain preliminary. Nonetheless, we are hopeful that the results will help stimulate further discussion and investigation of this phenomena.

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The Use of Predictive Modeling in the Evaluation of Technical Acquisition Performance Using Survival Analysis

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Abstract: In the recent statistical literature, the difference between explanatory and predictive statistical models has been emphasized. One of the tenents of this dichotomy is that variable selection methods should only be applied to predictive models. Because it is well-known that explanatory models and predictive models are different. In this paper, we consider comparing the effectiveness of the acquisition strategies implemented by Google and Yahoo for the management of innovations. We argue that this is a predictive situation and thus apply lasso variable selection to a Cox regression model in order to compare the Google and Yahoo results. We show that the predictive approach yields different results than an explanatory approach and thus refutes the conventional wisdom that Google was always superior to Yahoo during the period under consideration.

Keywords: *Innovation Performance, Acquisitions, Innovation Knowledge, Hazards Model, Cox Proportional Hazards, Survival Analysis, Google, Yahoo, predictive model, explanatory model.*

Introduction

It is well known that management of innovation performance can be crucial to the success of a technology firm. Recently several authors have used survival analysis (also known as event history analysis) as a method to gauge the innovation performance of a firm. Most recently Datta and Roumani (2015) have attempted to do this by means of a proportional hazards (Cox) regression (Cox, 1972) model. We comment that such a time-to-event study is quite a reasonable approach to take but unfortunately the authors were unaware of the statistical difference between predictive and explanatory models as described in the seminal work by Shmueli (2010). This caused Datta and Roumani to confuse the techniques of explanatory modeling (which they used) in their analysis with the appropriate predictive modeling for the analysis of the proposed models. The present paper does the following, it

1) Argues that this is indeed a predictive situation as described by Shmueli (2010)
2) Treats the data analysis of the Cox Regression model, that Datta and Roumani treated by explanatory methods, by the appropriate predictive methodology (in this case adaptive lasso variable selection) and thus
3) Shows that the previous authors' conclusions were in error and
4) Draws the appropriate conclusions and shows that Datta and Roumani were in error in their overall conclusions

This paper thus provides a template for carrying out a statistical analysis of the performance effects of an innovation management program.

Figure 1

Net US Search Ad Revenues, by Company, 2016-2019
billions, % change and % of total

	2016	2017	2018	2019
Google	**$24.60**	**$28.55**	**$32.40**	**$36.62**
—% change	20.2%	16.1%	13.5%	13.0%
—% of total	75.8%	77.8%	80.0%	80.2%
Microsoft	**$2.61**	**$2.79**	**$2.92**	**$3.02**
—% change	8.1%	6.9%	4.7%	3.3%
—% of total	8.0%	7.6%	7.2%	6.6%
Yahoo	**$0.99**	**$1.00**	**$1.02**	**$1.04**
—% change	-20.8%	1.0%	2.0%	2.0%
—% of total	3.0%	2.7%	2.5%	2.3%
Yelp	**$0.61**	**$0.73**	**$0.86**	**$1.00**
—% change	37.8%	20.0%	19.0%	16.0%
—% of total	8.2%	6.9%	5.1%	5.8%
IAC	**$0.51**	**$0.50**	**$0.51**	**$0.51**
—% change	-30.5%	-0.5%	1.0%	1.0%
—% of total	0.9%	1.0%	1.2%	1.3%
Amazon	**$0.28**	**$0.37**	**$0.48**	**$0.60**
—% change	58.0%	32.0%	29.2%	26.3%
—% of total	1.9%	2.0%	2.1%	2.2%
Verizon (AOL)	**$0.21**	**$0.21**	**$0.21**	**$0.22**
—% change	-1.4%	1.6%	1.0%	0.8%
—% of total	1.6%	1.4%	1.3%	1.1%
Total search ad spending	**$32.47**	**$36.69**	**$40.49**	**$45.63**

Note: includes advertising that appears on desktop and laptop computers as well as mobile phones, tablets and other internet-connected devices; net ad revenues after companies pay traffic acquisition costs (TAC) to partner sites; includes contextual text links, paid inclusion, paid listings (paid search) and SEO
Source: company reports; eMarketer, March 2017

223927 www.eMarketer.com

The Figure 1 shows the adverting revenues by companies, as you can see in the Figure 1. Google has most advertisement and highest percentage change.

Model Development

It is well known that Google and Yahoo have used acquisitions as a major part of a strategy to manage innovation performance (Datta and Roumani, 2015). In particular, both have tried to increase their pace of innovation by means of acquisitions. It would be ideal if a way was available to measure the success of each company's program. Datta and Roumani (2015) have attempted to do this by means of a proportional hazards (Cox) regression (Cox, 1972) model.

In order to do this, they posited a number of variables as being important to the company's success. They took the measure of innovation success to be the time to patent (TTP) and the time to launch (TTL) a product, where each was the first such event, which is the first such event of each type that happened after an acquisition measured in days, where a few observations were right censored. The data were found in publicly available data sources (Datta and Roumani, 2015). Because of the type of data a Cox regression seemed a reasonable way to start. They begin by setting up a set of hypotheses to be tested using the parameters of the Cox model and proceeded to test the hypotheses. This is a typical explanatory approach to modeling (Shmueli (2010)). However, for some time many statisticians have made the distinction between explanatory and predictive models. It is well known Shmueli (2010) that one type of model will not always replace the other. Further, the model building methods should often be different for the two types of models. We argue here that by the very method of a time-to-event study predictive modeling is the more appropriate approach. To see why this is so, let us consider the goal of the research. The main goal is to determine which organization made better use of the acquisition process. With their explanatory model, Datta and Roumani (2015) conclude that Google out performs Yahoo on both measures TTP and TTL. Let us now consider if an explanatory model is the most appropriate. Following Shmueli (2010), we wish to infer from the data which of Google or Yahoo has been most successful at using the adopted acquisition strategy as measured by TTL and TTP. In Section 1.5 of the work, Shmueli (2010) says that "Laws connecting sets of variables allow inferences or predictions to be made from known values of some of the variables to unknown values of other variables." Thus here we argue that what we really want to do is to infer whether Google or Yahoo produced the best application of its strategy in the two cases TTP and TTL. We argue that knowing which of the firms is making the best use of the adopted strategy is a forward-looking concept. This is an important distinction because the two types of models in a particular instance are often not the same and the methods used to construct the model are often different. We conclude that a predictive model is most appropriate and thus proceed to use variable selection model building techniques. In particular, shrinkage methods of regression are suitable for predictive but not explanatory models Shmueli (2010). We will show that the result of a predictive model analysis is not the same as an explanatory analysis and further we will show that the predictive model better answers the research question of which firm was most successful in applying each measure of a successful strategy. We further show that the distinction is important because the results of the two analyses are not the same.

Data and Methods

In this section, we discuss the methods that were used in the predictive analysis. The data set was that used by Datta and Roumani (2015) and is described there. We then arranged the data into four subsets for analysis labeled as:

GTTP YTTP
GTTL YTTL

*The Time to Patent (TTP) and The Time to Launch (TTL)

*Google(G), Yahoo(Y)

where the first letter represents the firm, Google or Yahoo, and the remainder of the name represents the dependent measure described. The size of these four sets is shown in Table 1. Cox propositional hazards regression (Cox, 1972) was chosen as the base for building the predictive model. The reason was that we wished to know which firm was more efficient in terms of the goals of patenting and bringing products to market. Outliers were identified by using the robust Cox regression estimator proposed by Faracomeni and Viviani (2011) that is based on trimming. The 5% outliers were removed and set aside for further analysis. The reason for this is that we want to be sure that we have the best measure possible of the average performance of the two firms. The final predictive model was obtained by using the adaptive lasso procedure for Cox regression (Zhang and Lu (2007), Lu et al., 2012, 2013) using a Bayesian Information Criterion (BIC). All final prediction equations were validated as described in Harrell (2001) using bootstrap cross validation with 150 bootstrap samples each, using Harrell's R packages. All computing was done in R. The Kaplan-Meier survival estimates were calculated with the final variable selected reduced Cox regression model as described in Lander (2013). The predictors were those of Tables 2-5. The chosen predictors had at least one non-zero Adaptive lasso coefficient. R programs and the data set are available from the authors.

Cox regression

Outliers can cause serious errors in Cox regression (Faracomeni and Viviani (2011)). Because we are building a predictive model we want the final model to represent the majority of data points without the possible deficiencies introduced by outliers by using the Faracomeni and Viviani (2011) procedure to ameliorate such outliers. We identified and removed the most serious outliers (5%). Because no other information was publically available about the observations removed nothing further was done with them. Table 1 shows the 5% outliers as defined in Faracomeni and Viviani's (2011) algorithm.

Table 1

5% Outliers

Data Set	N	Outliers
GTTP	63	10 13 36
GTTL	63	18 27 40
YTTL	55	13 23
YTTP	55	51 55

One of the major differences between explanatory and predictive modeling is the possible use of variable selection techniques to choose the independent predictor variables in the final selected predictive model. Because of its optimal predictive properties (Zhang and Lu (2007), Lu et al (2012), Lu et al (2013)) we chose adaptive lasso developed by Zhang and Lu (2007) to select the final predictive models for the data sets of Table 1 using a BIC criterion. All final prediction equations were selected by choosing the variables with non-zero adaptive lasso coefficients as shown in Tables 2-5. These prediction equations were successfully validated by bootstrap cross validation (Harrell (2001)) using 150 bootstrap samples each. Kaplan-Meier survival curves were calculated from the final prediction equations as described in Lander (2013). In the case of the Kaplan-Meier curves, the selected prediction equations contained all variables for which at least one Table showed a non-zero Adaptive lasso coefficient.

The analysis proceeds in the following manner. First, we know that outlying data points can cause errors in the conclusions drawn from a data analysis using Cox regression (Faracomeni and Viviani (2011), Lander (2013)). In order to deal with this potential problem, we begin the analysis by looking for outlying observations in our data set using the robust Cox regression method of Faracomeni and Viviani (2011) to identify the 5% outliers in the data. These results are indicated in Table 1. Again, because it is known that outliers are different from the majority of data observations, we removed the Table 1 outlying observations from the data sets and set them aside for separate analysis (Booth, 1984). Second, we then do variable selection on our four data sets after outlier removal in order to choose the optimal predictive model for each data set. Because of the many advantages of the adaptive lasso procedure (Zhang and Lu (2007), Lu et al (2012), Lu et al (2013)), we choose that method, using the R program of Zhang and Lu (2007), as reported by Boos (2014) using a BIC. These results are given in Tables 2-5. The final reduced prediction selected variables were those without 0 adaptive lasso coefficients using a BIC. Equations were validated using bootstrap cross validation with 150 bootstrap samples as described in Harrell (2001) using Harrell's R packages. The Kaplan-Meier survival curves were calculated for each of the selected models (Aalen et al 2008, Lander, 2013). The Google and Yahoo curves were then compared for the patent and product launch data sets to determine whether Google or Yahoo was

more successful in those particular cases over the years studied. The lower of the two curves shows the firm that is the faster of the two in getting patents approved or launching products(Lee, 1992). All programs and data sets are available from the author (DEB).

Discussion of Products for both Yahoo and Google

The results of the analysis are shown in Tables 1-5 and Figures 2 and 3. It is interesting to note the similarities of the Tables. In the patent case (Tables 2 and 5) the major predictor selected was Product_or_Process for both Yahoo and Google. While country was selected for only Yahoo both variables were included in the rest of the analysis. In the product launch case (Tables 3 and 4) new_incremental was selected for both but size of knowledge base was also included in the further analysis even though that selection was specific to Google. It is reassuring to note that the major predictor variables selected in the patent and launch cases were essentially the same for both firms indicating the major drivers were the same in both cases.

We now consider the Kaplan-Meier (Lachin, 2011), (Lee, 1992) curves for the above models. For the Kaplan-Meier curves, in the Time to Patent case (Figure 2) Yahoo is the lower curve while in the Time to Launch case (Figure 3) Google is the lower curve. In both cases there is very little overlap between the 95% confidence bands. In the Kaplan-Meier curves the lower the curve the faster the event happens (Lee, 1992). Hence Yahoo was faster patenting but Google was faster launching products. Because Google was undoubtedly the market leader during this period (Datta and Roumani (2015)) this would indicate that the speed of bringing products to market was a key factor in the competitive leadership at this point in time given that both firms had similar strategies subject to the limitations of the analysis to be described in a moment. This results in variance with the Datta and Roumani (2015) result based on an explanatory model analysis. We suggest based on the previous discussion that the predictive model is to be preferred and hence that the result reported here is to be preferred.

Limitations

There are, of course, limitations to this analysis. These are mostly caused because some information is proprietary. The biggest two such pieces of information that are missing are the amount spent on research and development for each of these products and the amounts spent for marketing the products. Either or both of these sources of funds could have shortened the time for patenting and launching the products. Thus varying amounts spent could have an effect that should have been included in the Kaplan-Meier curves. However, the amounts spent are known only to the two firms.

Conclusion

Since we use adaptive lasso (a variable selection method) the model we built must be predictive. We further argue that the appropriate model in our case is predictive not explanatory before the

model building steps are introduced. We avoid the fact that the use of Cox regression in the original paper (Datta and Roumani (2015)) is incorrect. They have treated the Cox regression coefficients as if they are estimated by least squares which are not the case for Cox regression. Based on our analysis we conclude that Google was more effective at bringing products to market and that Yahoo was more effective at getting patents during the periods studied and that predictive models are more appropriate for this application than explanatory models.

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Table 2

Regression Coefficients – GTTP Data

Dep. Var. – days to patent

X	Robust	Alasso
country	-0.63146	0
base	-0.79707	0
New_incremental	-0.20183	0
Related_or_not	0.00896	0
Product_process	-0.48540	-0.25342
(group) specialization	-0.19025	0

Table 3

Regression Coefficients – GTTL Data

Dep. Var. – days to launch product

X	Robust	Alasso
country	-0.15148	0
base	0.10624	-.07999
New_incremental	-0.75734	3.28530
Related_or_not	-1.45981	0
Product_process	-1.63336	0
(group) specialization	-0.12635	0

Table 4

Regression Coefficients – YTTL Data

Dep. Var. – days to launch product

X	Robust	Alasso
country	-0.28095	0
base	0.02071	0
New_incremental	-1.258578	-0.20215
Related_or_not	-2.458044	0
Product_process	-0.719901	0
(group) specialization	0.159702	0

Table 5

Regression Coefficients – YTTP Data

Dep. Var. – days to patent

X	Robust	Alasso
country	-0.674438	-1.060182
base	-0.051255	0
New_incremental	0.786351	0
Related_or_not	0.858125	0
Product_process	-1.087786	-0.21000
(group) specialization	-0.166944	0

Figure 2
Kaplan-Meier Curve for Time to Patent
The lower curve is Yahoo

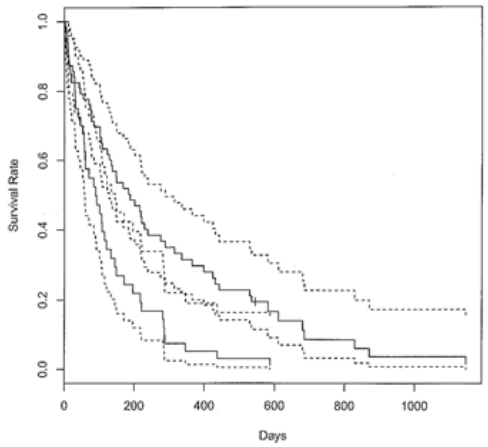
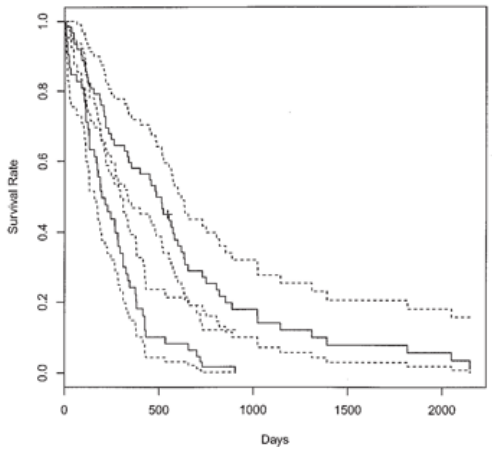


Figure 3
Kaplan-Meier Curve for time to launch product
Google is the lower curve



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Data sources Tools:
https://trends.google.com
https://finance.yahoo.com/

DECISION SCIENCES INSTITUTE
Transparency in Crowdfunding for Emergency Management

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ABSTRACT

We study online crowdfunding as a tool to increase funding for emergency relief campaigns. Crowdfunding campaigns can use two tools to increase the transparency provided to potential donors: certification and online updates. Certification is a form of conventional transparency that ensures the campaign is benefiting a charitable purpose. Alternatively, updates are additional status posts and are a form of operational transparency when they communicate the work of the campaign. Using data from a large crowdfunding website, we show that work-related updates (operational transparency) have a stronger effect on increasing donations than certification (conventional transparency).

KEYWORDS: Operations strategy, Humanitarian aid, Crowdfunding, Operational transparency, Donations

DECISION SCIENCES INSTITUTE

Tweets and posts: Social networking sites and political knowledge in the 2016 U.S. presidential election

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ABSTRACT

To what extent does a political candidate's social media presence influence people's views and their real-world political activities? We conducted a survey using Mechanical Turk asking questions about social networking use and political involvement with regard to the 2016 presidential election. We asked factual questions about politics to gauge political knowledge. We find low-information voters are more easily influenced by friends' posts and are more likely to be influenced by candidates' social media to change real-world political activities; in contrast, high-information voters are less easily influenced by friends' posts and less likely to be influenced by what candidates post.

KEYWORDS: Social media, political knowledge, participation

INTRODUCTION

Tens of millions of people are using social networking sites (SNS), and social media use has exploded in recent years. Businesses, celebrities, and politicians are trying to use this to their advantage. In particular, politicians now have a new method through which they can reach out to large numbers of people in a relatively inexpensive way (Gueorguieva 2008), with presidential candidates relying on Facebook and Twitter to communicate directly with voters (Kreiss 2016). However, the effectiveness of using social media in this way for political gain is still a matter of debate.

A growing literature discusses the connections between SNS and political participation. Studies have examined how candidates for office use their public pages (Robertson, Vatrapu, and Medina 2010; Haynes and Pitts 2009; Williams and Gulati 2013); how those pages create space for political discourse (Robertson, Vatrapu, and Medina 2009); if SNS are altering basic democratic values (Swigger 2013); and whether SNS encourage people to become politically active (Conroy, Feezell, and Guerrero 2012; Baumgartner and Morris 2010; Bode 2012; Vitak et al. 2011; Vesnic-Alujevic 2012; Towner 2013; Zhang, Seltzer, and Bichard 2013; Dimitrova and Bystrom 2013; Bode et al. 2014). In one notable recent study, a 61 million person experiment of Facebook users was conducted to see if political messages would

mobilize people to be politically engaged. They concluded that the messages affected political behavior both online and offline (Bond et al. 2012).

Others, however, have argued that the high hopes surrounding the possibilities of online political discussions have not yet been fulfilled (Larsson 2013). There is, so far, no consensus in the existing literature on whether or how offline and online political activities influence each other, with some studies seeing a direct connection and others separating the two. Clearly much work on understanding the impact of the Internet on politics remains to be done (Farrell 2012).

We propose here to expand on this literature by examining the extent to which a political candidate's social media presence influences citizens' views on candidates for high public office and their real-world political activities. In particular, we are interested in understanding how political knowledge (or lack thereof) mediates the relationship between politicians' social media use and the ways average citizens behave as a result. We recruited 717 subjects for a survey via Amazon.com's Mechanical Turk platform. The survey asked questions about their demographic and political characteristics, social media use, the extent to which they are influenced by politicians' presence on social media, as well as questions about their level of political knowledge. The results suggest an important role for political knowledge in mediating the relationship between politicians and citizens on social media platforms. This has important implications for our democracy: to the extent that people's lack of knowledge informs their political actions online, the discourse on social networking sites may be significantly poorer as a result.

LITERATURE REVIEW

The literature on social media use by citizens is divided on the question of whether users of social networking sites are more or less likely to be politically engaged as a result of their social media use. Baumgartner and Morris (2010), Kushin and Yamamoto (2010), and Larsson (2013), for instance, found that users of SNS were no more likely to engage in offline political participation than those without social networking accounts. Harlow and Guo (2014) also suggest that digital communication tools may lead users to engage in "clicktivism" rather than real-world activism, while Theocharis and Lowe (2016) find that Facebook use actually negatively correlates with political and civic participation. A study by Richey and Zhu (2015) also found that Internet usage does not improve political efficacy, political interest, or political knowledge for late adopters of this technology. Qiu et al (2015) find that network effects help content to go viral.

On the other hand, studies by Bode (2012), Towner (2013), Towner (2017), Rice et al. (2013), and Zhang et al. (2013) did find a positive relationship between online social media political involvement and real-world political participation. Pasek et al. (2009) argue that different types of social networking sites will affect offline participation in different ways, and Chan (2016) similarly notes that the size of a person's Facebook network affects their political participation on that site. The massive experiment conducted by Bond et al. (2012) also found that political messages posted on people's Facebook news feeds did cause those targeted to become more active in politics, to be more likely to vote, and more likely to influence their friends to participate in politics as well. Similarly, a meta-analysis by Boulianne (2015) found that there is generally a positive relationship between social media use and real-world participation, both in the U.S. and across the world. Bimber and Copeland (2013) qualify some of this by suggesting that the relationship between digital media use and political participation may vary over time.

A subset of this literature on the relationship between social media and political participation examines the question of how political knowledge affects the relationship between social media usage by political actors and citizens' involvement in political activities. Although knowledge of political affairs is a key component of civic understanding and political participation (Galston 2001) most Americans seem to have a somewhat limited understanding of the details of politics and policy (Delli Carpini and Keeter 1996). Scholars have long understood that political information is not evenly distributed among the public, with important implications for understanding vote choice (Converse 1962, 2000). Some studies demonstrate a link between gaining knowledge about the issues and the public's judgment of those issues (Gilens 2001), with misleading information having a detrimental effect on that judgment (Jerit and Barabas 2006). Many studies have shown that partisanship acts as an important informational cue, especially for low-information voters (Bartels 2002; Bolsen, Druckman, and Cook 2014; Jerit and Barabas 2012; Schaffner and Streb 2002). Increased levels of partisan polarization in recent decades have also significantly affected the information environment by making party endorsements more important and decreasing the relevance of substantive information (Druckman, Peterson, and Slothuus 2013). Bullock (2011), however, argues that the impact of partisan cues has been overstated, at least for citizens who already possess good information about policy.

Kenski and Stroud (2006) suggest that the Internet does contribute positively to political knowledge, though the overall effect in their findings is small. Similarly, a study by Cacciatore et al. (2014) argues that Internet use can narrow knowledge gaps in the public. Dimitrova et al. (2014), however, suggest that the effects of online media consumption may assist only weakly in political learning with some possible effects on greater political participation. In a similar vein, Baumgartner and Morris (2010) show that, while social networking may be a potential tool for people to increase their political knowledge, the news gathered this way does not tend to enhance democratic discourse. As they note, "there is little evidence to suggest individuals who get their news about politics on SN Web sites are well informed" (Baumgartner and Morris 2010, 34).

On the other hand, Groshek and Dimitrova (2011, 368) argue that "more frequent exposure to Internet news and more attention to campaign information online was a significant predictor of political knowledge." Tran (2013) also suggests that online news use does lead to gains in political knowledge. Kaufhold et al. (2010) compared the effects of professional and citizen journalism, finding that consumers of professional journalism were slightly better informed, but that consumption of any form of news tended to produce more political involvement. Bode (2016) presents a more nuanced view that citizens may be *able* to learn more from social media, but do not always do so in practice. Similarly, Towner (2017) found that, while offline sources do not affect young adults' levels of political knowledge, some types of online information (specifically those from online newspapers and television campaign websites) are linked to improved political knowledge levels. This literature does not, however, fully examine whether political knowledge may act as a mediating influence between what political actors post on social media and how citizens' involvement in political activities is affected as a result.

HYPOTHESES

Researchers have found a positive relationship between political involvement on social media and real world participation (Bode 2012; Towner 2013; Towner 2017; Rice, Moffett, and Madupalli 2013; Zhang, Seltzer, and Bichard 2013). News gathered through SNS does not necessarily keep people well informed (Baumgartner and Morris 2010), and yet those who

consume any form of news tend to have more political involvement (Kaufhold, Valenzuela, and Zúñiga 2010). However, those with lower levels of political knowledge may be more easily influenced by their exposure to the media environment (Galston 2001; Lupia 2016).

Therefore, we hypothesize:

H1. Low-information voters will be more easily influenced by friends' posts and more likely to be influenced by candidates' social media presence to change their real-world political activities (such as voting or donating to the campaign).

In the current era of growing partisan polarization, party endorsements have become ever more important and the relevance of unbiased information has decreased (Druckman, Peterson, and Slothuus 2013). Bullock (2011), however, argues that the impact of partisan cues has been overstated for citizens who already possess good information about policy. In contrast, those with less information in any political party will be at a disadvantage.

Therefore, we hypothesize:

H2. *Low-information voters will be more easily influenced by friends' posts and candidates' social media presence regardless of their political party.*

MECHANICAL TURK AS A RECRUITMENT TOOL

Mechanical Turk is a relatively new platform that acts as an online labor market. Participants who wish to serve as subjects or are willing to carry out various tasks are paid relatively small sums of money (often as little as 10 cents) for their time. Requesters, often conducting various types of research, are thereby able to recruit large numbers of subjects at minimal cost. The total number of participants on Mechanical Turk is estimated at over 500,000. The effectiveness of this method of subject recruitment has been demonstrated in recent studies that find MTurk samples to be generally reliable and comparable to more expensive methods (Berinsky, Huber, and Lenz 2012; Buhrmester, Kwang, and Gosling 2011; Chandler, Mueller, and Paolacci 2014; Horton, Rand, and Zeckhauser 2011; Mason and Suri 2012; Shapiro, Chandler, and Mueller 2013; Berinsky, Margolis, and Sances 2014; Clifford, Jewell, and Waggoner 2015; Huff and Tingley 2015; Ipeirotis 2010; Levay, Freese, and Druckman 2016). Studies using MTurk have been published in fields as diverse as political science, psychology, computer science, and economics (Berinsky, Huber, and Lenz 2012; Horton, Rand, and Zeckhauser 2011; Amir, Rand, and Gal 2012; Grose, Malhotra, and Parks Van Houweling 2015). This new platform opens up the possibility of recruiting a larger number of subjects with relative ease and at low cost.

METHODOLOGY

We recruited 717 participants via Mechanical Turk (332 female, 383 male, and 2 who identified as other). We limited the survey only to those in the United States, and it was open from November 5, 2016 – November 7, 2016 and therefore closed before Election Day. All participants received 40 cents to answer our survey. Before beginning, participants had to affirm that they had either a Facebook account or Twitter account and were eligible to vote in the U.S. election. They were then asked to select whether they had a Facebook account,

Twitter account, or both. 232 respondents (32.36%) had only a Facebook account, 25 (3.49%) had only a Twitter account, and 460 (64.16%) had both a Facebook and Twitter account.

Using a Likert-scale from 1-5 where 1 is *Strongly Disagree* and 5 is *Strongly Agree*, we asked participants a series of questions pertaining to their social networking and political activity, broken down into four different categories: their social networking usage (Facebook or Twitter), political activity, their political activity on social networking sites, and the influence candidates and their friends on SNS had on modifying their political beliefs.

Statements on SNS Activity (*SNS_Active*):

I check my social networking site often
I post on my social networking site
I read people's posts often
I reply to people's posts often

Statements on Political Activity (*POL_ACTIVE*):

I volunteer in support of political causes
I attend political events
I have worked for candidates for office
I have donated to candidates for office

Statements on Political Activity on SNS (*POL_ACTIVE_SNS*):

I have joined political discussions through a social networking site
My status updates are often about political events
My status updates are often about political candidates

Statements on Politically Influenced on SNS (*POL_INFLUENCED_SNS*):

A political candidate's active presence on a social networking site affects my decision on how to vote

A political candidate's active presence on a social networking site affects my willingness to donate to his/her campaign

I often change my mind based on my friends' political opinions via social networking sites

I often change my mind based on my friends' opinions on political candidates via social networking sites

These items loaded into their respective factors, and Cronbach's Alpha is .85 for SNS_ACTIVE, .88 for POL_ACTIVE, .86 for POL_ACTIVE_SNS, and .83 for POL_INFLUENCED_SNS. Four statements that did not load into these factors were removed.

Furthermore, we asked participants five factual questions about political issues to gauge their level of political knowledge. These questions are, word for word, the same ones used as part of the pre-election survey conducted by the American National Election Study (http://www.electionstudies.org/studypages/anes_timeseries_2012/anes_timeseries_2012_qnaire_pre.pdf) as part of its massive panel study during every presidential election year. These questions are therefore a reliable and proven method for measuring political knowledge. See questions below:

Do you happen to know how many times an individual can be elected President of the United States under current laws?

1. Once
2. Twice
3. Three Times
4. Four Times

Is the U.S. federal budget deficit – the amount by which the government's spending exceeds the amount of money it collects – now bigger, about the same, or smaller than it was during most of the 1990s?

1. Bigger
2. About the Same
3. Smaller

For how many years is a United States Senator elected – that is, how many years are there in one full term of office for a U.S. Senator?

1. 2 years
2. 4 years
3. 6 years
4. 8 years

What is Medicare?

1. A program run by the U.S. federal government to pay for old people's health care
2. A program run by state governments to provide health care to poor people
3. A private health insurance plan sold to individuals in all 50 states
4. A private, non-profit organization that runs free health clinics

On which of the following does the U.S. federal government currently spend the least?

1. Foreign aid
2. Medicare
3. National defense
4. Social Security

We added the results of the five political knowledge questions together for each participant to get their *political knowledge score* in order to determine the relationship between political knowledge score and participants' likelihood to be influenced by SNS.

RESULTS

The mean, maximum, minimum, and standard deviation of the respondents' political knowledge scores as well as their SNS activity, Political Activity, Political Activity on SNS, and their level of Influence through SNS can be seen in Table 1.

Table 1. Participants' Average Political Knowledge Score and Political and SNS Activity (N=717)

Variables	Mean	Std Dev	Minimum	Maximum
Political Knowledge Score	3.62	1.05	0	5
SNS_ACTIVE	3.54	0.90	1	5
POL_ACTIVE	2.00	1.02	1	5
POL_ACTIVE_SNS	2.33	1.09	1	5
POL_INFLUENCED_SNS	2.03	0.86	1	5

Table 2 shows the breakdown of participants' demographics and political knowledge scores. Spearman's rank correlations were computed and there were significant and positive relationships between education and score (ρ=0.20187, p<.0001) and age and score (ρ=0.21256, p<.0001). The more educated and older participants were, the better their political knowledge scores. The results of t-tests show that there were no differences between males and females with regard to their political knowledge score,t(713)=-.89, p=0.37, or whites and non-whites, t(715)=0.07, p=0.95. In addition, using an ANOVA we found no differences in political knowledge score between Republicans, Democrats, and Independents, F(2, 693)=0.48, p=0.62.

Table 2. Participants' Demographic Information and Political Knowledge Scores (N=717)

Demographics	N	Score	Std Dev
Ethnicity			
White	555	3.62	1.04
African American	49	3.27	1.04
Asian American	55	3.91	1.02
Hispanic	38	3.47	1.25
Native American	4	3.75	0.5
Other	13	4.08	0.64
Prefer not to answer	3	4.33	1.15
Education			
Did not complete high school	1	5	.
High school Graduate / GED	71	3.32	1.09
Some college / Associate degree	247	3.44	1.08
College graduate	303	3.70	1.00
Postgraduate degree	95	4.05	0.93
Gender			

Female	332	3.59	0.94
Male	383	3.66	1.14
Other	2	2.5	0.71
Age			
18-25	106	3.24	1.12
26-30	157	3.46	1.13
31-40	214	3.63	1.01
41-50	107	3.84	0.97
51-60	89	3.87	0.92
61-70	38	4.11	0.83
70+	6	4.17	0.75
Political Orientation			
Democrat	336	3.61	1.04
Independent	217	3.67	1.05
Republican	143	3.57	1.09
Other	21	3.81	0.93

Participants generally checked their social networking sites (Facebook and/or Twitter) often. See Table 3 for a breakdown of how often participants checked their social networking sites. Over 80% checked their SNS at least once a day (column 2). While Table 1 shows that participants were not very politically active, Table 3 reveals that over 70% of the participants discussed political events (column 3) and the presidential election (column 4) at least a few times a week. Spearman's rank correlations show a negative relationship between the frequency of checking SNS with their political knowledge score (ρ=-0.09, p=0.01). The lower the score, the more they checked SNS. However, there were no significant correlations between the number of times they discussed political events (ρ=0.03, p=0.42) or the 2016 election (ρ=0.06, p=0.09) with their political knowledge score.

Table 3. Frequency of SNS Usage and Political Discourse

	Check SNS	**Discuss Political Events**	**Discuss 2016 Election**
At least a few times a day	410 (57.18%)	114 (15.90%)	138 (19.25%)
About once a day	182 (25.38%)	192 (26.78%)	190 (26.5%)
At least a few times a week	80 (11.16%)	220 (30.68%)	206 (28.73%)
Once a week	25 (3.49%)	98 (13.67%)	113 (15.76%)
Less than once a week	20 (2.79%)	93 (12.97%)	70 (9.76%)

On a 5-point scale ranging from not at all likely to very likely, 542 (76%) of the respondents stated that they were very likely to vote, and another 78 (11%) said they were likely to vote. The mean for likelihood to vote was 4.5.

Table 4 shows a correlation matrix depicting significant and negative relationships between political knowledge score and SNS_ACTIVE, POL_ACTIVE, POL_ACTIVE_SNS, and POL_INFLUENCED_SNS. The lower the score, the more likely participants were to be active on SNS, politically active, politically active on SNS, and influenced by a candidates' presence on SNS as well as by their friends' political opinions on SNS. While it is statistically significant, the correlation coefficients are relatively low in terms of practical significance. The largest coefficient is with the negative relationship between participants' political knowledge score and level of political influence on SNS. There is a negative relationship showing the more they were influenced on SNS the lower their political knowledge score, which supports H1. While the direction as we hypothesized was negative and significant, it was not too strong (ρ=-.26). However, even small impacts can have the potential to help determine an election.

Table 4. Pearson Correlation Matrix (N=717)

	Political Knowledge Score	**SNS ACTIVE**	**POL ACTIVE**	**POL ACTIVE SNS**	**POL INFLUENCED SNS**
Political Knowledge Score	1	-0.13**	-0.12**	-0.15**	**-0.26*** **
SNS ACTIVE		1	0.18**	0.45***	0.24***
POL ACTIVE			1	0.54***	0.43***
POL ACTIVE SNS				1	0.46***
POL INFLUENCED SNS					1

*p<.05; ** p<.01; *** p<.001

Tables 5-7 show correlation matrices broken down by political party. For all party affiliations (Democrat, Republican, and Independent) there was a significant and negative relationship between political knowledge score and politically influenced on SNS. Therefore, H2 was supported. The lower the political knowledge score, the more likely participants were to be influenced by their friends' statuses as well as by candidates' presence on SNS, regardless of whether they were Republicans, Democrats, or independents. Using Fisher's r to z transformation, we were able to calculate the z values in order to assess whether there were any significant differences between political parties and their level of influence on SNS (POL_INFLUENCED_SNS). The differences between the correlations were not significant (Influence between Democrats and Republicans: Z=0.87, p=0.38; Independents and Republicans: Z=1.1, p=0.27; Democrats and Independents: Z=-0.36, p=0.72).

Table 5. Pearson Correlation Matrix For Democrats (N=336)

	Political Knowledge Score	**SNS Active**	**POL ACTIVE**	**POL ACTIVE SNS**	**POL INFLUENCED SNS**

Political Knowledge Score	1	-0.12*	-0.07	-0.14*	**-0.25*** **
SNS ACTIVE		1	0.21***	0.47***	0.22***
POL ACTIVE			1	0.54***	0.39***
POL ACTIVE SNS				1	0.46***
POL INFLUENCED SNS					1

*p<.05; **p<.01; ***p<.001

Table 6. Pearson Correlation Matrix For Republications (N=143)

	Political Knowledge Score	SNS ACTIVE	POL ACTIVE	POL ACTIVE SNS	POL INFLUENCED SNS
Political Knowledge Score	1	-0.01	-0.25**	-0.19*	**-0.33*** **
SNS_Active		1	0.17*	0.43***	0.24**
POL_ACTIVE			1	0.55***	0.48***
PSNS_ACTIVE				1	0.52***
POL_INFLUENCED_SNS					1

*p<.05; ** p<.01; *** p<.001

Table 7. Pearson Correlation Table for Independents (N=217)

	Political Knowledge Score	SNS Active	POL ACTIVE	POL ACTIVE SNS	POL INFLUENCED SNS
Political Knowledge Score	1	-0.22**	-0.10	-0.13*	**-0.22** **
SNS_Active		1	0.15*	0.44***	0.26***
POL_ACTIVE			1	0.51***	0.45***
PSNS_ACTIVE				1	0.41***
POL_INFLUENCED_SNS					1

*p<.05; ** p<.01; *** p<.001

DISCUSSION

The results we have reported above suggest several tentative conclusions about the mediating role of political knowledge on the relationship between political candidates' use of social media and citizen involvement in political affairs. The hypotheses we laid out at the beginning seem to be borne out: citizens with low levels of political knowledge are more likely to be influenced by the posts of their friends as well as a candidates' presence on social networking sites to change their real-world political behaviors, in particular to vote for them or donate to them. Those with greater levels of political knowledge, on the other hand, are less likely to be influenced by candidates' SN presence to carry out those activities. These findings seem to hold true across lines of political party affiliation. All parties showed a significant and negative relationship between their political knowledge score and level of influence via SNS. Similar to the findings in studies by Baumgartner and Morris (2010), Bode (2016), Dimitrova et al. (2014), and Richey and Zhu (2015), who have examined the relationship between Internet usage and political knowledge, this suggests reasons for skepticism about the possibility of social networking usage being a tool for enhancing political knowledge.

Interestingly, though the coefficients were not too strong, we did see patterns emerging that those with higher levels of political knowledge reported being less active on SNS, politically active, and politically active on SNS than those with low levels of political knowledge. In contrast, those with low political knowledge scores were more likely to be active. To the extent that social media is flooded with posts by people with low levels of information about politics and policy (Delli Carpini and Keeter 1996), we should be concerned that democratic citizenship may be damaged through the sharing of incorrect information, or at least information not subject to critical scrutiny (Farrell 2012). Online deliberation has been shown to over-represent certain demographic groups (Baek, Wojcieszak, and Carpini 2012), but it may also be the case that political conversations via social media are also more likely to be sidetracked through disinformation and lack of policy understanding. Partisanship did not seem to be particularly relevant, with most of the results (people's political activities on SNS, and being politically influenced by SNS) suggesting that Democrats, Republicans, and Independents all behave in similar ways.

The comments left by some survey respondents indicated that their misunderstandings of certain policy issues run quite deep. One of the political knowledge questions was about federal government spending:

> On which of the following does the U.S. federal government currently spend the least?
> 1. Foreign aid
> 2. Medicare
> 3. National defense
> 4. Social Security

The correct answer is foreign aid. At least two survey responders commented with specific reference to the fourth choice, Social Security. One remarked, "Social Security is NOT funded by the government." Another said, "I may be mistaken, but I think that Social Security is funded by those who have paid into it in the past. I keep hearing that it will run out of money in the near future." Both of these are misunderstandings of how the program operates; the first is a clear factual error, but even the second confuses the status of the Social Security trust fund with current Social Security payments in the overall federal budget (see https://www.ssa.gov/pubs/EN-05-10024.pdf). Contrary to many onlookers' hopes (Bimber 2003), people with incorrect information may be driving online debates about politics, to our detriment as a democratic polity.

One potential limitation of this study is that we have only examined results from one election cycle. As Bimber and Copeland (2013) suggest, the relationship between Internet usage and political activity may vary as patterns of Internet usage change, Future research in this vein should continue to examine these questions in other elections, especially to see if these results hold true in midterm elections as well as in presidential election years. Additionally, future research should expand the range of social networking platforms examined, including others such as Snapchat or Instagram.

CONCLUSION

This study has examined the question of how political knowledge mediates the relationship between political candidates' use of social media and how citizens respond to them. We find that there is a significant and negative relationship between political knowledge and SNS activity, political activity, political activity on social networking sites, as well as being politically influenced via those sites. Those with less political knowledge are more likely to be

influenced by their friends' statuses as well as by candidates' presence on SNS. Our findings should be seen as a step toward deeper examinations of this topic. Future research should examine the extent to which this relationship persists across different election cycles, especially to compare midterm and presidential-election years, as well as examining the strength of this relationship across time. We also suggest that scholars should continue to explore whether lack of political knowledge is an insuperable obstacle to democratic citizenship online, or if learning can occur to improve deliberation.

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DECISION SCIENCES INSTITUTE

Uncertainty and asymmetric information: Impact of credence inputs on firm competitiveness

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ABSTRACT

The main contribution of the paper is in proposing a model that relates the buying firm's level of risk associated with the purchase of critical inputs to the disclosure, by the supplier, of input information characteristics and means of production. It suggests that as the level of risk and seclusion of information increases, buying firms will tend to engage in more complex contracts with their suppliers to safeguard their position. Implications for further research are discussed.

KEYWORDS: Asymmetry, information, credence, uncertainty, competitiveness

INTRODUCTION

One of the main problems faced by managers in the food industry is how to guarantee the delivery of wholesome and safe food to markets. Since the mid-nineties both the US and the European Union engaged in intensive legislative activity to increase food safety, through pathogen and contaminants reduction (Hennessy, Roosen, & Jensen, 2003). Under this changing environment, where firms face increasing pressure from governments, and are increasingly being liable for failing to meet safety standards, it is important to understand how management strategies are developing. Furthermore, consumers are now demanding a larger variety of products, there is increasing vertical integration and horizontal consolidation of firms at all levels of the supply chain and retailers have increasing power and are demanding more value from other players in the supply chain (Kinsey, 2003). Managers of large food processing corporations such as Nestle, General Mills, or Heinz, have to be increasingly concerned with the quality and safety of their inputs and at, the same time, are being forced to deliver more attributes for less money by retailers.

A central problem with food safety is asymmetric information on the quality of inputs, which leads to uncertainty, increasing risks and market failures with considerable economic and political consequences (Hennessy et al., 2003). The development of suitable policies to reduce food safety hazards has been extensively treated by economists in recent years. In the US there is increasing consensus that performance standards are more effective than command and control ones in achieving food safety. Even though firms have more flexibility under performance standards, managers will face increasing pressure as now they have to make strategic and

tactical decisions leading to compliance with food safety goals. The objective of this paper is to shed light into decision-making on a complex environment where there is asymmetric information on the characteristics of inputs, opportunities to seclude crucial information on input characteristics and risks of being held accountable for problems originated on inputs. It analyzes the vertical relationships between firms in sequential tiers of a supply chain, reasoning about different options available using the resource-based view (RBV), transaction costs economics (TCE), and to some extent, institutional theory frameworks.

BACKGROUND

In the field of strategic management, asymmetric information has been treated in the context of vertical integration, diversification and consolidation strategies (Prahalad and Bettis, 1986; Chatterjee and Wernelfelt, 1991; Reuer and Koza, 2000; Hennart and Reddy, 2000). The transaction cost theory and resource-based view have both been used to develop frameworks on which to evaluate and propose strategies leading to merger between firms. There has not been much focus of the resource-based view on the food industry.

Before making a purchase, buyers need information about the price and quality of the good or service that they are considering to purchase. Obtaining this information is particularly difficult in the case of a most credence goods or services because of their intangible nature. What makes particularly difficult for the consumer is the standard credence good problem, i.e., the asymmetrical nature of information they possess. The seller often knows more about the quality of the good or service than the uninformed consumer him/herself (Bester & Dahm, 2018). The veracity of a credence good depends on trusting the word of the seller, and service goods are simultaneously consumed while being produced (Mills, 1986; Nayyar, 1990). As shown in Table 1 below, the most recent research on information asymmetry has discussed the prevalence of misleading and deceptive credence claims in market place, specifically dividing them into broad three broad categories related to provenance of the good/service, where it was manufactured or produced, and its quality (Hobill & Sanderson, 2017).

Table 1: Deleterious Claims that Information Asymmetry May Conceal

Categories	Types of claims
Sources/derivation of foods or products	Claiming that foods are sourced from, or made in, a particular location when they are not, e.g., claiming that a food or product is manufactured or produced in the America, when it is not.
Manufacture and production of foods	Claiming that foods are produced or manufactured in a particular way when they are not, e.g., claiming that eggs are from ‘free-range’ or ‘free to roam’ hens, when it is not; or that mean was prepared ‘kosher’ when it was not.
Qualities and characteristics of foods	Claiming that foods have a particular standard, quality or value when they do not, e.g., claiming that a beverage contains ‘real’ fruit or is ‘healthy’ when it does not; or that bread is ‘fresh’ when it is stale.

It is also more difficult for the buyer to obtain information on the costs involved in producing the good or service to be able to estimate the value added to the final product or service they are

considering to purchase (Stigler, 1961). Sellers, on the other hand, possess greater information about their product or service than buyers, which is the basis of information asymmetry (Nayyar, 1990). In situations where buyers lack such key information, the resultant buyer-seller information asymmetry provides buyers with the opportunity to engage in behaviors that may be detrimental to the buyer. According to agency and moral hazard theories, these situations may provide agents (managers or sellers) with opportunities to engage in self-aggrandizing behavior vis-à-vis their clients (or owners or customers) with relative guile and impunity (Richardson, 2000; Williamson). This is done by the "incomplete or distorted disclosure of information, especially to calculated efforts to mislead, distort, disguise, obfuscate, or otherwise confuse" (Williamson, 1985: 47). Furthermore, when sellers do not bear full responsibility for the costs or risks associated with their products, not only are they inclined to raise prices, but they are also likely to exercise less effort toward reducing the costs (Holmstrom, 1979; Pauly, 1974). In fact, lately some research has revealed that moral hazard is not limited to its primary manifestations, but is often ramped up to what has become known as second-degree moral hazard (Balafoutas, Kerschbamer, & Sutter, 2017). This has been reported in the market for taxi rides, where moral hazard was empirically observed to exhibit a significant positive effect on the likelihood of overcharging when passengers had explicitly stated that their expenses would be reimbursed their employers (Balafoutas, et al. 2017).

Different institutional arrangements are suggested when the levels of risk and information seclusion on relevant characteristics of inputs. When the risk of inputs and information seclusion is low, the market is a reliable and probably the most efficient institution. However, if risks and seclusion levels are high, buyer will better engage in hard contract to safeguard their position. From this framework three propositions are derived and commented below. The paper is divided into five parts. The introduction is followed by a section two, which reviews the most recent literature specifically related to the resource-based view and transaction cost economics theory. Section three presents a series of proposition that summarize the options available to firms. This is followed by section four that discusses of the implications of the propositions. The paper ends with a concluding section that offers suggestions for future research.

LITERATURE REVIEW

This second part reviews relevant literature in asymmetric information, the resource based view (Barney, 2001; Priem & Butler, 2001; Penronse, 1959; Verbeke & Kano, 2012); transaction cost theory (Coase, 1937; Madhok, 2002; Tong & Crosno, 2016; Williamson, 1989); and institutional theory (DiMaggio & Powell, 1983; Haveman, 1993; Scott & Meyer, 1983; and Tolbert & Zucker, 1996). The latter, especially through mimetic isomorphism – the achievement of conformity through imitation (DiMaggio and Powell. 1983: 151-152) – is one of the processes through which organizations change over time in due to pressure to conform with other organizations in their environments. Researchers in institutional theory assert that mimetic isomorphism can result from efficient responses to uncertainty (DiMaggio and Powell, 983).

Asymmetric information on quality of inputs

In several industries characteristics of the inputs are directly associated to those of the products from them derived. Information on the attributes of inputs is then critical to managers, as the efficiency of processing or manufacturing and the value of the final product depends on inputs. The economics literature identifies three types of goods or attributes with respect to the way users can get information about them: search goods are those about which information is readily available; experience goods have to be tested before information on their characteristics can be

obtained and finally the quality of credence goods cannot be judge even after they have been consumed (Antle, 2001).

The problems resulting from asymmetric information were first discovered in investigations of leading causes for fluctuations in output and employment-large variations in the sales of new cars (Akerlof, 1970). In those investigations it was discovered, rather by chance, that the informational problems that exist in the used car market were potentially present to some degree in all markets. In some markets, asymmetric information is fairly easily resolved by repeat sale and through reputation. In other markets, asymmetric information between buyers and sellers is not easily resolved and often results in serious market breakdowns. For example, in insurance markets the elderly have a hard time getting health insurance; in credit markets, (Hobill & Sanderson, 2017) small businesses are likely to be credit-rationed; and in the market for labor, minorities and women are likely to experience statistical discrimination because people are lumped together into categories of those with similar observable traits (Akerlof, 2002: 413). Asymmetries in information are prevalent in credence goods or attributes, and lead to important inefficiencies, as there are incentives for opportunistic behavior on the suppliers of such type of products leading to under provision of high quality similar to the market of lemons (Akerlof, 1970). In fact, more recent research on information asymmetry theory conducted on online marketing suggests that lemons could drive high quality items away from a market, leaving a dominance of poor quality goods (Scott, Gregg, & Choi, 2015). This situation is particularly critical when associated to input attributes that affect not only firms but society as a whole, as is clearly the case of food safety. The literature in food safety provision is on a dead end, as either it becomes possible to convert credence attributes into experience ones, through credible labeling, third party certification or some other regulatory mechanism, or profit maximizing firms will always under provide credence quality attributes (Antle, 2001).

When the credence attribute or input is critical for a processing firm, managers have to find ways around the information asymmetry, as otherwise firm's profitability may be hurt. Goldsmith (2004) suggest that for purposes of high risk mitigation or market up lift, managers in buying firms may engage in hard contract on products identity preservation to increase control over products characteristic, and example outside the food industry is the Intel chips. What this suggests is that in the case of critical inputs, firms actively pursue institutional arrangements to solve information asymmetries. Along with input's identity preservation firms may require some sort of insurance or certification that the inputs they are buying have the required characteristics, if firms upstream on the supply chain have buying power, as it seems to be the case of retailers in the US and EU (Kinsey, 2003), the costs of such guarantee may successfully be passed down to the seller. This creates a problem, however, for the former may retaliate and cheat whenever they think they can go along with it.

Resource Based View (RBV)

The resource-based view was proposed by Wernerfelt (1984) in his classic paper, where he analyses the firm from the assets it has available and suggests that firm's diversification and competitiveness may be associated to control over critical resources. These can increase the competitive position of the firm by: leading to barriers to entry, facilitate diversification and expansion, and by reasons for mergers and acquisitions. When revisiting the paper in 1995, Wernerfelt acknowledges contributions from Rumelt (1984), who provides an explanation for heterogeneous resource endowments, and Montgomery and Wernerfelt (1988) and Montgomery and Hariharan (1991) who incorporate transaction cost economics into the resource-based view. He suspects that future research in the field will focus on how firm's resource endowment translates into successful strategies.

In subsequent years, Locket and Thompson (2001) focus on the apparent rejection of the RBV by economist, insisting that this strategic management theory is closely associated to economics, namely to industrial organization from which the concepts were originally derived. They argue that path-dependency of firm's competitive advantage is an important contribution derived from the RBV and it should be more used in economics. The authors identify in the literature a number of points of tension, between the RBV and economics: the first relates to the concept of efficiency in resource allocation, which is not much used in RBV; second to economist the way strategic management researchers establish the relationship between resources and outcomes, is somewhat ambiguous (Prim and Butler, 2001); third hypothesis generation is tautological. However, Lockett and Thompson argue that economist willing to understand in more detail why some firms become more competitive than others, should consider using more concepts of RBV and identify four areas where this theory could provide insights into economics: new institutional economics; dynamic proprieties of RBV; explanation of radical changes in firms and RBV insights to anti-trust issues.

Another recent paper in this area tries to reconcile the RBV with the competitive strategy perspective formulated by Porter (1980). The authors propose and test a model comparing these two perspectives of strategic management, aiming at reconciliation of these theories to a more general causal logic for firm's success (Spanos and Lioukas, 2001). They find that both industry and firm effects are important in explaining firm's behavior and therefore call for more intensive use of both RBV and competitive strategy concepts in the identification of sources of firm's sustainability. In the RBV, resources are normally seen as assets that firms have and which ensure their competitiveness. To Wernerfelt (1984) brand names, in-house knowledge of technology, trade contacts, machinery, capital are all examples of resources. But he also seems to suggest that buying and/or selling power and access to specific resources can also be considered resources leading to competitive strategies in Porter's sense. Therefore, gaining information on a critical credence input seems to be a reasonable way to obtain competitive advantages using a RBV insight.

Transaction Costs Economics (TCE)

The sphere of influence of a firm, the role of prices on resource allocation and the coordination actions of the entrepreneur are discussed by Coase (1937). According to the TCE theory firms are a particular form of organization called a "hierarchy" for administering exchanges, or "transactions," between one party and another. This form (the "hierarchy") is then contrasted with "markets," in which transactions take place without managerial oversight (Coase, 1937; Williamson, 1975; 1985). At the heart of the TCE theory are three characteristics, namely, asset specificity, uncertainty, and frequency of interaction. Asset specificity is the extent to which the seller possesses unique proprietary inputs to the product/service being purchased. Uncertainty is the inability to predict future business conditions. Frequency is the number of times the buyer will make repeat purchases of the same good/service. Asset specificity and uncertainty are the two important dimensions of TCE, which lead to an increase in costs to the buyer of using the market. They are essential motivators for the drafting of protective contracts that are prompted by the likelihood of failures in the market mechanism due to friction in bilateral transactions between parties (Williamson, 1989). Firms therefore exist because they can reduce the costs of negotiating and are more effective than the market in resolving disputes that would arise from the exchange (Coase, 1937).

TCE theory has had great influence in economics and strategic management as it sheds light into firm's organization, reasons for vertical integration, buyer/sellers contracts, multinational enterprises, the role of managers and many other issues. Analyzing the extent to which vertical integration leads to better performance, D'Aveni and Ravencraft (1994) find that

strategic management researchers and economist have opposing views on the role of vertical integration in improving performance. The conflict seems to originate on the gains from efficiency assumed by economists and the increasing bureaucracy cost recognized by strategic management researchers. D'Aveni and Ravenscraft (1994) develop an empirical model to test three hypotheses emerging from this conflict: the first argues in favor of vertical integration posing it leads to lower costs and higher profitability; the second poses that vertical integrated firms face higher administrative and ratios of production costs to sales, and, last, the third relates demand uncertainty to higher costs in vertically integrated firms, when compared to non-integrated ones. In their model, they control for economies of scale and scope as they may generate noise on the hypothesis. They use data from 1976 Federal Trade Commission (FTC) line-of-business database, which they claim to be the only one suited for strategic and competitive advantage variables of interest. Their main result is that integration economies are more important than increases in costs due to bureaucracy, which seem to be mostly associated to higher production cost due to lack of market pressure. Forward integration seems to be more profitable than backward, the results were consistent across industries included in the FTC database.

In a more integrative paper, Madhok (2002) tries to reconcile two important theories of the firm, the transaction costs economics (TCE) and the resource based view (RBV). While TCE is mainly concerned with why firms exist, hence concerned in understanding the coordination through the market or through an authority with an organization, the RBV focus on each firm, and on its competitive advantage. After suggesting why there hasn't been any effort to combine the insights of TCE and RBV, the author provides his main contribution: the triangular alignment hypothesis, in which the boundaries between the firm and the market and their competitive advantage depend not only on transaction costs (as suggested by TCE), nor on the resources (associated to he RBV), but on both of these and also on the governance structure. Madhok's main conclusion is that Coase's contribution is even more significant for strategic management when one recognizes the association between TCE and RBV and then adds the governance structure to these. There is already some evidence that both costs and skills matter, but there is still need for further research unifying these two theories.

Institutional theory

According to institutional theory, organizations are embedded in a social environment that is constituted by institutional rules and norms (Meyer & Rowan, 1977). These rules and norms represent expectations shared by the members of a society or industry about what constitutes "good" management and how an organization should be structured to be effective. When they eventually become established or taken for granted, these expectations then become accepted as norms that govern behavior, in other word, they become institutionalized. When that stage is reached, institutionalized norms and mores shape the cognitive processes of decision-makers by reducing many of the uncertainty surrounding such decision processes. (DiMaggio & Powell, 1983). Because of their emphasis on uncertainty reduction and the search for legitimacy, the assumptions of the institutional theory stand in contrast to those of the transaction cost economics theory whose emphasis is on economic efficiency and profits maximizing. The incongruity between the goals of efficiency and legitimacy has accepted in the extant literature since the pursuit of legitimacy often requires the adoption of practices that impede efficiency (Dacin, 1997; Meyer & Rowan, 1977). However, over the years, the scholarly literature has slowly been moving in the direction of accepting a convergence between the mandates of legitimacy and pursuit of efficiency goals (Dacin, 1997). Furthermore, deviation from institutional prescriptions is sometimes possible as organizational actors pursue their strategic interests, or

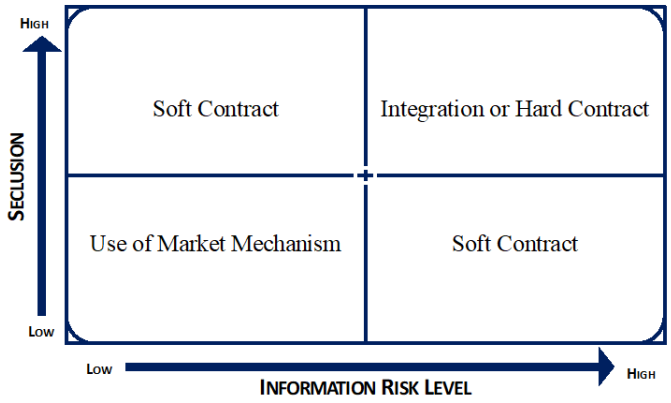
exercise discretion in ambiguous institutional contexts (Goodrick & Salancik, 1996; Oliver, 1991).

THEORETICAL DEVELOPMENT/MODEL

The literature on TCE and RBV will now be used to develop a construct for the analysis of the strategic formulation under asymmetric information on critical inputs. Throughout it will be assumed that the inputs or its attributes are credence in nature, meaning it is difficult and costly to assess the quality of the input even after its use. Furthermore, it will be assumed that firms at consecutive stages of a supply chain are heterogeneous and may take actions to improved credibility and reduce the level of information asymmetry if it improves their sustainability or competitiveness. One of the problems associated to asymmetric information is that it may to lead to a trap, for while information is a source of market power and therefore the rational decision maker, as described in the neoclassical model of economic, will seek rents to disclose it, under the circumstances considered in here retaining information may weaken the competitiveness of the firm with more information.

Asymmetric information increases the risk to the buyer of a critical input, especially in the case of credence inputs taken in here, as if the supplier opportunistically cheats on the quality of the product delivered, the product produced will under-perform, affecting the competitiveness of the buyer. Hence both the seller and the buyer of a credence input may improve their competitive position if they respectively disclose truthful information and engage in actions to increase their level of information on the product they buy to the other party. As Antle (2001) suggests the price mechanism fails when there is asymmetric information on credence attributes, hence some other institutional organization must be devised to solve this problem. One possibility is to vertically integrate, form some sort of partnership or contract with the seller, all of these clearly fall in the realm of TCE. Buying firms that are able to resolve the problem will control an important asset and improve their competitive position in the industry, the same can be said about those selling credence inputs, this competitive difference originates on assets of firms and therefore falls in the RBV explanation of competitive position.

Figure 1: Institutional arrangements: buyer/seller vs. information risk and seclusion



The discussion above proposes that firms selling credence inputs may improve their competitiveness by voluntarily disclosing private information on the characteristic and production process of the product they are selling. Also, depending on the risks associated to the product in question different institutional arrangements may be devised. Figure 1 suggests

such arrangements as the level of risk and seclusion (in the sense of non-disclosure of information) increases. The model is inspired on Goldsmith (2004), and identifies three different institutional arrangements.

In the context of this construct a soft contract is one where the parties retain control over their operations and penalties from breaking it do not severely hinder the position of firms. On a hard contract the parties agree on giving up some control over their operation, namely disclosing information that is relevant for the other party, a third party may inspect the quality of the information and severe penalties possibly leading to as much as the shut down of the business belonging to the offending party are included. Note that the market is not absent in this construct, in fact if there is easy access to information and low risks associated to the product or input being sold, transaction costs are low and the use of the market is justified. From this figure, several propositions may be derived, relating the strategic actions available to both buyers and sellers transacting a credence product subject to asymmetric information, with different levels of risk. We present the following three propositions, which are followed by a brief comment.

Proposition 1*: A supplier willing to disclose information on the characteristic and production process of the product it sells improves his competitive position by either having an easier access to market or to less strict contract forms.*

Given that at the core of the problem is an information gap, if a supplier voluntarily decides to disclose full information on whatever he is selling, it becomes less risky to deal with him and hence its opportunities are improved. In the food industry, the main causes of food safety hazards are well established and are associated to certain malpractices at the farm or processing levels, if information on these are made readily available then it become easier to prevent consequences of such actions. A firm in this industry that strives to always use the best practices and actively corrects errors and prevents accidents on the production process will certainly have a better competitive position than careless competitors. In such a situation disclosing information on its practices and allowing its clients to check how it is operating, will further extend a firm's competitiveness. In this sense, this proposition seems to be plausible and logical, as by adopting an open doors policy a firm becomes more trustworthy and will become a more attractive provider of inputs, where quality is associated with certain procedures. In consequence, this will improve the competitive position of the firm.

Proposition 2: *Buyers of high-risk inputs will avoid the market and use contract or even other complex institutional to have more control over information and avoid exposure to opportunistic behavior of sellers.*

Market transactions are necessarily anonymous in the sense that no relationship is established between buyer and seller, there is no guarantee that the same actors will ever meet again on a transaction. In this sense the seller as no incentive to disclose more information that the one provided by other participants in the market because it will be impossible to reap any rents from such action. When the product being sold has the characteristic under consideration here, the costs of transacting will be too high for a buyer. Hence, since sellers on the market have no incentive to offer more information than the one provided by peers, the only possibility to a buyer facing high risks on a critical input is to turn to other institutional arrangements. As Figure 1 suggests, a supplier in such circumstances will have to choose on being more open about the level information, face a harder contract form or simply abandon his operations. Buyers that are

able to establish contractual relations with firms downstream, will improve their competitive position as they will be less exposed to risks associated to under-performance of inputs.

Proposition 3: *A buyer that develops a method to obtain accurate information on the credence attribute, may improve his competitive situation.*

In the case that no seller is willing to accept a contract, a buyer that is able to develop a method to differentiate suppliers according to their level of risk will improve its competitive position. Investment of research and technology is one of the assets identified by Wernerfelt (1984) as a resource that leads to an improved competitive strategy. The question remains whether a buyer can really obtain the requisite information on a product in a neoclassic market if such a development is possible. The answer would be a rejection of the assertion since, by definition, all relevant information is readily available and costless for all participants. However, in real world markets, purchases often involve some sort of test to the product before a decision is made, for example car test drives are now commonly offered by most dealers. Therefore, it seams reasonable that a firm may want to test a product, specially a critical input, before a purchase, if such a test provides crucial information at a negligible cost, it will certainly have an edge to competitors using the same resource**.**

DISCUSSION

The propositions above may be criticized at several levels, for one they contradict a common practice in current business strategies, where firms kept as much information as possible from competitors, being they at the same or different tiers of the supply chain. In this sense, the propositions above, namely the first one, may be regarded as unrealistic. Another possible criticism is that opportunistic behavior will lead to just another form of problem, for buyers will have incentives to provide incomplete or even false information and still have their way. Also, it could be argued that by definition of credence attributes or goods, it is impossible to provide credible information on them, which severely limits the practicality of such construct. Yet there is some evidence that firms in the food industry do take strategic positions as those proposed on part 3, as the work of Golan et al (2004) suggests. She and her co-authors investigate the implementation of voluntary traceability systems (through which information on sources and characteristics of food are kept along supply chains) and find that firms sharing information improve their competitive advantage by reducing the risks and costs associated to food safety hazards.

Kinsey (2003) announces that a new paradigm or economic system in the food industry is emerging and changing the way information is shared, as well redefining ownerships and management styles. It is a fact that markets of all types of food are more and more differentiated and that globalization is creating enormous distances between producers and consumers of products. As these realize the consequences of such situation retaining information may severely hurt the competitive status of firms. Also, firms adopting systems for disclosing information seem to be getting a better positioning in the market, either by improving their image on the face of consumers or by acquiring more contractual opportunities, in the case of producers of inputs. It is interesting to note how the reality of markets appears to be solving the impasse suggested by theory. But further analysis is required in order to investigate whether there is change on then structure of the market, in the sense that the rules of the game are being revised so that previous best responses are no longer useful, or if nothing really changed and the uncertainty as shifted from the product to the level of information.

An important insight of the RBV, as suggested by Locket and Thompson (2001) is its dynamic proprieties. This certainly can be introduced on a model analyzing the propositions

above, as it seems reasonable to assume that by having more information some preventive measures currently used by firms to avoid consequences of critical inputs may no longer be required, leading to efficiencies and improved competitive position. Also, it seems important to study how disclosing information changes the position of selling firms in the market. An interesting ethical and socially responsible argument may be made here. Are firms realizing that in order to keep they position in the market they have to do the right thing just because that is the way it should be done? This will remain an open question, for it is out of the scope of this article, but it should be carefully analyzed and tested in future research.

CONCLUSION

'This paper contributes to the literature in strategic management when there is asymmetric information and risk in crucial inputs for the performance of firms. A real application would be the food industry, where unavailability of information on credence inputs may lead to severe food safety hazards. Economists analyzing the consequences and remedies of food safety, suggest that more efficient food safety hazards reduction would be achieve if firms were given the opportunity of finding the most appropriate method of meeting a certain level of performance.

While allowing more flexibility this solution places a burden on managers. TCE, RBV, and Institutional Theory are found relevant for the formulation of constructs, models or frameworks to approach this problem, for on one hand asymmetric information rises the costs of using the market and decisions on disclosing or hiding information affect the competitive standing of firms in the industry. The main contribution that this paper makes is proposing a model that relates the level of risk associated to the purchase of critical inputs to the disclosure of information on its characteristics and means of production. As the level of risk and seclusion of information increases buying firms will tend to engage in harder contracts with their suppliers to safeguard their position.

Three propositions are offered and briefly discussed in the paper. The first proposition is that sellers of inputs with credence proprieties will improve their competitive position if they are willing to disclose their private information on the product they sell. The second is that buyers of very risky inputs will avoid the market and engage on different types of contracts upstream. The third and final proposition is that buyers investing in methods to check the quality or truthfulness information on their seller's input will presumably improve competitive standings in the industry. Though the insights from both neoclassical economics and opportunistic behavior on TCE cast doubts on the validity of the propositions suggested, there is some evidence that the food industry is undergoing a paradigm shift and some firms voluntarily adopting institutional arrangements, such as traceability systems, that increase the levels of transparency on products characteristics. The question is whether there is really a change in the way relationships between firms are established in an industry, or if it is the quality and accuracy of information, rather than that of products, that is the new source of uncertainty in this industry. Future research would use the propositions offered here on a coherent model to prove their implications. The work of Goldsmith (2004) is another good starting point for such an effort. Then, the industries described on the case studies elaborated by Golan, et al. (2004) could come under closer scrutiny to investigate whether the proposition have empirical support.

Finally, with the proliferation of product information websites, it is appropriate to raise questions about their impact on firm profitability, consumer surplus, and social welfare. Recent studies have raised concerns about effect of information in the market place (Fernqvist & Ekelund, 2014; Markopoulos, Aron, & Ungar, 2016). One study has shown that it is actually the firms that are more able to take advantage of information availability especially from websites, reduce their own information investments, and increase their profitability. The same research found that the existence of these websites may actually reduce social welfare, which seems to

contradict the conventional belief that more product information is beneficial for buyers (Markopoulos, Aron, & Ungar, 2016). More research would bring additional light on this important revelation since if the stated goal of transparency and information availability is to maximize consumer surplus, then a Pandora's Box of ethical concerns might be opened by such findings. Indeed, it appears that ethical issues may be at the core of the evolution observed in the food industry, as there may be some moral or social responsibility positioning under the current trend of providing more information on the supply chain. If this can be confirmed then there is a real chance of a Kuhnian (1970) paradigm shift in this industry. Either way, more research is necessary to clarify the dynamic.

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DECISION SCIENCES INSTITUTE
Understanding Cuban Internet Use: A Digital Citizenship Perspective

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ABSTRACT

Cuba is a territory where having Internet access is luxurious and challenging. To understand Cuban Internet use by individuals, we conducted this exploratory, mixed methods study. Drawing upon digital citizenship and digital divide literature, we collected and analyzed survey data of 60 Cuban users. The Chi-square analysis shows significant relationships existing among age group, network type, durations per connection, and frequency, location and medium of access. The qualitative data analysis reveals that, although Cubans encountered both physical and social barriers to global Internet and national intranet, they valued the Internet capabilities of communicating and online knowledge acquisition. Practical and policy implications are discussed.

KEYWORDS: Internet, Intranet, Digital citizenship, User value, Mixed methods, Cuba

> "I enter the 12-digit user name and 12-digit password from my paper slip and wait. The operation fails. I type it in again. And then again. I realize I should have charged my laptop for this. Eventually the spinny wheel stops. I have been rejected. I enter my user name and password three more times, each time more determined…. I am not giving up. I have already come this far…..This is going to be the time. I can feel it. … I type in my 12-digit login and 12-digit password for what must be the 100th attempt. … Hemingway never wasted an hour wrestling with crappy Wi-Fi. I smash an ant crawling across my screen with my login paper…" [Reported from Havana, Cuba, 4/22/2016]

MOTIVATION: CUBAN PARTICIPATION ONLINE

The opening vignette is an excerpt from the *Fortune* news article written by Erin Griffith who expressed her frustration and anxiety during the one hour of trying to go online from a WiFi hotspot in La Rampa, a six-block long stretch of the 23rd street in Havana. During her 3-day trip to Cuba to report on former U.S. President Obama's historic visit to Cuba in April 2016, Erin Griffith observed that "People don't get on the Internet in Cuba... They 'go to Internet,' …" such as making trips to the limited number of Wi-Fi hotspots across the island country.

In a networked world where citizens of developed countries enjoy the affordable and ubiquitous Internet access and social media technologies, it's difficult to imagine a place on the Earth where getting online is not only a luxury but also a challenging experience. Cuba is such a territory. An estimate 5 percent of its citizens have access to the global internet and roughly 25 percent of the people have access to the Cuban intranet, based on the self-reported statements by Empresa de Telecomunicaciones de Cuba S.A. (ETECSA), government monopoly controlling cell phone, fixed phone and Internet markets in Cuba. This makes Cuba one of the least connected countries in the world (BBC News, 2016). Among the barriers to Internet access, high prices, exceptionally slow connectivity, and extensive government regulation have become the major hurdles to Cuban citizens to go online.

In 2015, Cuban government opened 35 public Wi-Fi hotspots in Havana and the rest of the country. Those Wi-Fi hotspots provided global Internet access. As of March 2018, there were 673 hotspots, 207 fixed navigation rooms, and 771 navigation areas in hotels, Joven Clubs, and post offices, according to the 2018 Informatica conference and trade show concluded held in Havana (http://www.informaticahabana.cu/). However, the daunting cost of access has prevented majority of Cuban citizens from having an Internet access. According to a BBC news report published in February 2016, the daunting cost for the slow Internet connection was $2 (£1.4) an hour, or about one-tenth of a Cuban's average monthly salary (BBC news, 2016). Although the cost was reduced to 1.5 CUC per hour (about $1.5) as of March 2018, the access to the global Internet remains slow and unreliable, at a maximum of 1 mbps due to radio and backhaul congestion (http://www.informaticahabana.cu/). Moreover, most citizens only have access to the national intranet, the internal network controlled by the state-owned telecom provider, ETECSA.

In this paper, we intend to address two questions: (1) how do Cuban citizens engage in the Internet technology? (2) do their behaviors of the technology use differ?

To achieve our research objectives, we conducted an exploratory study of Cuban Internet use from individual citizens' viewpoints. This research is informed by literature of digital citizenship, which we define as regular and effective use of digital network in terms of access and skills, consistent with prior research (e.g., Mossberger, Tolbert, and McNeal, 2007). We seek to understand individual Cuban's digital citizenship behavior associated the Internet technology. In particular, we view digital citizenship behavior as enactment of individual behaviors (in relation to *how, when, what* and *why*) in performing activities in the electronic network, including both the global Internet and national intranet.

We adopted a mixed methods approach, combining qualitative and quantitative analyses, which allowed us to explore linkages across variables systematically and to provide a rich account of user perceptions and backgrounds (cf. Mingers, 2001). Findings arising from this exploratory study are intended to provide insights into the emerging Internet adoption and use phenomenon in Cuba, and in furthering our conceptualization of information technology literacy in a different national context.

INVESTIGATIVE CONTEXT: CUBA INTERNET HISTORY AND CURRENT STATUS

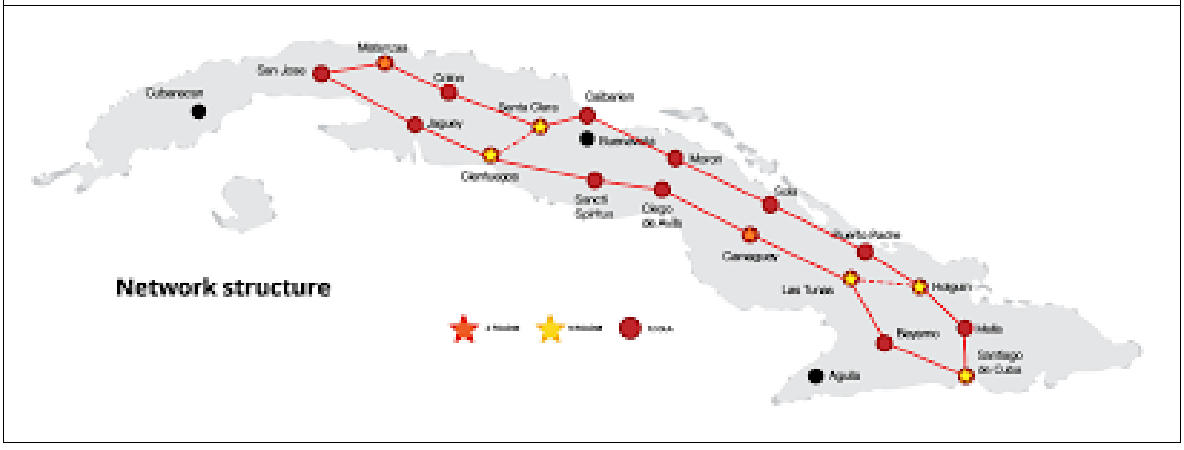
Three indices, the United Nations Development Program Human Development Index (HDI), the Freedom House Freedom on the Net score (FON) and the International Telecommunication Union ICT Development Index (IDI), establish context for the Cuban Internet. The HDI is a function of income, health and education and Cuba is the tenth ranked nation in Latin America and the Caribbean. FON is a function of obstacles to Internet access, limits on content and

violations of user rights and only five of 65 nations are rated as less free than Cuba. The IDI is a function of user access, use and skills. Cuba's IDI is ranked 135th of 175 nations.
Cuban policy emphasizes education and health care, which compensates for a relatively poor economy in determining their HDI and their emphasis on education drives the relatively high HDI skill component, offsetting low access and use ratings. According to the ITU's ranking of 175 countries, Cuba is ranked 135 in ICT Development Index (IDI), 167 in Access, 150 in use, and 57 in skills.

The sad state of the Cuban Internet is a product of its history. Cuba connected to the Internet shortly after the fall of the Soviet Union, which Raúl Castro and others thought was due in part to Soviet glasnost (openness). The Soviet collapse also triggered a Cuban economic crisis caused by the end of Soviet subsidy (Press, 2011). Bureaucracy and vested financial interests are believed to play a large role in Cuba's highly restricted global Internet access (Press, 2016a). In early 2017, ETECSA conducted a free home-connectivity trial in Havana by using the DSL technology, but challenges of the technology infrastructure persisted. As Press explained (Press, 2017a), the quality of a DSL connection is a function of the length and condition of the telephone wire running between a home and the central office serving it, thus requiring comprehensive planning and heavy investing by ETECSA in wiring as well as in central office equipment.

Today, the economy is hurting to a lesser degree because of the Venezuelan crisis. The Cuban government has learned to censor the Internet and use it for surveillance and propaganda, but bureaucratic greed and power within ETECSA, the state-connected monopoly provider, hold the Internet back (Press, 2016a). The image below shows the backbone network of the island nation (Nearshore Americas Report, 2015).

Figure 1. The Backbone Network in Cuba (Source: Nearshore American Report, 2015)



The Cuban Internet has opened slightly. The state-owned telecom ETECSA (http://www.etecsa.cu/) is one of the few government monopoly suppliers of Internet and landline and mobile telephone in the world. Over the last few years, they have created public access Wi-Fi hotspots. Home "broadband" service is now available in a small portion of Havana; there were 358 paying customers as of April 2017 (Press, 2017b). ETECSA is also conducting a 3G mobile trial in a small area. 3G has progressed significantly. Coverage is up and they are running trials in which any Cuban with a cell phone (as opposed to tourists and selected journalists and insiders)

can use 3G. Those trials are expected to end soon and 3G will be accessible to the general public in many places. Although it will still be slow and expensive, this would provide more access than Wi-Fi hotspots (Press, 2018).

While these efforts indicate a change in attitude and are of symbolic importance, they reach only a tiny part of the population and use obsolete technology. It is noteworthy that Chinese companies have been instrumental in much of this development. The most significant improvement in the Cuban Internet was the installation of an undersea cable connecting Cuba and Venezuela in 2015, but it is a strong link in a very weak chain leading to Cuban users. Google recently installed caching servers in Cuba and they will speed access to whichever services Google caches. As with the other measures, slightly better YouTube performance is of little value, but it may signify an important shift in Internet policy and policy on dealing with a US company.

We are also witnessing what may be somewhat more than symbolic changes in Internet-related applications and services. Cuba has legalized self-employment in 201 occupations, among them computer programmer (Press, 2017b). As of April 2017, there were 1,432 active, registered programmers in Cuba and the number has grown at an increasing rate every year since 2009, when there was only one. These people are doing contract programming (within and outside of Cuba) and developing services. There is also the beginning of a startup scene. The most recent indication of changing attitudes was a workshop intended to foster collaboration between the government software companies and independent software entrepreneurs.

As discussed below, prior studies have discussed the barriers to Internet access, information technology literacy, and the four kinds of access, all of which have provided us with useful insights when we explore and understand the Internet use and emerging digital citizenship in Cuba.

THEORETICAL BACKGROUND: DIGITAL CITIZENSHIP

Digital citizenship is defined as regular and effective use of digital networks, which depends upon having access and skills (e.g., Mossberger, Tolbert, and McNeal, 2007). The pervasive Internet technology in the U.S. and other developed nations has enabled communication and information dissemination online and contributed to the interactions between government and its citizens on electronic networks. All of these communicative functions are key aspects of the digital citizenship (e.g. Davis, 1999). In U.S. and other developed countries where Internet technology has become ubiquitous and governments use the Internet as an important channel to conduct their business (such as filing income tax and managing property tax), digital citizenship has been taken for granted. However, in countries that lag behind in information technology infrastructure such as Cuba, digital citizenship can only emerge with access to computers and digital networks.

Digital citizenship is affected by two types of barriers: infrastructural barriers to access and social barriers to access. First, infrastructure of digital networks includes computer hardware, software and network equipment for telecommunication network. At individual level, one good indicator is the computer ownership and usage. Researchers have referred the gap in computer ownership and usage as persistent indicator of a digital divide. The concept of the digital divide has, until now, been focused on “the gap separating those individuals who have access to new forms of information technology from those who do not” (Gunkel, 2003, p. 499). Lack of possession of a computer and a network connection is considered the critical factor contributing to digital divide. Second, social barriers to access refer to the access barriers arising from one’s social economics status (SES), including income, education, age, race etc. According to National Telecommunications and Information Administration’s reports (2000, 2002), income and

education are two of the SES that positively correlated with levels of access to and familiarity with computers and the Internet in the U.S. more than fifteen years ago.

Prior studies of digital citizenship and digital divide also suggest that digital divide led to information inequality, as Internet has become a major medium for information dissemination and information transmission. To further study the barriers to digital citizenship, van Dijk (2002) proposed a framework of four kinds of access. According to the framework, no possession of computer and network connection is only one of four kinds of access; other three kinds of access include: mental access (lack of elementary digital experience cause by lack of interest, computer anxiety and unattractiveness of the new technology), skill access (lack of digital skills caused by insufficient user-friendliness and inadequate education or social support), and usage access (lack of significant usage opportunities or unequal distribution of them). According to van Dijk (2002), framework of digital divide study contains a model of the four successive kinds of access.

Moreover, prior studies suggest that individual ability to take advantage of Internet access relies on the levels of information technology literacy (ITL) among them. For example, a study of 2002 Midwest urban random sample by Shelley et al. (2004) shows that interest in developing computer skills was positively associated with digital citizenship, and viewing technology as a source of informational power was positively related to support for computer access equity. As noted in the section above, Cuban computer skill is relatively high due to their emphasis on education.

RESEARCH METHODOLY: MIXED METHODS OF QUANTITATIVE & QUALITATIVE ANALYSES

Following Mingers (2001) and Mingers et al. (2013), we adopted a mixed methods approach – combining quantitative and qualitative analyses – to better understand the phenomenon under investigation. Quantitative and qualitative methods complement each other and have the potential to provide a richer exploration of the associations across variables (Mingers, 2001). In particular, we believe that this approach is appropriate for our investigation because there has been little sufficient evidence regarding individual Internet access and usage behavior in the Cuban context.

In conducting this mixed methods research, we followed the guidelines proposed by Venkatesh and colleagues (2013). Although relatively less frequently used in the IS field, mixed methods have been adopted by a number of IS scholars in their research, including Newell and Edelman (2008) in their investigation of effective mechanisms in cross-project learning and Deng, Wang, and Galliers (2015) in their exploration of customer-oriented citizenship behaviors by IS personnel. By combining quantitative and qualitative analyses in this study, we hoped to better understand the emerging phenomenon of Internet use and digital citizenship in the developing country of Cuba, particularly from the perspective of the Cuban citizens themselves.

Data Collection

We designed and administered a national survey on cubava.cu, one of the most popular digital platforms in Cuba. Cubava.cu is a hosting service for blogs, which provide easy access to Cubans to access via the Intranet or Internet, and allow them to read and manage blogs with relative simplicity. "Reflejos" is the name of their blogging platform -- like Blogger.com or Wordpress.com. Cubans can create blogs there. We offered that survey on our co-author's blogging site.

We collected data by using the survey instrument that included both structured and unstructured questions on individual access to Internet and their experiences. Rather than directly asking what Cubans value most in Internet access and use, we asked them to share experience in accessing and use Intranet and Internet. In this regard, we followed Friedman et al. (2006) by employing the indirect approach, which helps to "engage people's reasoning about the topic under investigation" (ibid., p. 19). The survey also included questions about their Internet tenure (how long they had been using the Internet), Internet use (frequency of connection and duration of each connection), and their demographics (e.g., gender; age; geographic location/province).

The survey was well received, with the following comments being typical:

> "Interesting proposal you do. I'll promote it on my blog." [Dec. 1, 2016; User D]

> "Very good your intention! I already have the link published in my blog xxxx.cubava.cu I have filled the whole survey, to see what results brings us this." [Dec. 5, 2016; User M]

Sample Characteristics

Our data sample includes 60 users who responded to the key demographics questions and Intranet/Internet use questions. Half of the 60 users are still new to Intranet/Internet, with experience of 1-3 years, and majority of the newcomers had access to Intranet only. Only 12% of the users reported experience of more than 10 years. The distribution of use experience is: 1-3 years, 50%; 3-5 years, 12%; 5-10 years, 27%; more than 10 years, 12%. In terms of users' age, majority of them (58%) are 21-30 years old, followed by 23% of them in 31-40 years old group. The distribution in the remaining categories is: 14-20 years, 5%; 41-50 years, 7%; 51-60 years, 7%.

The dominant medium for Intranet/Internet access is desktop PC, as reported by 85% of the users in our data sample. Only 15% of the respondents used notebook or mobile phone to access Internet and Intranet. In addition, workplace remains the popular location for their Intranet/Internet, as reported by 72% of the respondents.

The Intranet/Internet use (in terms of frequency) seemed to distribute across multiple categories, ranging from several times a day to several times a week. Of the 60 respondents, 33% accessed the network almost on a daily basis, with the reminder in the following categories: several times a day, 25%; several times a week, 22%; once a week, 8%; a couple of times a month, 10%; once a month, 2%. Similarly, the duration time per access ranged from 15 minutes to 8 hours plus. The distribution of duration time per connection is: less than 15 minutes, 12%; 15-30 minutes, 10%; 30-60 minutes, 18%; 1-2 hours, 18%; 2-4 hours, 13%, 4-8 hours, 20%; more than 8 hours, 8%.

ANALYSIS AND RESULTS

Quantitative Analysis and Results

As most of the quantitative data we collected from the online poll is categorical data, we perform an Chi-Square Test on the relationships between two categorical variables, including demographics factor (age groups), user type (Intranet vs. Internet), and the three types of Internet use behaviors (years of experience, frequency of connection, and duration of a connection). The analysis shows that there is no relationship between age groups and frequency of access.

However, some kinds of significant relationships exist between age group and the network use measures: time durations per connection, access location, and medium for access.

First, 14-20 years old are more likely to show a frequency of access one a week than others (chi-square 2.5). Moreover, they are more likely to access from Center and University (Chi-square: 18.05) and home (Chi-square: 4.5), than others, and less likely to access from work than others (Chi-square: 2.15). This result makes sense as people of this age group are still attending schools and university and study centers and home naturally become their main access location for digital network. For those in 41-50 years, they are more likely to use notebook for access, compared to other age groups (Chi-square, 2.0167). For 31-40 year-olds, they are more likely to spend 30-60 minutes per connection, than others (Chi-square: 4.593).

We also analyze the associations between type of user (Internet vs. Intranet) and other access measures. The chi-square analysis shows that Internet users are less likely to have access frequency of several times a day (Chi-square=2.131) compared to Intranet users. Internet users are more likely to have access frequency of couple of times a month (Chi-square=2.61), compared to Intranet users. In addition, internet users are more likely to use mobile phone (Chi-square=5.853) and notebook (Chi-square=2.926) for access medium, compared to others.

However, we'd like to point out that, given the nature of the sample, we are unable to make further statistical inference based on this data analysis.

Qualitative Analysis and Findings: Barriers and Perceived Values of Internet Use in Cuba

Our research objective was to investigate how human actors interacted with information and communication technology, rather than to hypothesize or test cause-and-effect relationships. This is consistent with interpretive approaches to IS research (Galliers and Land, 1987; Walsham 2006). We asked our survey respondents open-ended questions on their experience with Internet connection. We analyzed the written narratives from the respondents by following the well-accepted qualitative research methods outlined by Miles and Huberman (1994). For example, we started with open coding and codes suggested by the technology acceptance model (TAM) literature and e-commerce studies, then revised codes as we refined and clarified our theoretical interpretation. Our analysis reveals Cubans encounter both physical and social barriers to Intranet/Internet use. In addition, the data analysis shows two aspects of ICT that are particularly attractive to Cuban citizens – communication and knowledge acquisition.

Barriers to Internet Use in Cuba: Physical and Social Barriers

When responding to questions about their Internet/Intranet experience, our informants overwhelmingly talked about the slow and cost network access and connection. One user provided a detailed account of the two major barriers to network access:

> "It is also known by all, that the payment rates are excessively high because they are equivalent to a very high percentage of the basic salary of our country and only to sail for 1 hour. It is incredibly absurd but it is what we have. What are we going to do! In addition to this absurdity, we also have against us the connectivity they give us because it is limited and very minimum because we only have 1 mega of Wi-Fi. Which means that if you only pay for one hour for the high cost of it, you can hardly do anything, because it is extremely slow." [Dec. 2, 2016 by User L]

Another respondents shared this frustration of slow network connectivity and high cost, as shown below:

> "[The Internet access] is still very expensive and for the average worker who lives on his salary. It is a bit difficult to be paying 50 pesos to have only one hour of connection that goes as water because of the slowness of it." [Dec. 1, 2016 by User R]

In a country where the purchasing power of the locals is a $25 per person per month, with $25 equivalent to 687 pesos in 2015 (Rapoza, 2016), it would cause a financial burden to many Cubans if they have to spend 50 pesos-out of their 687 monthly salary—on one hour of network access. Under this circumstance, some users adapt their network access and usage behavior, such as accessing to Intranet more frequently than to the global internet. In other words, for those who have both Internet and Intranet accounts, their access frequency differed by the two types of network. In general, their Internet access was less frequently than Intranet access, as shown in the following remark:

> "If it is Internet, I access almost once a month from the Nauta Wi-Fi or sometimes I go to the club 1, where there is a Nauta room. If it is intranet, I access a few times a week." [Dec. 1, 2016; User T]

Although experiencing the difficulties and inconveniences, some respondents expressed hope for an improved Internet environment in Cuba. The following remark reflects the hopeful thinking:

> "Well in my case I access sparingly, either by speed or by cost. They should do something with the cost because not everyone has the same facilities at the time of payment (I have seen people who have logged in once every six months). But, well, everything is in the possibilities of the Revolution so I hope that the systems of access to the INTERNET for all will gradually improve." [Dec. 1, 2016 by User N]

Personal Values in Internet/Intranet: Communication & Knowledge Acquisition

The respondents of the survey valued their access to the network (both Internet and Intranet). Yet, the access is multifaceted; it conveys different meanings to different users. For majority of the users, the communication enabled by Internet access is personally meaningful to them. It allows them to connect to the outside world. One explained:

> "It is important to gain access to the Internet (.com) and improve connection speed and data transmission, this is the twenty-first century and step that we takes us XXII."

For some, this Internet-enabled communication was experientially meaningful, as they experienced joy and excitement in connecting with friends and family members. This is reflected in the remark:

> "What I see in most people use it to communicate with family and friends, and research topics they are interested, leisure, music, entertainment, etc"

For some users, the Internet access enabled them to gain more knowledge and develop competence in their technology-related field, as a result of having exposure to useful resources and documentations online. This is evidenced in the following two remarks:

> "I really use the intranet more than the internet but it is a tool for me of work that helps me increase and exceed my knowledge." [Dec. 5, 2016; User C]

> "I access systematically to the internet, since I dedicate myself to the development of software, and really there it appears all the necessary documentation. In addition, I have a site in Cuba, xxxxxxx.cuba.cu, which I try to update systematically." [Dec. 1, 2016, User R1]

For an island country with the low level of Internet penetration, the communicative capabilities afforded by the Internet are meaningful. To some users, they view Internet access meaningful not only personally but also at the national level:

> "As long as I can connect, I think that the national intranet should be given free of charge and thus promote services for the technological development of the country, and give the programmers a place to put their jobs or to be provided with ADSL to create their own servers to generate content in the network that is very scarce." [Dec. 6, 2016; User R2]

DISCUSSION

The objective of the study was to explore and understand how Cubans are getting online. Our quantitative analysis shows that accessing to Internet remains costly and constrained by the technological infrastructure in Cuba. Digital citizenship in Cuba is still at its incipient stage. As the Chi-square analysis shows, younger generation (14-20 years) are more likely to gain access from study centers, universities, and home, and they are more likely to use mobile phone and notebook. Internet users are more likely to have access frequency of couple of times a month, and more likely to access using mobile phones and notebooks.

Our analysis of the respondents' narratives reflects Cuban's value of Internet access for communication and knowledge acquisition. This finding is consistent with those reported by Aida Zekić, in her ethnographic study of Cuban Internet use based on her interviews with 50 Cuban Internet users at nine Wi-Fi hotspots in Havana during September and October 2016. In her data analysis, Zekić found that more than 90 percent of the 50 informants used the Internet for communication purpose (such as making long-distance calls and using social media), followed by 40 percent of them using it for informational purposes, such as searching information for school and work related activities, and reading foreign and domestic news. Fewer informants (fewer than 20 percent) used the Internet for entertainment, such as watching sports and movies.

In our study, the perceived benefits of communication and knowledge source valued and shared by the Cuban citizens reflected their experience of empowerment. For example, most of the Cubans in our survey valued the network-enabled communication with their families and friends living in different places and countries, which was personally meaning to them. In addition, Cubans valued Internet as a useful source of knowledge, as those Internet users felt that they had improved their knowledge and gained competency in their field (such as software development) via accessing to the resources and documents online. In both cases, the respondents expressed a sense of empowerment as Internet access became personally meaningful to them and enabled them to become more competent. These cognitions of meaning and of competence reflect the two dimensions of empowerment discussed by Thomas and Velthouse (1990): empowerment via meaning and empowerment via competence. According to Thomas and Velthouse (1990), the cognition of meaning reflects the personal meaningfulness of

a job activity, and the cognition of competence reflects one's confidence about his/her skills and capabilities to do the work.

CONTRIBUTION, LIMITATION, AND NEXT STEPS OF THE STUDY

This paper reported an exploratory study of emerging digital citizenship in Cuba. The study contributes to digital divide literature by providing nuanced understanding of digital divide in the Cuban context. The digital divide has tended to refer to whether individuals have access to ICT. In Western contexts. Selwyn (2004) differentiates between 'access to' and 'use of' ICT, and considers the consequences of engagement with the technology. However, the notion of digital divide and digital citizenship has been become outdated in developed countries. For example, In their work of crowd access to and engaged in the Internet-enabled online labor market, Deng, Galliers, and Joshi (2016) extend this digital divide work by pointing to the power imbalances between platform providers and job requesters and those who rely on crowdworking as their sole or partial source of income.

Given the difficulties of collecting large-scale survey data in Cuba, we collected data from online polls posted on a blogging site. We emphasized that each person only completed the survey once, and used IP host to identify unique responses. As a computer in the network might be shared by multiple users, a potential bias exists in this sampling approach. Initial findings form this exploratory study should be applied to other groups of users with caution. However, we tried to mitigate this bias by emphasizing unique responses among the visitors to the blogging site. Moreover, as our objective was to understand user behaviors associated with network access and usage, eliciting responses from those who have Internet/Intranet accounts became appropriate for the study.

Next Steps for the research project: First, we plan to analyze data of the remaining questions and of the larger sample. Second, based on the findings of the larger data set, we seek to propose a model of factors influencing digital citizenship to be tested in a large-scale data collection including those having Intranet/Internet and those who don't.

CONCLUDING REMARKS

The International Telecommunication Union (ITU) published an annual report on "Trends in Telecommunication Reform" and in the 2015 edition, they defined four generations of telecommunication regulation, including: G1 for regulated public monopolies, G2 for basic reform of partial liberalization and privatization across the layers, G3 for enabling investment, innovation and access, and G4 based on integrated regulation. Cuba was not included in the analysis shown here because of insufficient data, but, if they had been, they would have clearly been a first-generation nation (Press, 2016b).

New information technologies have empowering impacts on a society. At the national level, Zheng (2007) examined the role of new information technologies, especially the Internet, in facilitating political liberalization and making government more open, transparent, and accountable in China. The study concluded that the Internet empowered both the state and society in China, and the interactions between the state and society over the Internet ended up reshaping both the state and society. It remains an open question if/how Cuba government will deploy the Internet technology to improve the digital citizenship of Cubans.

The aforementioned 3G mobile trial illustrates Cuba's need to leapfrog technology. The ITU estimated there would be approximately 6.1 billion smartphones in the world by 2020 when we would expect to see the first deployments of 5G mobile networks, which promise faster data transmission rates, increased coverage, and more (ITU, 2015). Ironically, Cuba began a highly limited 3G trial less than a month after the ITU agreed on 5G performance requirements. They should leapfrog landline and mobile technology, which will require leapfrogging infrastructure, ownership and regulation policy (Press, 2016b).

Cuban Internet access is gradually improving. According to a Reuter report published in October last year, the increased availability of Wi-Fi hotspots in Cuba made it possible for nearly half the population of 11 million to be connected online at least once in a year (Meneghini & Marsh, 2017). Given the relative expense of connecting to the global Internet, Cubans use it mostly to stay in touch with relatives and friends. The report further stated that, Internet access prices had dropped to the $1.50 hourly tariff by November 2017, but it still represented 5 percent of the average monthly state salary of $30. More recently, Cuba witnessed the transition of its top leadership, with the stepping down of Raúl Castro in April this year (Faiola, 2018). Cubans may have a reason to hope that the new generation of their leaders will make significant change in the island country's economic development, including more Wi-Fi hotspots and reduced cost of Internet access, so that Cubans' trips to visit a Wi-Fi hotspots in the island country become shorter and more affordable.

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DECISION SCIENCES INSTITUTE

Understanding Population Health Disparities: An Analysis of Social Determinants of Health

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ABSTRACT

Social determinants of health (SDoH) including economic stability, healthcare access, and education, impact specific disease conditions and contribute to geographic disparities in health outcomes. This study investigates geographic disparities in health outcomes across Florida by analyzing SDoH and health outcomes data, and guides the development of interventions for specific populations.

KEYWORDS: Social Determinants of Health, Health Disparities, Healthcare Data Analytics, Cluster Analysis

INTRODUCTION

How long children born today live depends on the country in which they were born. Life expectancy for children varies from 80 years in Japan to less than 50 years in some African countries. In Europe, middle-aged adults from the lowest socio-economic groups are much more likely to die than those in the higher groups. Eighty percent of all people with diabetes live in low and middle income countries (WHO, 2008). Air pollution was responsible for 4.3 million deaths globally in 2012. This accounts for almost 10% of deaths in low and middle-income countries, as compared to only 0.2% of deaths in high-income countries (www.who.int, accessed Oct. 30, 2016). In the United States, those who finish high school live about 5 years longer than those who do not finish high school (McGill, 2016). Disparities in health caused by socio-economic and other factors including education and environmental conditions exist between and within nations, and need to be reduced.

According to the World Health Organization, the definition of the Social Determinants of Health (SDoH) is “the conditions in which people are born, grow, live, work and age” and “the fundamental driver of these conditions.” (www.who.int, accessed Oct. 8, 2016) These can include the socio-economic factors and access to certain resources in one’s community, as well as the behavioral factors. Examples of SDoH include the quality of education and workplaces, cleanliness of food, water or air, access to health care, diet and exercise, access to social and economic opportunities, race, gender, and the presence of any physical hazards such as poor housing and toxins (www.healthypeople.gov, accessed Oct. 14, 2016). The five key areas of SDoH are economic stability, neighborhood and built environment, health and health care

access, education, and social and community context (www.healthypeople.gov, accessed Oct. 14, 2016).

Poor socio-economic conditions can create negative impacts on health. According to the World Health Organization (www.who.int, accessed on Oct. 8, 2016), a person living in lower socio-economic communities is twice as likely to contract diseases which might lead to premature death. People living in such communities have few family assets, poorer education, insecure employment, poor housing, a family in challenging circumstances, and less than sufficient retirement pension. These disadvantages can continue to worsen throughout life, and lead to lower life expectancy.

LITERATURE REVIEW

SDoH Areas

Key areas of SDoH include economic conditions, the neighborhoods and built environment, access to healthcare, education, social and community conditions in which people live. Examples of economic stability determinants are poverty, employment, food security, and housing stability (www.healthypeople.gov, accessed Oct. 14). A major factor in the economic stability of an individual is employment based earnings including work related health benefits, such as medical insurance, paid leave, scheduled leave, workplace wellness programs, child and elder care resources and retirement benefits. Employment can also increase financial security and allow people to afford healthier living conditions. However, the working poor—7.4 million US workers in 2006—do not earn enough to cover health necessities and they often do not have access to many health benefits (US Bureau of Labor Statistics, 2008). Socially disadvantaged groups are more likely to have health damaging working conditions along with poor quality living conditions due to lower pay and lower economic stability (Egerter et al., 2008).

Neighborhood and built environment includes access to healthy foods, quality of housing, crime and violence levels in the community, and environmental conditions, such as pollution and proximity to hazardous substances (www.healthypeople.gov, accessed Oct. 14). Hazardous substances might include lead paint, mold, dust, or pest infestations. Braveman et al. (2011) reported that the built environment of an individual also includes quality of services such as schools, transportation, health care, and jobs that influence the prospects people have to make a living for themselves and their families. Work can influence health in many ways, the most significant ones being the physical factors or the workspace. Such factors might include poor ventilation, high noise levels, and exposure to hazardous materials, which can harm health. Jobs that require high amounts of physical activity can put individuals at a greater risk for musculoskeletal damages. However, jobs with too little physical activity are at a much higher risk of heart disease, obesity, and diabetes (Warburton et al., 2006). Psychological facets of work can also influence health such as working overtime, which, according to Braveman et al. (2011), has been connected to injury, illness and mortality.

Health and health care access is defined as how easily one is able to access health and primary care and one’s level of health literacy or understanding of their health (www.healthypeople.gov, accessed Oct. 14). According to Braveman et al. (2011), having a greater health literacy is related to the level of education one has. By having a higher level of education, individuals have the opportunity to get better paying jobs with many health benefits. These individuals can access health care much easier than educationally and economically disadvantaged individuals.

The determinants of education in a community are literacy, access to early childhood education and development programs, the number of high school graduates, and the number enrolled in higher education (www.healthypeople.gov, accessed Oct. 14). Education can also relate to health literacy, or one's knowledge about their health and what is beneficial to them. Higher quality education can lead to higher health literacy and allows individuals to make more informed decisions about their health (Sanders et al., 2009). Braveman et al. (2011) reported that better education allows for individuals to have a larger spectrum of employment opportunities, which can greatly reduce the risk of poor health and higher mortality. It can also protect against the effects of stress. These individuals are also more likely to get jobs with better physical and psychological working conditions, more health benefits and higher compensation (Crissey, 2009). It is also shown that these individuals have greater personal control and will make better behavioral choices. Education has been underestimated as an important determinant of health.

The social and community context is the social cohesion, civic participation, discrimination, and incarceration levels in one's community (www.healthypeople.gov, accessed Oct. 14). For example, in communities when members express mutual trust with one another and are more integrated, they will experience lower homicide rates and less anxiety and depression cases (Phongsavan et al., 2006). Similarly, workplace environments that enable mutual support among co-workers can help to safeguard against physical and mental health problems. Increased social support and more social advantages can allow someone to perceive themselves as a part of a higher social status which can lead to educational fulfillment, which is an important determinant of health (Demakakos et al., 2008). Race is also an important part of the social context determinants of health. Intentional or unintentional discrimination based on race or ethnicity can limit an individual's potential, and therefore "perpetuates social disadvantage" (Braveman et al., 2011). African Americans and Latinos are more likely to be residents in these poor neighborhoods with inadequate opportunities, which can lead to adverse health effects (Rouse and Barrow, 2006). Race can also more directly affect health through the stress of racial bias and prejudicial experiences regardless of neighborhood, income, and level of education (Nuru-Jeter et al., 2009 Williams and Mohammed, 2009).

SDoH Research

There are two main areas of research in SDoH and health outcomes. These are the study of the impact of SDoH on specific diseases, and the study of geographic disparities in health outcomes. Researchers have studied the impact of SDoH on many specific diseases and found links between SDoH and specific disease conditions. Victorino and Gauthier (2009) found that children are more likely to have illness such asthma, migraines, or ear infections if their family is closer to the federal poverty level. In another study, Rossen and Talih (2014) found that neighborhood socioeconomic and demographic factors may explain disparities in weight among US children and adolescents. Heart disease and diabetes are leading causes of death in the United States. Saiz et al. (2016) in a state-wide study in Wisconsin found that food insecurity could contribute to poor cardiovascular health. Patel et al. (2016) found that financial stress and worry impacts adults with diabetes resulting in them not following the required treatments. Mental health, which is also a large problem in the United States, is significantly affected by SDoH (Sederer, 2016).

The other area of research is to study SDoH and geographic disparity in health outcomes. Hood et al. (2015) study geographic disparities by examining the relationship between SDoH

and health outcomes in the United States. Their research compares county-level data from all states based on the County Health Rankings (CHR) database (CountyHealthRankings.org). They developed a model in which 35 different SDoH are combined into four health factors: socio-economic factors, health behaviors, clinical care including access, and the physical environment. The model determines health outcomes (length and quality of life) by combining these factors. Genus et al. (2016) have also used the CHR data to study the SDoH that contribute to health disparity in eight states in the Mississippi Delta region. They found that Delta and non-Delta counties had some common SDoH (tobacco use, diet, exercise). But they also found that some Delta counties were different with respect to community safety and income. Based on these findings, specific interventions can be made to improve the health of the region.
This study also uses the CHR data to study SDoH to examine health disparities among Florida counties. The study hypotheses are discussed below.

HYPOTHESES, DATA AND METHODS

Braveman et al. (2011) identify four areas for further research in their review of SDoH. These include the need to: (1) monitor changes of SDoH and health outcomes over time to determine progress, (2) study SDoH and health outcomes of children to see how childhood experiences have consequences over time, (3) better understand how SDoH ultimately affect health through various pathways, and (4) evaluate a combination of interventions to improve health disparities. This study follows the recommendation of monitoring changes to determine progress over time. Based on this, the purpose of this study is to better understand the health disparities between the counties in Florida by analyzing key SDoH. For this, the study will first investigate changes in measures and rankings of health outcomes by analyzing county-level data over time (2012-2016).

Hypothesis 1: If there are no changes in measures and ranking of health outcomes in Florida counties over the 2012-2016 time period, then there are no changes in the SDoH over this period.

Many interventions to improve SDoH are being made in Florida. But the Florida Health Gaps report for 2015 (Catlin et al., 2015) still identified significant gaps in some SDoH. But these gaps are identified at the State level and not for specific counties. So this study will use the 2016 SDoH data to analyze and classify counties in Florida into clusters according to their health outcomes. These county clusters are not geographic clusters but groups of counties that have similar SDoH and health outcomes. The results will then be evaluated to identify what interventions are needed to improve the health of Floridians in these county clusters.

Hypothesis 2: If SDoH and health outcomes data can be used to create clusters of similar counties, then appropriate SDoH can be identified for each cluster to target for intervention and reduce health disparities in Florida.

Data and Methods

Since this is essentially an epidemiological study, it was focused on publicly available data. There are various sources of population health related data such as the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), HealthyPeople.gov, HealthIndicators.gov, and CountyHealthRankings.org. Data sets from the CDC and HealthyPeople.gov were more disease specific and not relevant for the purpose of this

study. The County Health Rankings and Roadmaps (CHR) program (CountyHealthRankings.org) is a collaboration between the Robert Wood Johnson Foundation and the University of Wisconsin Population Health Institute. They annually publish data that includes different variables from various government and other sources that are most current. This includes various SDoH such as high school graduation rates, obesity, smoking, unemployment, and access to healthy foods. These SDoH represent health behaviors, clinical care, social and economic factors, and the physical environment. It also provides data related to length and quality of life. The data is provided for almost every county in the United States, and ranks the counties based on the impact of the SDoH on health outcomes. CHR has its own scoring method for ranking health factors and health outcomes based on SDoH data, and ranks counties based on their model. In this study the data related to all the counties in Florida were studied using appropriate data analysis and statistical methods and software. The study used 2012-2016 Florida Health Rankings Data from CountyHealthRankings.org. Data Analysis and Visualization Software (Tableau 8.3, www.tableau.com) and Statistical Software (JMP 13; www.jmp.com) and Excel were used in the analysis.

For the study of changes over time in measures and rankings of health outcomes in Florida (2012-2016), county measures and ranking data for Florida from CountyHealthRankings.org was used. The individual annual measures and ranking data for 2012 and 2016 were combined into one data set. The data was reviewed to see how county measures and rankings of health outcomes changed over 2012-2016, and identify which health outcomes improved or declined over this period. Specifically, the 2016 SDoH and health outcomes data from CountyHealthRankings.org was then used to classify counties in Florida into clusters according to their SDoH and health outcomes. Cluster analysis was conducted to group Florida counties based on multiple SDoH and outcomes ranking data into clusters of similar counties. Data from Florida Department of Health, Division of Public Health Statistics and Performance Management (FLHealthCharts.com) was then further analyzed to understand the specific SDoH challenges in one of the clusters. The results were then evaluated to identify possible areas for interventions needed to improve the health of Floridians and reduce health disparities. Such a data based approach can help develop customized services to overcome healthcare disparities in different populations.

RESULTS AND DISCUSSION

The first hypothesis tested stated that if there are no changes in measures and ranking of health outcomes in Florida counties over the 2012-2016 time period, then there are no changes in the SDoH over this period. To determine whether or not there were changes in measures and rankings, the difference in health outcomes from 2012-2016 was used. First, the overall rank of the counties in health outcomes showed that 28 of Florida counties had become worse in health outcomes over this period, 31 Florida counties improved, and 8 counties experienced no change. When testing the measures of specific health outcomes over time, the health outcome with the largest overall improvement was the percent of adults that report poor or fair health, with 41 counties having improved measures, 17 counties with worsening measures and 9 counties that experienced no change. The health outcome with the largest overall worsening was the number of premature deaths, which is the number of deaths before the age of 75, and the average number of reported mentally unhealthy days per month. However, data that is a count tends to be more accurate than percentages and the number of poor health days reported because these are based on sample data, or data from a sample of a population and include sampling error. Also, because the percentage of poor or fair health and poor health days are only based on reported data, it does not take in to account the unreported fair or poor health

cases. As shown in Table 1, there is a worsening of health outcomes in counties for the number of premature deaths and for mental health. This is also shown in Figures 1 and 2.

Health Outcomes Ranks and Measures	Number of counties that have worsened	Number of counties that have experienced no change	Number of counties that have improved
Health Outcome Rank	28	8	31
Number of deaths under the age of 75	50	1	16
Percent of adults that report fair or poor	17	9	41
Average number of reported physically unhealthy days per month	28	7	32
Average number of reported mentally unhealthy days per month	44	5	18
Number of low birthweight births	26	1	40

Table 1: Change in Health Outcomes Ranks and Measures between 2012 and 2016

In addition, the 2016 SDoH county rankings of Social and Economic factors and Health Behaviors were statistically significant, while the county rankings of access to Clinical Care and the Physical Environment were not significant, as they related to the county Health Outcomes rankings (see Table 2).

	Coefficients	Standard Error	t Stat	P < 0.05 * significant
Intercept	-4.2384	3.2657	-1.2978	0.1992
Health Behaviors	0.5270	0.0801	6.5774	0.0012E-05*
Clinical Care	-0.0644	0.0801	-0.804	0.4245
Social & Economic Factors	0.5658	0.0701	8.0653	0.0031E-8*
Physical Environment	0.0963	0.0564	1.7081	0.0926

Table 2: 2016 County SDoH and Health Outcome Rankings Multiple Regression Results

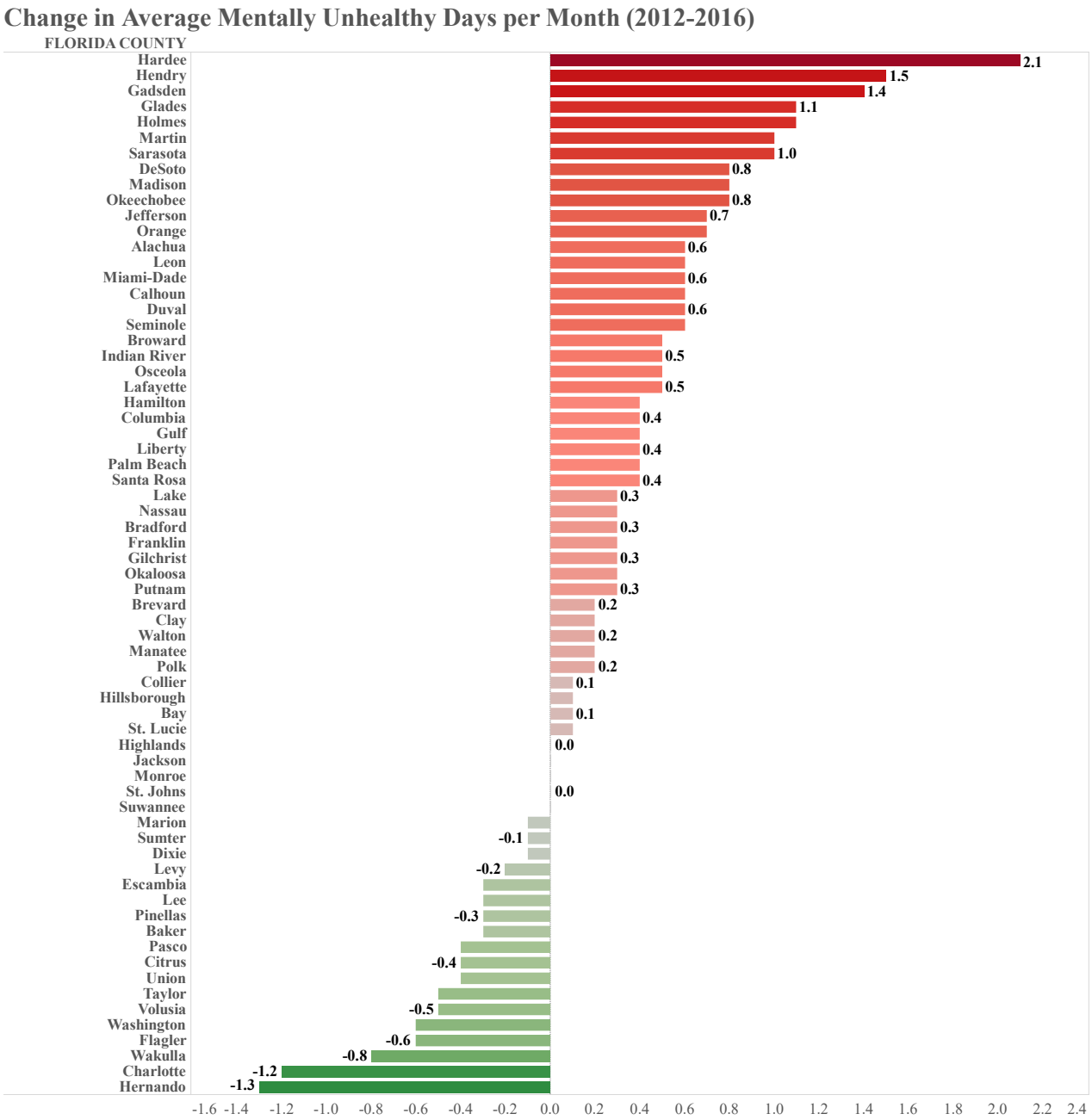

Figure 1: Change in Average Mentally Unhealthy Days per Month (2012-2016)

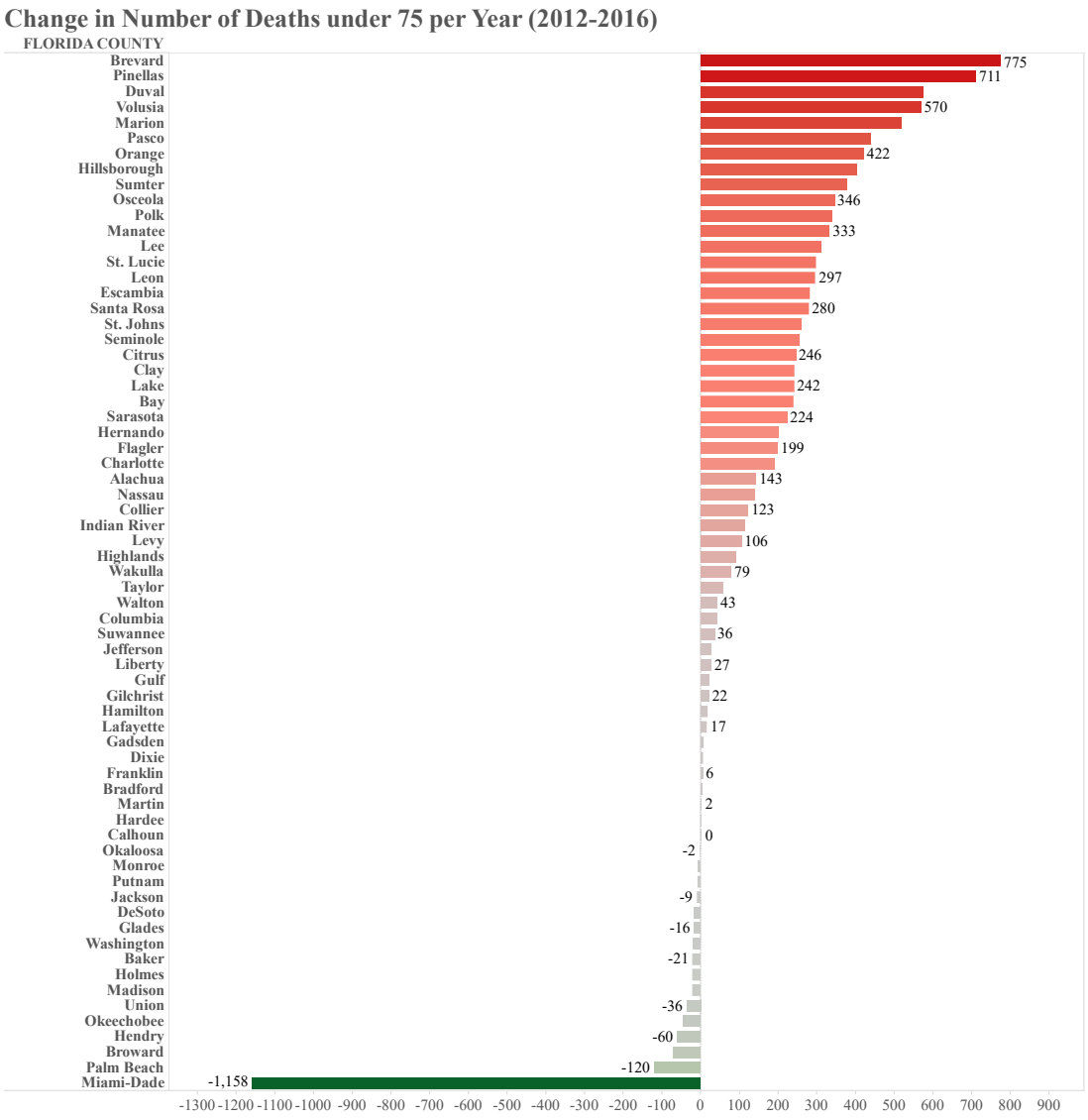

Figure 2: Change in Number of Deaths under 75 per Year

The second hypothesis tested stated that if SDoH and health outcomes data can be used to create clusters of similar counties, then appropriate SDoH can be identified for each cluster to target for intervention and reduce health disparities in Florida. The statistical software JMP was used to do cluster analysis. Cluster analysis is a technique of grouping rows of data (counties) together that share similar values across a number of variables (health outcomes and SDoH factors, ranks, and measures). It is a visual and exploratory technique to help understand the clumping structure of a data set. Hierarchical clustering was used and the resulting 7 clusters are shown in the constellation plot in Figure 3 below.

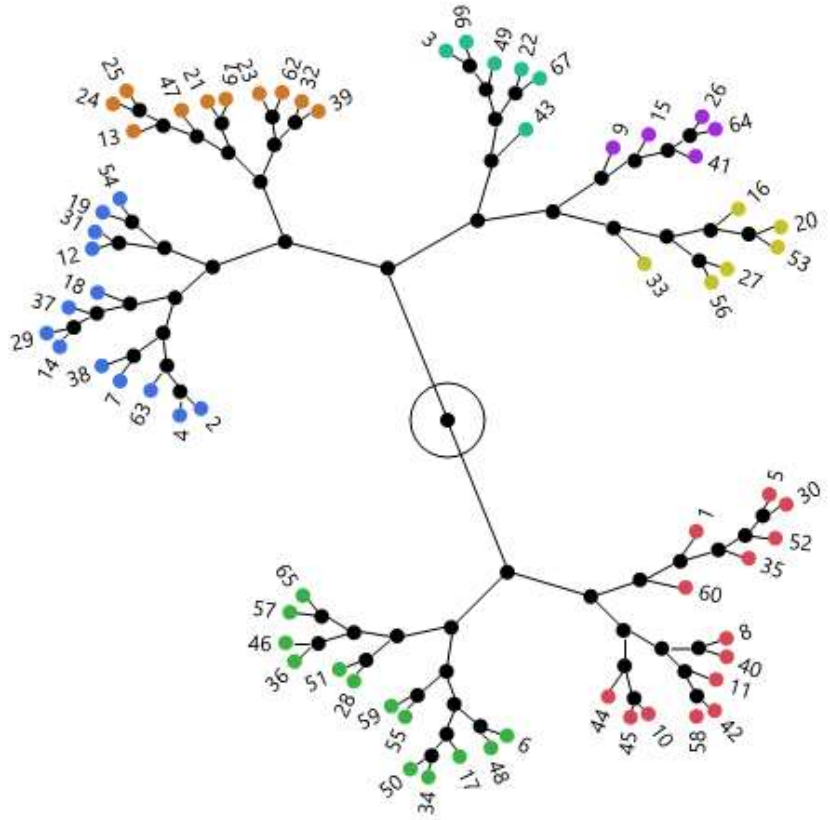

Figure 3: Constellation Plot for Cluster Analysis of Florida Counties by 2016 Factors and Outcomes Ranks

The counties corresponding to the clusters were identified from the data set. Then, the highest average rank SDoH factor was determined for each cluster. These are identified below in Table 3 for each of the related clusters of counties in Florida. These can be used for targeted intervention to reduce health disparities in Florida.

Cluster Number	Counties	SDoH with highest average rank
1	Alachua, Brevard, Charlotte, Clay, Collier, Indian River, Lee, Manatee, Martin, Monroe, Nassau, Pinellas, Sarasota, Sumter	Social & Economic Factors (education, employment, income, family & social support, community safety)
2	Broward, Flagler, Hillsborough, Lake, Leon, Okaloosa, Orange, Palm Beach, Pasco, St. Johns, Santa Rosa, Seminole, Wakulla	Physical Environment (housing, transit, air & water quality)
3	Baker, Bradford, Calhoun, Columbia, Dixie, Franklin, Gadsden, Holmes, Jackson, Levy, Liberty, Putnam, Union	Health Behaviors (tobacco use, diet & exercise, alcohol & drug use, sexual activity)
4	DeSoto, Glades, Hamilton, Hardee, Hendry, Jefferson, Madison, Okeechobee, Suwannee, Taylor	Social & Economic Factors (education, employment, income, family & social support, community safety)
5	Bay, Gulf, Miami-Dade, Osceola, Walton, Washington	Physical Environment (housing, transit, air & water quality)
6	Citrus, Duval, Hernando, Marion, Volusia	Social & Economic Factors (education, employment, income, family & social support, community safety) Physical Environment (housing, transit, air & water quality)
7	Escambia, Gilchrist, Highlands, Lafayette, Polk, St. Lucie	Clinical Care (access of care, quality of care)

Table 3: Key 2016 Social Determinants of Health by County Clusters in Florida

Further analysis could help in developing specific interventions in any county. For this Cluster 4 (see Table 3 above), which includes DeSoto, Glades, Hamilton, Hardee, Hendry, Jefferson, Madison, Okeechobee, Suwannee, Taylor counties, was further analyzed using detailed sociodemographic data from the Florida Department of Health. A two-tailed paired t-test indicated that percentage in poverty, percentage unemployment, and percentage poorly educated adults were all significantly higher than the overall State averages (Table 4). So poverty alleviating interventions would greatly help these counties improve their population health outcomes.

Socioeconomic Indicators	Cluster 4 Mean	FL Mean	P < 0.05 * significant
Percentage of individuals below poverty level	23.74	16.1	0.0012*
Percentage of families below poverty level	18.72	11.7	0.0006*
Percentage of individuals under 18 below poverty level	33.61	23.3	0.0058*
Percentage of civilian labor force which is unemployed	10.7	8.4	0.0082*
Median household income	36431.8	48900	0.0049E-04*
Percentage of 25 years and over with no high school diploma	25.61	12.8	0.0082E-02*
Percentage of population 5+ that speak English less than very well	9.67	11.7	0.4492
Median age (in years)	40.48	41.6	0.3820
Percentage of adults with health insurance coverage	81.13	83.6	0.2264

Table 4: 2012-2016 Socioeconomic Indicators for Cluster 4 Counties

CONCLUSIONS

The purpose of this study was to investigate geographic disparities in health outcomes across Florida counties by analyzing key SDoH and health outcomes at the county level. The initial analysis of the health outcomes data showed significant changes in two areas at the county level. It showed that health outcomes have worsened in many counties for the number of deaths before the age of 75 and for the average number of reported mentally unhealthy days per month. This does not support Hypothesis 1. So we conclude that the significant changes in county health outcome measures between 2012 and 2016 indicate changes in SDoH over this time period, with negative impact on health outcomes. So we must intervene to improve SDoH.

The second part of the study was to determine what SDoH areas need to be improved to positively change health outcomes for each county. For this, 2016 county data was analyzed and results supported Hypothesis 2. Clusters of similar counties based on SDoH and health outcomes were created. These clusters were evaluated to see which SDoH factor had the highest average rank (poorest performance) for the cluster. This helped identify appropriate SDoH for each cluster so that appropriate interventions can be used to improve health outcomes and thereby reduce health disparities in Florida. Further analysis using Florida State Department of Health data of a specific cluster of counties that had social and economic factors as the most significant, found that poverty and adult education should be specifically addressed to improve health outcomes in these counties. In this way, more detailed data analysis can help develop specific recommendations such as anti-poverty, anti-smoking, or diabetes prevention programs for a particular cluster of counties or a specific county.

This study was based on secondary data that was collected from many sources that are not always most recent. For example, the 2016 factors and outcomes data set was made up of data from other sources. While it used the latest available data, that data could have been from 2010 or 2014. This results in systematic errors that are caused by the environmental condition of data availability. Also, some of the information was reported data and would have errors in how people reported that data. The comparison of 2012 and 2016 outcomes was conducted in a basic fashion. This would introduce random errors because the difference was not statistically tested. But the clusters were formed through hierarchical cluster analysis. The technique is not perfect and so there is some random error that is introduced. It was statistically measured and

the clusters formed explained about 75 percent of the variation of the SDoH factors and health outcomes data.

This study identified two major health challenges in Florida: premature death before age 75 and worsening mental health. These are also challenges across the country today. The SDoH that drive these two health problems must be studied further. Understanding the SDoH for these at the county level will help us identify better interventions to overcome these health challenges, both in Florida and across the country. Healthcare is about both treatment and prevention. Improving SDoH is a very important and valuable way to prevent or reduce health problems in populations.

The study shows an approach to evaluate population health at the county level. It gives us a method to provide solutions to improve health outcomes that are specific to a community or region. By grouping similar counties, counties can also learn from each other's experience. That way, we can find what works and be able to improve health outcomes by improving SDoH. This method can also be used in other States in the country. By doing this at the county level, we develop a better understanding of the health and social needs of local communities. This approach can also be used across countries in the world. Such a study will help one country learn from another which would help improve global health.

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DECISION SCIENCES INSTITUTE
Understanding Social Media Participation Continuance Intention: A Perspective of Friends on Social Media

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ABSTRACT

This study aims at applying the expectation confirmation theory to explore how the friend factors affect on social commerce continuance intention, and further investigated the correlation between social media participation continuance intention and social shopping continuance intention. A total of 373 valid respondents involved in this study through an online survey. The findings demonstrated three antecedents of the related friend factors had a direct and indirect influence on confirmation, perceived usefulness, satisfaction, social media participation continuance intention and social shopping continuance intention. Social information influence was more effective than interpersonal trust and perceived friend's knowledge.

KEYWORDS: Social Commerce, Social Media Participation, Social Shopping, Perceived Friend's Knowledge, Continuance Intention

INTRODUCTION

In recent years, the rise of social media leads to online consumer behavior had profound changes. Aral, Dellarocas, and Godes (2011) indicated that social media is fundamentally not only changing our consuming, creating, communicating, and collaborating ways but also makes business activities changing revolutionarily. Enterprises tried to transfer online business activities from electronic commerce extend to social media, i.e., marketing activities of social media not only focus on good products, but also social relationship connection, interaction, and participation. Business model developed the so-called "social commerce."
Social commerce was a form of electronic commerce that comprises social participation and shopping activities via social media network (Liang and Turban, 2011). Most of the social network sites were working based on friendship (Trusov, Bodapati, and Bucklin, 2010). Compare with other formal reviews, positive or negative comments from friends are more influencial (Rad and Benyoucef, 2011), thus play an important role in the social shopping

process. Tang and Qiu(2016) examine these cross-platform impacts on content diffusion between different social media platforms. Although these platforms originally do not share information with each other, they are closely connected through users' cross-platform activities. Moreover, the effectiveness of information diffusion highly relies on well understanding the preference information of the targeted users. As users know more about their friends than marketers, the relations between the users become a natural medium and filter for message diffusion. Anderson et al. (2011) argue that "recommendations from the most influential people of all, the prospective buyer's friends and family" (p.1). Hence, social commerce needs to emphasize interacting with the shopper and friends.

Prior studies tried to involved social factors in electronic commerce and social commerce, for example, social CRM (Rishika et al., 2013), social influence (Bhattacherjee, 2000; Datta, 2011; Guo and Barnes, 2011; Lee, Shi, Cheung, Lim, and Sia, 2011; Li and Shiu, 2012), social tie (Wang and Chang, 2013; Wang et al., 2013), word of mouth (Kim and Park, 2013; Zheng, Zhu, and Lin, 2013; Wang et al., 2013, Awad and Ragowsky, 2008), social motivation (Guo and Barnes, 2011), social comparison (Hamari, 2013; Shen, 2012), online participation (Awad and Ragowsky, 2008; Casaló, Flavián, and Guinalíu, 2010), social value (Kim et al., 2011), social support (Liang et al., 2011), social interactive engagement (Pagani and Mirabello, 2011), user-generated social shopping features (Olbrich and Holsing, 2011). These studies focus on interaction with other online users, but social commerce needs to focus on interaction with shopper’s friends more than general online users.

However, most of the previous studies explored social commerce activities only focus on a single dimension to represent whole social commercial activities, such as Liang et al. (2011) and Zhang, Lu, Gupta, and Zhao (2014) explored the variable of social commerce intention only adopted to items of social media participation intention dimension to represent social commerce intention, and ignored the social shopping dimension. Thus, this study tried to fill this gap by exploring social media participation and social shopping dimensions, and the correlation between social media participation and social shopping in the context of social commerce.

Social commerce was a new business model of electronic commerce, and social media environment was a new platform for innovation that raises a variety of new and challenging research issues that require new theories (Liang and Turban, 2011). However, prior studies emphasized on individual perspective or interaction with other online users and lack of discussion about "friends' influence." Xu et al. (2014) indicated that peer influence was a critical factor on adopting new technology, and peer influence refers to as the influence of friends in the social network site. First of all, social commerce must focus on social perspective, especially the relationship between shoppers and friends. Previous studies tried to involved social factors, but related studies focus on interaction with other online members (weak ties) (such as Li and Shiu, 2012; Kim and Park, 2013); however, social commerce must emphasize on the interaction between shoppers and their friends (strong ties).

Kleiner (2011) demonstrated the influence of friends was very important in social commerce, 53% of consumers were willing to look up information about a brand if their friends had recommended it. Moreover, Crowdtap (2013) also showed that 41.7% of shoppers used social media to ask friends for opinions regarding a specific product or service via Facebook on purchasing holiday gift. Friends who have more related- shopping knowledge about specific product or service than shoppers their own, friends usually can facilitate consumer in shopping process (Mangleburg, Doney, and Bristol, 2004), and thus perceived friend's knowledge was a critical factor in shopping activities (Gershoff and Johar, 2006). Above, social commerce must emphasize the social perspective, emphasize interaction with one's friends (strong ties). However, prior studies emphasized on individual perspective or interaction with other online users, and couldn't not clear answer about the "friends' influence." This study tried to extend

expectation confirmation theory to explore friend's factor (interpersonal trust, perceived friends' knowledge, social information influence) how to indirectly influence on social media participation continuance intention and social shopping continuance intention in social commerce, and social media participation continuance intention between shopper and friend how to influence by social shopping continuance intention via social media. The research question includes the following:
Q1: How friend's factors (perceived friend's knowledge, social information influence, and interpersonal trust) might directly/indirectly affect social media participation continuance intention and social shopping continuance intention?
Q2: What kind of relationship might be between social media participation continuance intention and social shopping continuance intention in social commerce?

LITERATURE REVIEW

Expectation Confirmation Theory

Expectation confirmation theory (ECT) was a very famous and widely used theory in a lot of research field, as well as expectation confirmation theory developed based on the cognitive model of satisfaction decisions by Oliver (1980). The ECT model showed that consumer repurchase intention determined by the satisfaction factor of previous user experience, and the level of satisfaction also determined by prior confirmation or disconfirmation experience between expectation and perceived performance. ECT is majorly used to explore consumer behavior (such as satisfaction, repurchase, continuance intention, and post-purchase behavior) in the marketing field. However, Bhattacherjee (2001) found problems of ETC. Thus his study proposed a revised model to explore the information system (IS) continuance intention. The study indicated that perceived usefulness could replace post-adopted expectation. Secondly, the original testing time of ECT comprises pre-adopted and post-adopted, but the variables of pre-adopted also presented by confirmation and satisfaction of post-adopted. Thirdly, the post-acceptance model IS continuance pay attention to post-adopted expectation. The scholars of IS field had opportunity understanding and applying ECT to explore IS continuance usage behavior. Recently, the scholars of IS field still explore different new technology or information system continues usage behavior based on expectation confirmation theory. For example, Hong and Pavlou (2014) explored that product fit uncertainty is related to product returns, due to dissatisfaction based on expectation confirmation theory. Lankton et al. (2014) involved trust-in-technology into expectation disconfirmation theory to understand the trust how to influence the continued use of strategic information systems. This study also tried to examine how the friend's factor influences on social commerce continuance intention based on the post-acceptance model of IS continuance.

Social Commerce

Social commerce (SC) has been referred to "a subset of e-commerce that involves using social media, the online media that supports social interaction and user contributions, to assist in the online buying and selling of products and services" (Turban et al. 2012, p.305). Social commerce was a new business model, which was a form of electronic commerce, but social media technologies, interactions of communities, and commercial activities were different from electronic commerce. Thus, practice and academic field also do much research to understand the nature of social commerce. In recent three years, related studies tried to explore the each dimension of social commerce, such as social commerce concept and development history (Wang and Zhang 2012; Zhou et al. 2013), shopping flow (Kim et al. 2013), shopping motivation

(Pöyry et al. 2013; Guo and Barnes 2011), social tie (Wang and Chang 2013; Wang et al. 2012), social comparison (Hamari 2013; Shen 2012), word of mouth (Kim and Park 2013; Zheng et al. 2013; Wang et al. 2013), user-generated social shopping features (Olbrich and Holsing 2011), social interactive (Pagani and Mirabello 2011), social support (Liang et al. 2011). We found that prior studies had adopted different theories to explain the social media behaviors or specific phenomenon. However, the expectation-confirmation theory was not applied to explore social commerce continuance intention and related behavior. As the expectation-confirmation theory was suitable to explain this behavioral intention, it would be suitable to investigate consumers' intention in the context of social commerce. In addition, social factors were critical in social commerce environment. Previous related studies showed social factors only indicated the interaction between shoppers and other users or shoppers. However, this study reviewed that other scholars pointed out the definition of social commerce or research implications that found friend's role in social media was important. Thus this study deeply examined how the social factor-the shopper's friends indirectly or directly influence on social commerce behavior intention.

Social Media Participation and Social Shopping

The role of consumer participation initially began to receive attention in virtual community area (Casaló et al. 2010) and service marketing area (Cermak et al. 2011). Kang et al. (2010) pointed out participation is defined as "involvement in life situations and represents an interaction between an individual and the physical, social, and attitudinal environments." Social participation involves forming and maintaining social relationships and is supported by accessible environments and positive interactions” (p.1744). Zhang et al. (2014) pointed out participation behavior in social commerce includes requesting and sharing commercial information on social media. Pagani and Mirabello (2011) tried to explore the effect of social-interactive engagement and experiential personal engagement on active and passive behavior on social TV, and further study the advertising strategies of social commerce. Dholakia et al. (2004) explored that value perceptions on how to influence social influence (group norms and social identity), and indirectly impact on consumer intention to participation and participation behavior. They saw participation as "intentional social action."
Social shopping refers to "a method of e-commerce where shoppers' friends become involved in the shopping experience. Also, Kim et al. (2013) showed that social shopping “is a form of eCommerce based on social relationships in which friends influence each other’s shopping experiences and purchasing behavior on the Web” (p.170). Also, Ng (2013) indicated that intention to social shopping refers as “the perceptions and intentions to accept a friend’s product recommendation or review when purchasing a product on a social commerce site" (p.612).
From previous studies demonstrated that participation influences on shopping behavior viewpoint. Phang et al. (2013) demonstrated that higher levels of social media participation had significant enhance consumption intention. Casaló et al. (2010) also described that major outcome of online participation was the intention to purchase and adopt the products or services in the future. Maamar (2003) also pointed out consumers would ask their friends about the specific product before their purchase behavior. According to the discussion above, business activity viewpoint, purchase process viewpoint, and the participation influence on shopping behavior viewpoint, this study identifies two key consumer behaviors of social commerce were social participation and social shopping via social media.

Interpersonal Trust

Ng (2013) proposed the dimension of trust in social network community as "the sense of protection, care, and perception of reliability from the messages, feedback, or recommendations from other friends on a social network site." (p.612). Previous studies indicated that social media participation and social shopping intention significantly decided by trust construct. Pentina et al. (2013) presented trust on social media had a positive influence on continuance intention to use social media platform and provide some recommends to another member. Chu and Kim (2011) reported that consumers' become friends by having a mutual agreement and joining each other's social networks. Customers can review their friends' profiles, and thus social connections can enhance their credibility and social trust between the consumers and their friends. Their study also demonstrated that users trust their friends in the list of social network site; user perceived reliability and trustworthiness would directly significant affect their opinion seeking, opinion giving, and opinion expressing on social network site of social media participation.

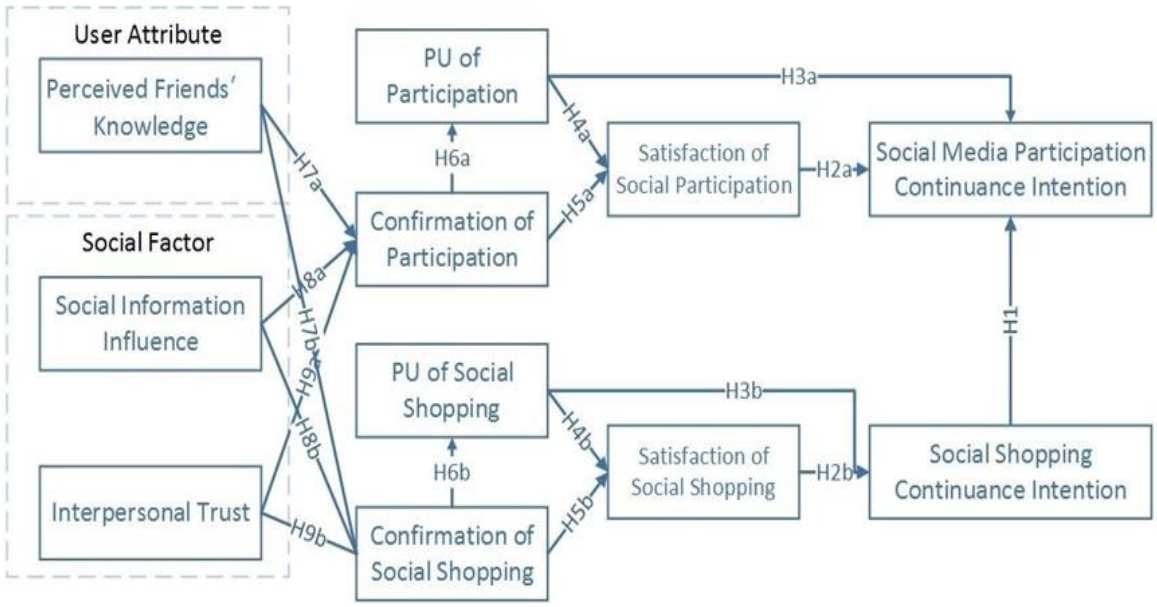
Social Information Influence

Informational social influence refers to “an influence to accept information obtained from another as evidence about reality” (Deutsch and Gerard 1955, p. 629). Kuan et al. (2014) indicated that informational influence was “one's tendency to conform to the opinions of others, based on information obtained as evidence in judgment" (p.154). Social information influence exists power in influencing social network behavior, and previous studies tried to involve social information influence to explore social network intention or social shopping behavior. Kuan et al. (2014) examined how informational and normative social influence on group-buying, and their study adopted brain imaging tools and self-reported to collect data. Wang and Chou (2014) indicated that group-buying repurchasing intention had indirectly significantly influenced by social influence. Risselada et al. (2014) explored the dynamic effects of social influence on adoption of high-technology products in a social network environment, and their study found social influence affected on adoption through different social influence variable. Ogara et al. (2014) adopted empirical study to demonstrate that social influence directly affects user's satisfaction with mobile instant messaging.

RESEARCH MODEL

According to previous studies, this study found friends of social media play an important role in social commerce environment. Therefore, friend's factors as antecedents would impact on shopper to confirm the prior expectation and post-adoption perception, and user's perception of system usefulness for social media participation and shopping via social media. Confirmation would directly affect user's perception of system usefulness and satisfaction with social media participation and social shopping. Next, the user's perception of system usefulness also affects satisfaction with social media participation and social shopping, as well as directly affects social media participation continuance intention and social shopping continuance intention. Based on expectation confirmation theory, interpersonal trust, perceived friends' knowledge, and social information influence literature, here is a research model showed in Figure 1.

Figure 1: Research model



Research Hypotheses

Social Media Participation and Social Shopping

Ng (2013) refers intention to social shopping as “the perceptions and intentions to accept a friend’s product recommendation or review when purchasing a product on a social commerce site” (p.612). Maamar (2003) pointed out online transaction context should consider about the relationship between shopping and friends, and such as pre-purchase phase, a consumer would ask the opinion of his or her friends about the specific product. Moreover, Pavlou and Fygenson (2006) demonstrated that intention to get information influenced by intention to purchase based on implementation intention theory. Also, consumers would like to visit social shopping via social media platform, because they can obtain product information, recommendation, and evaluation from friends of social media, and thus they go to social media platform to request their friends on social media. According to the discussion above, this study proposed the following hypotheses:
H1: social shopping continuance intention will influence social media participation continuance intention.

Satisfaction

Liang et al. (2011) pointed out "satisfaction is the degree to which a user is pleased with the overall experiences of using the social medium."(p.78). Hayta (2013) showed that satisfaction or dissatisfaction provides important opportunities for businesses to predict the buying decisions of other consumers. Satisfaction was a useful predictor of continuance intention (Xu et al. 2014; Zhou et al. 2014). Lin et al. (2014) pointed out satisfaction with social media had a strong correlation with continuance intention to use social media platform. Also, Huang et al. (2014) demonstrated that satisfaction with the seller had a significant direct correlation with two types of participation (positive rating and textual feedback submission). Pentina et al. (2014) also analyzed the previous empirical studies found one of the determinant factors of social media participation was satisfaction. Park (2014) demonstrated that continuance intention in social

network site was directly affected by satisfaction. When consumer had the higher satisfaction with social media, he/she would see the correlation with social media participation continuance intention and social shopping continuance intention. Therefore, this study proposal Hypotheses 2.
H2a: Satisfaction with social media participation will influence social media participation continuance intention.
H2b: Satisfaction with social shopping will influence social shopping continuance intention.

Perceived Usefulness and Confirmation

The concept of perceived usefulness was widely accepted in the information system field proposed by Davis (1989). Perceived usefulness be used to predict usage and measuring information system application. The definition of perceived usefulness refers to "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis 1989). Xu et al. (2014) also showed that perceived usefulness was theorized as the major antecedent of adopting intention or continuance intention. Previous studies demonstrated perceived usefulness has a directly significant influence on intention to shop through empirical data in social media environment (Hajli 2014; Han and Windsor 2011). Another according to a post-acceptance model of IS continuance, satisfaction was determined by perceived usefulness (Bhattacherjee 2001). Wang and Chu (2014) pointed out perceived usefulness had a direct influence on intention to research information in group-buying site. Zhou et al. (2014) examined social virtual world continuance intention; they used utilitarian benefit to represent the concept of perceived usefulness. Their study found perceived usefulness has an influence on satisfaction, and then satisfaction also has a strong direct influence on continuance intention by empirical data. Therefore, this study proposal Hypotheses 3 and Hypotheses 4.
H3a: Perceived usefulness of social media participation will influence social media participation continuance intention.
H3b: Perceived usefulness of social shopping will influence social shopping continuance intention.
H4a: Perceived usefulness of social media participation will influence satisfaction with social media participation.
H4b: Perceived usefulness of social shopping will influence satisfaction with social shopping.
Another, Xu et al. (2014) also presented that confirmation is a function to compare the difference between initial expectation and post-adoption; confirmation strongly affects perceived usefulness and satisfaction, and indirectly affects continuance intention. Based on the post-acceptance model of IS continuance proposed by Bhattacherjee (2001), the model presented confirmation had a significant and positive influence on perceived usefulness. Therefore, this study proposed Hypotheses 5 and Hypotheses 6:
H5a: Confirmation of social media participation will influence satisfaction with social media participation.
H5b: Confirmation of social shopping will influence satisfaction with social shopping.
H6a: Confirmation of social media participation will influence perceived usefulness of social media participation.
H6b: Confirmation of social shopping will influence perceived usefulness of social shopping.

Social Factor

Ngai et al. (2015) pointed out social factors were significant antecedents to predicate the social media outcome (such as user intention) through literature support. This study adopted

perceived friend's knowledge, social information influence, and interpersonal trust as three critical antecedents. Park (2014) pointed out customer perceived social network usage is usually affected by their close friends from a social network site. A popular application of social media also facilitates consumers to discuss, easily communicate, and self-disclosure among friends (Xu et al. 2014). When making a purchase decision, consumers often tried to obtain friends' prior purchasing experience, recommendations, purchasing evaluation, or product information. Gershoff and Johar (2006) indicated that a friend plays as an agent depend, and consumer decision relies on the friend's knowledge. Pentina et al. (2014) also analyzed the previous empirical studies found consumer knowledge had indirect influences on social media participation. Mangleburg et al. (2004) also found consumer perceived friends knowledge is better than the consumer, friends' knowledge (such as product, stores, brand, etc.) can facilitate the process of shopping for teen's group. Thus, consumer higher perceived friends' knowledge would increase correlation with higher satisfaction for social media. This study proposed the following hypotheses:

H7a: Perceived friends' knowledge will influence confirmation of social media participation.

H7b: Perceived friends' knowledge will influence confirmation of social shopping.

Recently, some studies tried to explore how social influence affect continuance usage in a social network environment (Xu et al. 2014; Kane et al. 2014). Wang and Chou (2014) pointed out "social influence is the extent to which social networks influence people's behavior through messages and signals from others that facilitate the formation of people's perceived value of a technology system."(p.122). Besides, Ogara et al. (2014) demonstrated social influence directly affect user satisfaction with mobile instant messaging. Dholakia et al. (2004) showed social influence (group norms and social identity) had an indirect influence on the intention of participation. Thus, this study proposed Hypotheses 8:

H8a: Social information influence will influence the confirmation of social media participation.

H8b: Social information influence will influence confirmation of social shopping.

Another, Lankton et al. (2014) showed that trust is related to satisfaction. Pentina et al. (2014) pointed out trust in social media site would have a direct positive influence on the intention to continue usage and social media participation. Liang et al. (2011) also showed that trust would have a significant indirect effect on continuance intention to social commerce. Ng (2013) pointed out trust had a substantial effect on purchase intention. Hajli (2014) demonstrated that trust had significant positive influence intention to buy in the social network site. Chu and Kim (2011) demonstrated that users perceived reliability and trustworthiness would have directly significant affect their opinion seeking, opinion giving, and opinion expressing on social network site of social media participation. Ngai et al. (2015) showed trust was one of the social factors that directly and indirectly affects personal intention. This study proposed the following hypotheses:

H9a: Interpersonal trust will influence the confirmation of social media participation.

H9b: Interpersonal trust will influence confirmation of social shopping.

RESEARCH METHOD

Questionnaire Development

This study adopted an online survey to collect data. All measures of each construct in Figure. 1 was adopted from previous studies and was measured using a 5-point and 7-point Likert scale. Questionnaires comprised of five parts: First, the title described the welcoming message, research purpose, subject requirement, data protecting strategy, incentive respondent strategy, and term explaining. The measurement variables of this study include: (1) independent variables: social factor (social information influence, interpersonal trust, and perceived friend's

knowledge); (2) mediating variables: perceived usefulness of social media participation, confirmation of social media participation, perceived usefulness of social shopping, confirmation of social shopping, satisfaction with social media participation, satisfaction with social shopping, and social shopping continuance intention; (3) dependent variables: social media participation continuance intention. This study used partial least squares (PLS) that was one of analyzing SEM technique that helped this study conducted the path analysis. The operational definition of variables, source, and the items see Table 1.

Table 1: Measurement of Variables

Variable		Operational Definition	Source
Independent Variable	Perceived friends' knowledge	Consumer feels the knowledge of social media friends that regarding product, shopping, or store.	Mangleburg et al. (2004)
	Interpersonal trust	Consumer perceived the level of confidence, beliefs and trust in the friends of social media.	Chu and Kim(2011)
	Social information influence	The consumer was obtained information from friends of social media, and then influence the shopping opinions, participate intention.	Mangleburg et al. (2004)
Mediating variables	Confirmation	Consumer confirmed the level of difference between expecting of pre-using and feel of post-using the social media participation and social shopping.	Bhattacherjee (2001)
	Perceived usefulness	Consumer feels the degree of useful and expected benefit with the functions of social media participation and shopping provided by the social media network.	Dang et al. (2014)
	Satisfaction	Consumer perceived satisfied, happy or pleased with social media participation related to shopping, and shopping via social media network.	Liang et al. (2011)
	Social shopping continuance intention	Consumer intended to continue shopping via social media network.	Bhattacherjee (2001)
Dependent Variable	Social media participation continuance intention	Consumer intended continuing social participation related shopping via social media network.	Bhattacherjee (2001)

Sample and Data Collection

This study adopted on online survey system to collect data. Subject must have social media participation and social shopping experience. This study total received 478 respondents; however, after data cleaning, this study removed 105 sample. Here are removing reasons: (1) never used social shopping or social media participation who have13 respondents; (2)19 respondents repeatedly fill the questionnaire. This study confirmed repeat e-mail respondents,

or if respondents did not write e-mail then check the fill time (similar time to check the answers, if the answers were the same, the respondents would be dropped); (3) 73 respondents were also dropped for outliers through box plot of SPSS analyzing. Finally, 373 respondents were involved in this study, and the effective response rate was 78%.

RESEARCH RESULTS

Respondent Characteristics

This study uses descriptive analysis to analyze subjects' demographics including gender, age, education, occupation, user experience (social media experience, social shopping experience, social media participation experience), and social media type (for using, for social shopping, and for social media participation) by SPSS 22 software. Table 2 showed the demographic analysis of 373 respondents.

Table 2: Demographic Analysis

Characteristics	Item	Frequency	Percentage
Gender	Male	133	35.7
	Female	240	64.3
Age	Under 20	24	6.4
	20-30	126	33.8
	30-40	158	42.4
	40-50	54	14.5
	Over 50	11	2.9
Education	High school	17	4.6
	University/College	221	59.2
	Graduate school	135	36.2
Occupation	Student	88	23.6
	Housewife	21	5.6
	High tech	53	14.2
	Military and Government/Researcher	76	20.4
	Service	84	22.5
	Manufacturing	29	7.8
	Freelancer	14	3.8
	Finance	4	1.1
	Medical	4	1.1
Social media experience	Less than 6 months	19	5.1
	6 months-1 year	16	4.3
	1-3 years	74	19.8
	3-5 years	106	28.4
	Over 5 years	158	42.4
Social shopping experience	Less than 3 months	70	18.8
	3-6 months	48	12.9
	6 months-1 years	60	16.1
	1-2 years	82	22.0
	2-3 years	39	10.5

	Over 3 years	74	19.8
Social media participation for shopping experience	Less than 3 months	71	19.0
	3-6 months	63	16.9
	6 months-1 years	79	21.2
	1-3 years	93	24.9
	Over 3 years	67	18.0
Social shopping platform *	Facebook	318	49.4
	Line	161	25.0
	Google+	52	8.1
	Plurk	4	0.6
	Twitter	7	1.1
	WeChat	15	2.3
	QQ	16	2.5
	Mobile01	63	9.8
	Ptt	4	0.6
	Other	4	0.6
Social media participation platform *	Facebook	331	48.0
	Line	175	25.4
	Google+	54	7.8
	Plurk	12	1.7
	Twitter	9	1.3
	WeChat	18	2.6
	QQ	16	2.3
	Mobile01	67	9.7
	Ptt	5	0.7
	Other	3	0.4

Note: * presented the multiple responses from the question.

Reliability and Validity Analysis

All measurement items were theoretically grounded and based on the previous studies; thus this questionnaire has face validity. In order to obtain the content validity of the measurement, this study invited seven experts to review items which include two practical experts, four academic experts, and one language experts. Before the formal test, the pilot test invited twenty social media users who have social shopping and social media participation experience to identify problems of the research design. Thus, content validity will thus ensure.

The questionnaire of this study was modified using the scales provided from previous studies (Bhattacherjee 2001; Chu and Kim 2011; Dang et al. 2014; Liang et al. 2011; Mangleburg et al. 2004). This research using Cronbach's α and composite reliability (CR) to measure the reliability of constructs. All the value of Cronbach's α and composite reliability (CR) were higher than 0.7. Hair et al. (2006) pointed out the sample size was above 350, the value of factor loading must higher than 0.3. The factor loadings of this study were above 0.7, representing the items were reaching statistical significance. These results indicated that the reliability, convergent validity, and discriminant validity were at an acceptable level, as reported in Table 3.

Table 3: Reliability and Validity of the Scale

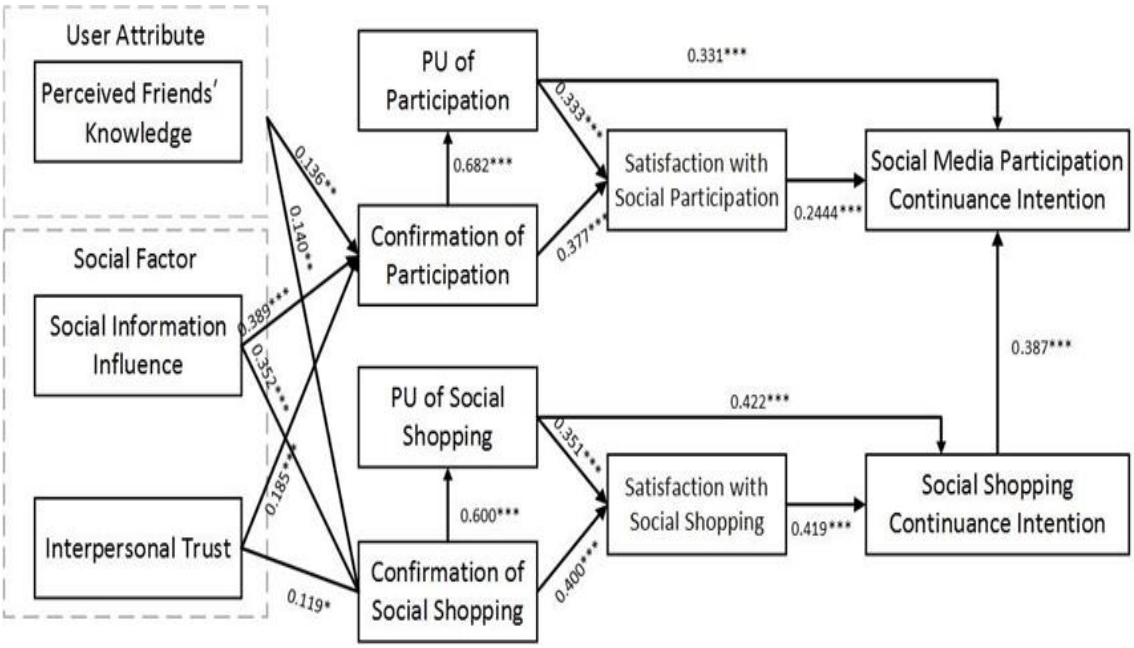
Construct	Item loading	CR	AVE	Cronbach's α	Correlation										
					PC	PCP	PK	PPU	PS	SC	SCS	SI	SPU	SS	TR
PC	0.81-0.86	0.88	0.72	0.80	0.84										
PCP	0.85-0.90	0.91	0.78	0.85	0.68	0.88									
PK	0.85-0.87	0.90	0.75	0.83	0.31	0.22	0.86								
PPU	0.83-0.84	0.87	0.70	0.78	0.68	0.68	0.29	0.83							
PS	0.85-0.90	0.91	0.77	0.85	0.60	0.65	0.22	0.59	0.87						
SC	0.80-0.84	0.86	0.68	0.76	0.68	0.52	0.28	0.53	0.49	0.82					
SCS	0.88-0.90	0.92	0.80	0.87	0.65	0.70	0.24	0.55	0.55	0.64	0.89				
SI	0.70-0.81	0.85	0.60	0.77	0.51	0.43	0.34	0.47	0.38	0.45	0.44	0.77			
SPU	0.75-0.85	0.84	0.64	0.71	0.53	0.53	0.31	0.58	0.46	0.60	0.66	0.48	0.79		
SS	0.81-0.87	0.88	0.72	0.80	0.60	0.55	0.27	0.48	0.62	0.61	0.66	0.45	0.59	0.85	
TR	0.81-0.91	0.88	0.73	0.81	0.38	0.34	0.21	0.36	0.29	0.30	0.29	0.43	0.30	0.37	0.85

Note: Leading diagonal shows the square root of AVE of each construct
PC=Confirmation of participation; PCP=Participation continuance intention; PK=Friend's Knowledge; PPU= Perceived usefulness of participation; PS=Satisfaction of participation; SC=Confirmation of shopping; SCS=Shopping continuance intention; SI=Information Influence; SPU=Perceived usefulness of shopping; SS=Satisfaction of shopping; TR=Interpersonal trust

Hypothesis Testing

This study adopted SmartPLS technique conducting the path analysis. Two stages involved the structural model analysis. Using bootstrapping technique of SmartPLS 3 software to conducted the path analysis of the structural model, and then obtained the path coefficients and coefficient of determination. Figure 2 showed the results of path coefficients on every relationship. Table 4 pointed out the detail the path coefficients and p-value, and Table 5 also presented the R square (β) of the dependent variable.

Figure 2: Results of structural model



*p<0.05 **p<0.01 ***p<0.001

Table 4: Path Coefficients

	Path Coefficients	Standard Error	P Values
PC -> PPU	0.682	0.032	0.000***
PC -> PS	0.377	0.062	0.000***
PK -> PC	0.136	0.045	0.003**
PK -> SC	0.140	0.053	0.008**
PPU -> PCP	0.331	0.047	0.000***
PPU -> PS	0.333	0.061	0.000***
PS -> PCP	0.244	0.045	0.000***
SC -> SPU	0.600	0.033	0.000***
SC -> SS	0.400	0.053	0.000***
SCS -> PCP	0.387	0.065	0.000***
SI -> PC	0.389	0.049	0.000***
SI -> SC	0.352	0.052	0.000***
SPU -> SCS	0.422	0.040	0.000***
SPU -> SS	0.351	0.052	0.000***
SS -> SCS	0.419	0.040	0.000***
TR -> PC	0.185	0.050	0.000***
TR -> SC	0.119	0.053	0.024*

*p<0.05 **p<0.01 ***p<0.001

Note: PC=Confirmation of participation; PCP=Participation continuance intention; PK=Friend's Knowledge; PPU=Perceived usefulness of participation; PS=Satisfaction of participation; SC=Confirmation of shopping; SCS=Shopping continuance intention; SI=Information Influence; SPU=Perceived usefulness of shopping; SS=Satisfaction of shopping; TR=Interpersonal trust

Table 5: R Square of Dependent Variable	
Variable	R Square
Confirmation of participation	0.315
Participation continuance intention	0.660
PU of participation	0.466
Satisfaction of participation	0.424
Confirmation of shopping	0.236
Shopping continuance intention	0.562
PU of shopping	0.360
Satisfaction of shopping	0.451

Above, the results demonstrated that perceived friends' knowledge, social information influence, and interpersonal trust indirectly influence satisfaction (with social media participation and with social shopping) and continuance intention (social media participation and social shopping).

DISCUSSION

Analyzing results demonstrated that consumer perceived social shopping continuance intention had a positive and significant influence on social media participation continuance intention (β=0.387, $p<0.001$). R square of social shopping continuance intention was 0.562, and R square of social media participation continuance intention was 0.660. That represented social shopping continuance intention, and social media participation continuance intention had significant explaining power based on R square results. Analysis results showed the mean of social shopping continuance intention was 4.92 that represented the respondents almost fully agreed continuance intention to shop via social media. As well as the mean of social media participation continuance intention was 4.93 that also represented the respondents highly agreed continuance intention to social media participation related to shopping. The research results of Pavlou and Fygenson (2006) was similar to this study, which demonstrated the intention of getting information influenced by intention to purchase based on implementation intention by empirical study support. According to analyzing results, hypothesis 1 was supported.

Satisfaction with social media participation had a positive influence on social media participation continuance intention that support by data (β=0.2444, Satisfaction adopted the five points Likert scale, the respondents satisfied the social media participation (mean=3.56). Satisfaction was one of the significant predictors of continuance intention (Xu et al., 2014; Zhou et al., 2014). The results were similar to Lin et al. (2014), their study pointed out satisfaction with social media had a strong correlation with continuance intention to use social media platform. Higher satisfaction with social media participation indeed leads to higher social participation continuance intention that support by this study. The results were similar to Huang et al. (2014), and Pentina et al. (2014) demonstrated satisfaction had a positive influence on user participation intention (intention to submit a positive rating and intention to submit textual feedback).

The respondents perceived satisfaction with shopping via social media was satisfy, happy, and pleased (mean=3.55). R square of satisfaction with social shopping was 0.451. Satisfaction with shopping via social media had a significant and positive influence on social shopping continuance intention (β=0.419, $p<0.001$). Perceived social shopping satisfaction had a positive influence on social shopping continuance intention by this study supported. Consumers satisfied with the shopping playfulness and functional convenience of the previous social shopping

experience, and feel psychological happy and pleased that leads continuance intention to shop via social media platforms. The results were similar to the previous studies (Park, 2014 and Zhou et al., 2014). Therefore, hypothesis 2a and hypothesis 2b were supported.

Perceived usefulness (PU) of social media participation had a significant influence on satisfaction with social media participation (β=0.333, $p<0.001$) and social media participation continuance intention (β=0.331, $p<0.001$). R square of PU of social media participation was 0.466, and social shopping was 0.36. Mean of PU of social media participation was 5.07 and social shopping was 5.07.

Consumer obtained product information, group-buying activities, and store discount from social network friends, or given the comments for friends' shopping requests via social media platform. While consumers perceived the participation for shopping was usefulness, which leads to higher satisfaction with social media by data supported (Hypothesis 4a, $p<0.001$). The perceived social media could assist quickly to social media participation for shopping, such as collecting shopping or storing information, finding suitable requirement products, or real-time discussing with one's friends, and then influence social media participation continuance intention for shopping. Thus, analyzing results also supported that PU of social media participation had a significant influence on social media participation continuance intention (Hypothesis 3a, $p<0.001$).

Moreover, PU of social shopping also had a significant effect on social shopping continuance intention (β=0.422, $p<0.001$). The analyzing results also demonstrated that PU of social shopping positively influenced satisfaction with social shopping (β=0.351, $p<0.001$). The respondents perceived quick shopping via social media platform that assisted by social media functions and official website that enable consumers to order the product or service directly. Thus, the degree of satisfaction with social shopping was closer satisfaction (mean=3.55). The result of this study was similar to Awad and Ragowsky (2008) that presented perceived usefulness had significant influence intention to shop online. Analyzing the results of this study showed the respondents thought using the social media platform could enhance shopping effectiveness, and then, positive influence on satisfaction with social shopping. The result was similar to Casaló et al. (2010) study that pointed out PU would significantly affect satisfaction and responded Bhattacherjee (2001) pointed out satisfaction was a determination by perceived usefulness. Therefore, hypothesis 3b and hypothesis 4b were supported.

Confirmation of social media participation had a significant influence on satisfaction with social media participation (β=0.377, $p<0.001$). R square of confirmation of social media participation was 0.315. Furthermore, confirmation of social media participation had significant and positive influence PU of social media participation (β=0.682, $p<0.001$).

According to mean of confirmation of social media participation was 4.83, that represent the respondents perceived the service level by functions of social media participation for shopping was better than expected it. Using the experience of social media participation for shopping was better than respondents expected it, which lead to a significant influence on satisfaction with social media participation. Based on expectation confirmation theory, satisfaction positively influenced by confirmation. On the other hand, consumer perceived service or function level of social media participation was good, and that also directly affect perceived social media participation was usefulness. Thus, the results of this study demonstrated that confirmation of social media participation had statistically significant and positively influence PU of social media participation.

In social shopping part, the data also supported the confirmation of social shopping had a significant influence on satisfaction with social shopping (β=0.400, $p<0.001$). R square of confirmation of social shopping was 0.236. Mean of confirmation of social media participation was 4.68. Confirmation of social shopping also had a significant and positive influence on

satisfaction with social shopping (β=0.600, p<0.001). The results showed the experience of shopping via social media was better than originally expected, and the shopping service provided by social media was also better than expected (mean=4.68). This study also demonstrated the confirmation had a significant influence on satisfaction and PU by the expectation-disconfirmation theory proposed. The expectation of consumer was less than using the perception of shopping via social media, which leads to higher satisfaction with social shopping and perceived usefulness (such as enhances shopping performance, or shopping effectiveness via social media). Xu et al. (2014) also presented that confirmation likes a function to compare the difference between initial expectation and post-adoption, and confirmation strongly affects perceived usefulness and satisfaction and indirectly affect continuance intention. Therefore, hypothesis 5 and hypothesis 6 were supported.

Analyzing results demonstrated that perceived friend's knowledge had an influence on confirmation of social media participation (β=0.136, p<0.01), and perceived friend's knowledge had an influence on confirmation of social shopping (β=0.140, p<0.01). However, the statistically significant level and correlation coefficients between the relationship of perceived friends' knowledge and confirmation of social media participation, and perceived friends' knowledge and confirmation of social shopping were less than the relationship between other variables in this study.

Social information influence had positively and significantly influence on confirmation of social media participation (β=0.389, p<0.001), as well as social information influence had a significant influence on confirmation of social shopping (β=0.352, p<0.001) that supported by data. Mean of social information influence was 4.97. The results represent consumer often require the friends to help to choose the suit product, and obtain the product or service information or comments, or reference the prior shopping experience of user experience of friends. With social media had real time and quick search a lot of online friends, thus the respondents were willing to use the social media platform to communicate with friends than other communicate method (such as face-to-face, telephone, email). Social commerce was different from other electronic commerce. Consumers more care about friends' think than other members' comments of the network in social commerce. Therefore, consumers perceived friends' information influence ware high, and that lead to consumers perceive using experience, service level than initial expectation on social media participation activities and shopping via social media. Previous studies also had similar research findings.

Another variable of the social factor was interpersonal trust. The results also demonstrated that interpersonal trust had a positive influence on confirmation of social media participation (β=0.185, p<0.001) as well as interpersonal trust had an influence on confirmation of social shopping (β=0.119, p<0.05). Mean of interpersonal trust was 4.84 that represented the respondents trust the social media friends. Analyzing results showed the respondents trust most contacts on the friend's list of social media, and had the confidence to believe in the contacting friends of social media. From a statistical significant level, the interpersonal trust had a significant influence on confirmation of social media participation (p<0.001), then interpersonal trust influenced confirmation of social shopping (p<0.05). Pentina et al. (2013) also indicated trust on social media had a positive influence on continuance intention and provided some recommendations to other members. Also, Chu and Kim (2011) pointed out users trust their friends who in their friend's list of the social network site. Users perceived reliability and trustworthiness would significantly influence on their opinion seeking, opinion giving, and opinion expressing on social network site of social media participation. Therefore, hypothesis 7 to 9 were supported.

CONCLUSION

This study intends to apply the expectation confirmation theory to explore how the friend factors influence directly and indirectly on social media participation continuance intention and social shopping continuance intention, and further investigate the correlation between social media participation continuance intention and social shopping continuance intention. A total of 373 valid respondents involved in this study (valid response rate was 78%) through an online survey.

One of the interesting findings was social shopping continuance intention had a significant and positive influence on social media participation continuance intention. This study also demonstrated confirmation of social media participation had significant and positive influence on perceived usefulness of social media participation. The path coefficient is 0.682, which means after consumers participate in social media, the consumers perceived that social media participation is more useful than initially expected. The perceived usefulness of social media participation has become the most critical factor affecting satisfaction with social media participation.

In the social shopping section, confirmation of social shopping also had a significant and positive influence on the perceived usefulness of social shopping. The path coefficient is 0.600, which means after consumers shopping on social media, the consumers perceived that shopping on social media is more useful than initially expected. The results make the perceived usefulness of social media shopping has become the most crucial factor affecting social media shopping.

The perceived usefulness of social shopping also had a significant influence on social shopping continuance intention. The path coefficient is 0.422, which means that consumers perceive of using the social media platform are useful and can improve the shopping effect. For reasons outlined above, the perceived usefulness of social shopping is the most crucial factor affecting social shopping continuance intention.

Additionally, we also demonstrated three antecedents of related friend factors had, directly and indirectly, influence on confirmation, perceived usefulness, satisfaction, social media participation continuance intention and social shopping continuance intention, and social information influence was more effective than interpersonal trust and perceived friend's knowledge do. This study found perceived friends' knowledge, social information influence, and interpersonal trust were valuable variables in social commerce research.

This study has several implications to practice: For social media designers and vendors, friend's factor has a positive influence on social media participation and social shopping. The results showed social information influence affects indirectly social commerce continuance intention than other friend's factor (interpersonal trust and perceived friend's knowledge) does. Social media designers and vendors can design system function or mechanism for information exchange conveniently between shopper and shopper's friends. The results showed consumers like shopping via social media; they will go to the social media platform to obtain product or store information from friends of social media. Thus, designing the shopping functions creates the outstanding "interaction with friends" function. A consumer can merely see the friend's opinion of a specific product, or confirmation the online friends and then real-time talk with their friends to discuss the shopping questions.

For the marketing manager, the shopper's friends play an important role in social participation and social shopping. Thus, designing a marketing strategy can provide more social information, such as increase active alert about the friend's purchasing experience or friend's comments. Group- buying activities provide a friend's list of prior shopping experience on social media network and help shopper quickly look for the specific friend who had product knowledge or experience. For social media members, consumers understood how the personal social media

participation and shopping continuance intention influenced by friend's factors (interpersonal trust, perceived friends' knowledge, and friend's informational influence).

Research Limitation

Research design and implement were possible comprehensive in this study. However, three limitations still comprised of this study. First, this study adopted a cross-sectional study to investigate the research questions. Thus the results were not easy in-depth understanding of the relationship between independent variables, mediator, and dependent variables. Second, most of the respondents come from Taiwan, thus the results may not generalize to other cultures. Third, transnational respondents who cannot log in the Google survey system did not include this survey because the country had sent a limit of the specific network access.

Future Research

According to research limitations and results, above several research directions can provide a reference for future research. First, future study can adopt longitudinal study to deeply investigate the influence of friend factors (perceived friend's knowledge, interpersonal trust, and social influence), and understand the impact change of friend's factors in different time points. Second, future study can consider how different culture influence on social media participation and social shopping activities by friend's factors, due to social information influence was significant affects confirmation, then interpersonal trust and perceived friend's knowledge does in this study. Third, this study only explores continuance intention. However, previous studies also pointed out social media participation behavior would direct and significant social shopping behavior. Thus, future study can further examine behavioral relationship (social media participation behavior and social shopping behavior) by empirical study.

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DECISION SCIENCES INSTITUTE

Understanding Social Technology Competence and Digital Collaboration: From the Perspective of First-Generation College Students

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ABSTRACT

This research examines the relationship between social technology competence and digital collaboration among first-generation college students and their peers. To test our hypotheses, we collected survey data from a sample of 106 students in an urban 4-year university in the United States. The regression analysis showed that social technology competence had a positive effect on digital collaboration, and this positive effect is stronger for first-generation students. Our study contributes to the research on computer-supported collaborative learning and first-generation students, and offers insights into managing the social media technology practices at higher education institutions.

KEYWORDS: Social Technology, Competence, Computer-supported collaborative learning, Digital collaboration, First-generation students, Regression

INTRODUCTION

With the proliferation of social media (SM) technologies, academic institutions are increasingly using these tools for student outreach and student learning (Dabbagh & Kitsantas, 2012). SM technology refers to Web 2.0 technologies inclusive of social networks, blogs, wikis, multimedia platforms, and virtual worlds (Tess, 2013). In this paper, we refer to one's ability and skills with the use of SM technologies as social technology competence. Because SM technologies are tools that help users increase collaboration and gain a sense of community (Koch et al, 2013), users' competence with the social technologies of SM becomes important for them to achieve various outcomes. For example, college students may use some form of SM to create networks and stay connected with others. They use social media platforms for various activities ranging from socialization and communication to academic information search and information sharing. The benefits of SM such as Facebook on college students' academic work and college life have been evidenced in prior studies (e.g., Ellison et al, 2007; 2011).

Although most college students may have some pre-exposure to technology and resources such as social media technologies, others may not be so fortunate. While many students have been encouraged to attend college at a young age by their families where several generations have college degrees, there is another group of students with no family history of postsecondary

education. They are referred to as first-generation students, undergraduates whose parents' highest level of education is a high school diploma or less (Nunez & Cuccaro-Alamin, 1998). This population of college students faces economic, social, and cultural challenges in their college education. As first-generation students are from challenging economic backgrounds and are the first in their family to attend a postsecondary educational institution to attain a bachelor's degree, they are more likely to drop out of college compared to their better-equipped peers. For example, only 14 percent of low-income, first-generation students attending two-year institutions are eventually transferred to four-year institutions (Engle & Tinto, 2008).

Compared to their peers, first-generation students are generally older and less likely to receive financial aid from their parents. According to the study by Engle and Tinto (2008), 74 percent of low-income, first- generation students are financially independent. In addition, 30 percent of low-income, first-generation students are single parents and 38 percent have dependents. These first-generation students have many responsibilities to manage besides attending college: they may have to work outside of college or help take care of their families. This prevents them from accessing the full college experience, which explains why these students usually begin and end their postsecondary education at two-year institutions. When higher education institutions have a great concern for maintaining and increasing the college graduation rates, SM technology has the potential to offer various resources to a high risk population such as first-generation students.

The use of SM has been shown to have certain effects on the education of first-generation students. As suggested by Rahman, Ramakrishnan, and Ngamassi (2017), SM can bring the benefit of helping first-generation students improve learning outcomes at college. Another example of the SM impact is that first-generation students are more likely to use social media to search for colleges instead of relying on personal sources such as friends and family. For example, 27 percent of first-generation students discovered college on SM as compared to the 17 percent of non-first-generation students (Kelly, 2017).

However, little is known about the impacts of SM competence on first-generation students' digital collaboration for academic work. We refer to digital collaboration as the communication and collaborative activities enabled by digital technologies (such as social media platforms) for the purpose of getting help, consulting friends and classmates, and completing a joint learning task through social media. As many first-generation students spend a majority of their time working, they often do not have the time to fully participate in campus activities and obtain access to various academic support services (Eagle & Tinto, 2008). Therefore, it is important to understand if and how their social media use and competence affect their online collaboration with their peers at college.

In this study, we intend to address the following two questions: (1) What is the relationship between social technology competence and digital collaboration? (2) Does the effect of social technology vary by first-generation student status?

To answer these questions, we conduct an empirical study to investigate the association between social media technology competency and digital collaboration of first-generation college students. To do so, we built on the literature in computer supported collaborative learning as well as first-generation students and surveyed a sample of 106 students in a 4-year public urban university. Our regression analysis results suggest that social technology competence is positively related to digital collaboration and such effect is stronger for first-generation students.

This paper is organized as follows. In the next section, we present our theoretical foundation and research hypothesis. Then, we show our research methodology and data collection, followed by analysis of the survey data and discussion of the results. We conclude the paper with limitation of the study and directions for future research.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

To help us understand the impact of SM competence on digital collaboration, we drew upon the research on computer-supported collaborative learning. As Stahl, Koschmann, and Suthers (2006) explained, computer-supported collaborative learning (CSCL) arose in the 1990s as a result of employing software in the learning of isolated individuals. The advancements in the Internet technology in the 1990s and the early 2000s made it possible to connect people in innovative ways and to create an online environment for collaborative work. As students became more competent with the Internet technologies, they started to engage in asynchronous distributed learning groups supported by the computer-mediated world-wide networks. To make CSCL successful, users of the computer networks must have a desire for social interactions and must develop a sense of community of learning (Kreijns, Kirschner, & Jochems, 2003).

In today's society of digital social media, the influence of social media is growing at an unprecedented speed (Lenhart, Purcell, Smith & Zickuhr, 2010). Social media serves many different purposes, such as generating content and sharing photos (Tess, 2013). It also serves as an excellent form of communication when face-to-face meetings are not possible. With the ubiquitous use of social media in education, the purposes of creating, sharing, and communicating can greatly strengthen collaboration among students. Therefore, we hypothesize:

> Hypothesis 1: Social technology competence has a positive effect on perceived digital collaboration.

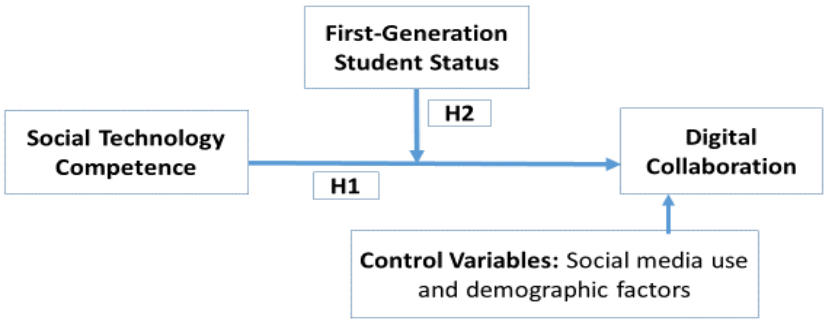
Social media is a great tool for students when searching for educational opportunities and being connected with others. Moreover, it provides a convenient channel for college students to work on collaborative projects and presentations online (e.g., Ellison et al, 2007; 2011). As college students become more competent with the technology, they are more likely to engage in online collaboration.

However, social media technology competence can have a larger influence on a first-generation student's digital collaboration, compared to those who are not first-generation students. This is because students who are first-generation students often encounter more barriers in completing their college degrees than their peers: their lack of financial support from their family and multiple obligations beyond their college responsibilities. According to Nunez & Cuccaro-Alamin (1998), some of the barriers students face include: "poor academic preparation, family responsibilities, and full-time work, for instance, can pose severe challenges to a student's ability to integrate into postsecondary institutional life" (p.2). By conveniently connecting with classmates and instructors through different social media platforms, they may be able to better mobilize the resources in the college classmate network, increasing their collaborative work with their classmates. Therefore, we hypothesize:

> Hypothesis 2: First-generation student status moderates the relationship between social technology competence and digital collaboration.

Both hypothesis 1 and 2 are depicted in the research model in Figure 1 below.

Figure 1: Research Model



METHODS

Research Site and Data Collection

The research site is a four-year public, urban university located in the west region of the United States. It is an ethnically and economically diverse university, as the campus recently reports that 61% of its student population identify themselves as the first in their families to go to college. Data was collected via an online survey in November 2017. The survey asked the students to first identify themselves as "first-generation college students" or not and ensured that no names or personal identity information would be collected to protect respondents' privacy and confidentiality. Then the survey asked students to assess their competence with using various social media tools and to evaluate their collaboration via social media channels. The survey also included questions about their social media usage behavior, such as time spent on social media, frequency of using social media, and the list of social media accounts they have.

A total data sample of 106 participants was analyzed and reported in this article. From a total of 106 students surveyed, 88 students (83 percent) were first-generation students. From this group, 62.26 percent of all students were female and first-generation students. Among all the participants, 72.6 percent were Hispanic or Latino and first-generation students, while 61.3 percent of those students were unemployed and first-generation students. The students who had a family income of less than $25,000 and who were first-generation students accounted for 39.6 percent of all the participants, followed by those who have a family income between $25,000 and $49,999 and who were first-generation students (34%).

The table below summarizes the demographic characteristics of the survey participants.

Table 1: Demographic Characteristics of Participants				
		Non-FirstGen (n=18)	FirstGen (n=88)	Grand Total (n=106)
	Total	17.0%	83.2%	100.00%
Gender	Female	12.26%	62.26%	74.53%
	Male	4.72%	18.87%	23.58%
	Gender Non-Conforming	0.00%	1.89%	1.89%
Ethnicity	American Indian or Alaskan Native	0.0%	0.9%	0.9%
	Asian or Pacific Islander	3.8%	1.9%	5.7%
	Black or African American	3.8%	6.6%	10.4%
	Hispanic or Latino	4.7%	72.6%	77.4%
	White / Caucasian	4.7%	0.9%	5.7%
Employment Status	Employed full-time	0.9%	1.9%	2.8%
	Employed part-time	5.7%	19.8%	25.5%
	Not employed (full-time students Only)	10.4%	61.3%	71.7%
Household Income	1_Less than $25,000	5.7%	39.6%	45.3%
	2_$25,000 - $49,999	2.8%	34.0%	36.8%
	3_$50,000 - $74,999	5.7%	4.7%	10.4%
	4_$75,000 - $99,999	0.0%	1.9%	1.9%
	5_$100,000 or more	2.8%	2.8%	5.7%

All the percentages are based on the grand total of 106 respondents.

Model

Our main model is Equation (1), which is estimated using the ordinary least squares (OLS) model for all students and for the first-generation students only. The model includes the two important measures of social media use, access frequency and duration time. We also control for age, gender, employment status, years of having a Smartphone, and household income.

$$\text{Digital Collaboration} = ß_0 + ß_1\, Competence + ß_2\, Frequency + ß_3\, Duration + ß_4\, Age + ß_5\, Gender + ß_6\, Employment + ß_7\, SmartPhoneYr + ß_8\, Household\_Income + \varepsilon \quad (1)$$

Digital collaboration is measured by two items adopted from Ng (2012); the items were slightly modified to fit the social technology context. Using the 5-likert scale, the two questions are ““*I frequently obtain help with my academic study from my friends over the Internet, e.g., through Facebook, Skype, Blogs.*” and “*Social media technology enables me to collaborate better with my peers on course projects and other learning activities*”. For each dimension, we coded “strongly agree” as 5, “agree” as 4, “neutral” as 3, and “disagree” as well as “strongly disagree” as 2 and 1. As a result, the total rating for each measure ranges from 1 to 5. We took the average of the two items to measure an individual’s overall digital collaboration.

For social media technology competence, we measure it by taking the average of the two items slightly modified from Ng (2012). The two items are: are “*I can learn new social media*

technologies easily" and *"I have the technical skills I need to use social media technologies for learning and to create artifacts (e.g., videos, digital stories, wikis, and blogs*".

RESULTS

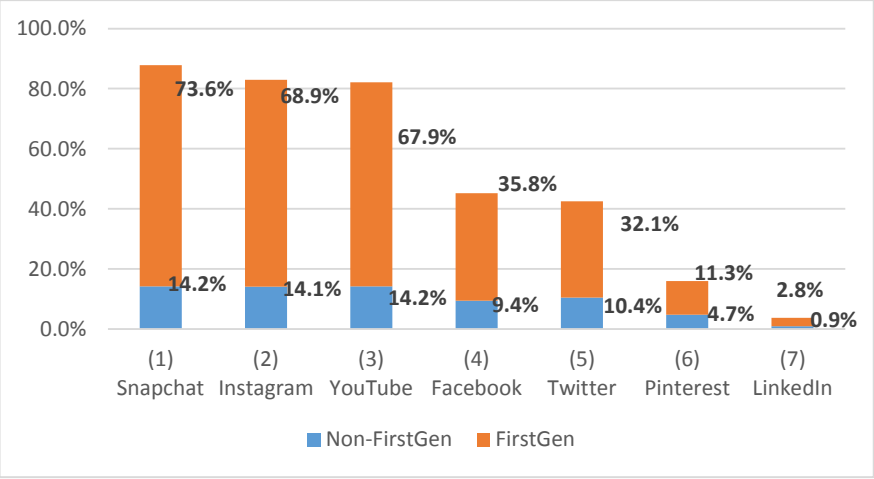
Descriptive Statistics

Distribution of Social Media Accounts by Participants

Among the 106 respondents, 83.02 percent of them own an Instagram, and 68.9 percent own an Instagram and are first-generation students. 82.1 percent of all students own a YouTube, and 67.9 percent of all students own a YouTube and are first-generation students. 45.3% of all students own a Facebook. 35.8 percent of those students own a Facebook and are first-generation students, and 47.2 percent of those students don't own a Facebook and are first-generation students. In total, 87.7 percent of all students own a Snapchat. 73.6 percent of all students own a Snapchat and are first-generation students.

42.5 percent of all students own a Twitter. 32.1 percent of all students own a Twitter and are first-generation students. Only 16.0 percent of all students own a Pinterest. 11.3 percent of all students own a Pinterest and are first-generation students. Finally, 3.8 percent of all students own a LinkedIn. 2.8 percent of all students own a LinkedIn and are first-generation students. The distribution of social media account ownership is represented in the figure below. Please note that percentages in this figure below are based on the grand total of 106 respondents.

Figure 2: Distribution of Social Media Accounts by Participants (n=106)



As shown in the figure, among all these social media accounts, the three most popular types of social media are Snapchat, Instagram and YouTube with 87.7 percent, 83 percent and 82.1 percent respectively. The two least popular types of social media are Pinterest and LinkedIn with 16.0 percent and 3.8 percent respectively.

Social Media Use Patterns among Participants

Among all the first-year college students, the majority use social media every 2-3 hours (33.0 percent), followed by every hour (23.6 percent). For the first-generation students, the pattern is similar with the majority using social media every 2-3 hours (33.0 percent), followed by an equal percent of first-generation students using social media every hour and every 4-6 hours (20.5 percent). The distribution of social media access pattern is summarized in the table below. Please note that percentages in this figure below are based on the column totals.

Table 2: Patterns of Social Media Use by Participants			
	Non-FirstGen (n=18)	FirstGen (n=88)	Grand Total (n=106)
By Social Media Access Frequency			
Frequency1_Every 30 minutes	5.6%	18.2%	16.0%
Frequency2_Every 1 hour	38.9%	20.5%	23.6%
Frequency3_Every 2-3 hours	33.3%	33.0%	33.0%
Frequency4_Every 4-6 hours	22.2%	20.5%	20.8%
Frequency5_Every 7 hours +	0.0%	8.0%	6.6%
Grand Total	100%	100%	100%
By Social Media Use Duration			
Duration1_Less than 1 hour	22.2%	20.5%	20.8%
Duration2_1-2 hours	33.3%	25.0%	26.4%
Duration3_3-4 hours	27.8%	26.1%	26.4%
Duration4_5 hours or more	16.7%	28.4%	26.4%
Grand Total	100%	100%	100%

As shown in the table above, the different amount of time spent on social media by all students in the data sample is equally proportioned between 1-2 hours, 3-4 hours, and 5 hours or more (26.4 percent) and a smaller percent of students using social media for less than 1 hour (20.8 percent). The pattern for first-generation students is slightly different with the largest percent using social media for 5 hours or more (28.4 percent of total first-generation students).

Self-Assessment of Perceived Digital Collaboration

When responding to the two questions on the effects of social media use on digital collaboration, more non-first-generation students hold a neutral stance on the effect of social media on supporting their academic learning, with 50 percent of non-first-generation students as compared to 28.4 percent of first-generation students. However, first-generation students tend to hold more defined views on the subject. The patterns in participants' self-evaluation are shown in the table below.

Table 3: Participants' Self-Assessment of Social Media Use for Digital Collaboration			
	Non-FirstGen (n=18)	FirstGen (n=88)	Grand Total (n=106)
Response to the statement: "I frequently obtain help with my academic study from my friends over the Internet, e.g., through Facebook, Skype, Blogs."			
Agree	33.3%	31.8%	32.1%

Agree strongly	5.6%	14.8%	13.2%
Neutral	50.0%	28.4%	32.1%
Disagree	11.1%	14.8%	14.2%
Disagree strongly	0.0%	10.2%	8.5%
Grand Total	100%	100%	100%
Response to the statement; "Social media technology enables me to collaborate better with my peers on course projects and other learning activities."			
Agree	27.8%	36.4%	34.9%
Agree strongly	22.2%	14.8%	16.0%
Neutral	50.0%	38.6%	40.6%
Disagree	0.0%	8.0%	6.6%
Disagree strongly	0.0%	2.3%	1.9%
Grand Total	100%	100%	100%

Table 3 demonstrates the responses to the second statement: more first-generation students disagree that social media technology enhances collaboration with 10.3 percent disagreeing and none of the non-first-generation students disagreeing.

Spearman Correlations

We have examined the spearman correlations for the variables used in our analysis. For different measures of digital collaboration, as expected, they are highly correlated. Other than that, the highest correlation we observed is 0.36 between digital collaboration and social technology competence, which does not raise any multicollinearity concerns for our regression model. The table below (Table 4) displays the mean and standard errors of variables, and correlations among all the variables.

Table 4: Spearman Correlations

Vars	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)	1.00										
(2)	0.52*	1.00									
(3)	0.89*	0.84*	1.00								
(4)	0.01	-0.12	-0.05	1.00							
(5)	-0.20*	-0.21*	-0.23*	0.08	1.00						
(6)	-0.12	-0.06	-0.11	-0.10	0.21*	1.00					
(7)	-0.13	-0.02	-0.10	-0.18	-0.08	-0.00	1.00				
(8)	0.04	0.14	0.10	-0.04	-0.13	-0.07	0.08	1.00			
(9)	0.01	-0.17	-0.08	0.11	0.18	0.23*	-0.17	-0.09	1.00		
(10)	0.16	0.20*	0.21*	0.06	0.04	0.07	0.06	0.10	-0.02	1.00	
(11)	0.29*	0.34*	0.36*	0.02	-0.20*	0.03	0.15	0.15	-0.13	0.28*	1.00
(12)	0.00	-0.05	-0.03	-0.04	-0.04	-0.11	-0.02	-0.23	0.03	0.08	-0.04

* $p < 0.05$

Note: Variables (1) Digital collaboration 1; (2) Digital collaboration 2; (3) Digital collaboration-aggregated; (4) Gender-male; (5) Age; (6) Employed; (7) Smart Phone Year; (8) Household income; (9) SM access frequency; (10) SM duration time; (11) Social technology competence; (12) First-generation student status

Main Results

Our main results are presented in Table 5, Table 6 and Table 7. Table 5 is based on the first digital collaboration measure, and Table 6 uses the second digital collaboration measure. Table 7 reported the results based on the average of the two measures. Each table presents three sets of results: full sample, first-generation, and non-first-generation.

Table 5 presents the regression results based on the first digital collaboration measure. It shows that in the full data sample, social technology competence is positively related to digital collaboration (0.35, $p < 0.05$). When we look at the findings of the first-generation students, the results are similar to those in the full sample, with a slight decrease of the coefficient of social media duration time (0.34, $p < 0.05$). However, the relationship between social technology competence and digital collaboration for non-first-generation students is not as significant when compared to the full sample and the sample of first-generation students (0.02, $p = 0.96$). Furthermore, although there is a positive relationship between social technology competence and digital collaboration for non-first-generation students, it is much smaller compared to the other sample groups. However, given the small sample size of the non-first-generation group, the results concerning this group need to be interpreted with caution.

Table 5: Main Results based on the First Collaboration Measure

	Full Sample	First-Gen	Non-First-Gen
Intercept	5.07 (3.43)	6.51 (4.38)	5.49 (6.32)
Gender_Male	-0.10 (0.26)	-0.07 (0.3)	0.36 (0.64)
Age	-0.15 (0.18)	-0.24 (0.24)	-0.12 (0.36)
Employed	-0.40 (0.25)	-0.51* (0.29)	0.54 (0.52)
SmartPhoneYear	-0.13* (0.07)	-0.16* (0.08)	0.21 (0.2)
Household_Income	-0.04 (0.1)	0.03 (0.14)	-0.25 (0.19)
Social Media Frequency	0.04 (0.1)	0.09 (0.11)	-0.22 (0.32)
Social Media Duration	0.14 (0.1)	0.17 (0.11)	-0.12 (0.29)
Social Technology Competence	0.35** (0.15)	0.34** (0.17)	0.02 (0.44)
N	106	88	18
Adj R^2	0.068	0.104	-0.19

Standard errors are in parenthesis, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6 presents the regression results based on the second digital collaboration measure. The results show that, in the full data sample, social technology competence is positively related to digital collaboration (0.28, $p < 0.05$). This is consistent with the result in Table 5 (the first digital collaboration measure). When we look at the findings of the first-generation students, we find that social media duration time remain significant (0.25, $p < 0.10$). However, in the non-first-

generation student group, the coefficient of social technology competence increases but is insignificant (0.51, $p < 0.25$). However, given the small sample size of this group, this result needs to be interpreted with caution.

Table 6: Main Results based on the Second Collaboration Measure

	Full Sample	First-Gen	Non-First-Gen
Intercept	6.72** (2.65)	6.20* (3.3)	12.63* (5.99)
Gender_Male	-0.28 (0.2)	-0.22 (0.23)	-1.07 (0.6)
Age	-0.22 (0.14)	-0.21 (0.18)	-0.58 (0.34)
Employed	-0.09 (0.19)	-0.1 (0.22)	-0.74 (0.5)
SmartPhoneYear	-0.06 (0.06)	-0.03 (0.06)	-0.14 (0.19)
Household_Income	0.04 (0.08)	0.11 (0.1)	-0.3 (0.18)
Social Media Frequency	-0.11 (0.08)	-0.11 (0.08)	0.27 (0.31)
Social Media Duration	0.15* (0.08)	0.17** (0.09)	0.42 (0.27)
Social Technology Competence	0.28** (0.12)	0.25* (0.13)	0.51 (0.42)
N	106	88	18
Adj R^2	0.139	0.152	0.077

Standard errors are in parenthesis, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7 presents the regression results based on the aggregated measure of digital collaboration. The results show that, in the full data sample, social technology competence is positively related to digital collaboration (0.31, $p < 0.01$). This is consistent with the results in both Table 5 and Table 6. When we look at the findings of the first-generation students, we find that social technology competence remains significant (0.29, $p < 0.05$), similar to the results in Table 5 and Table 6. However, in the non-first-generation student group, the coefficient of social technology competence becomes insignificant, which needs to be interpreted with caution, given the small sample size of this group.

Overall, the main results from the regression analysis supported the first hypothesis on the positive role of social technology competence on digital competence, based on the results of the full sample in Tables 5-7. This positive relationship holds in the sample of first-generation students (column 2, Tables 5-7), but not in the non-first-generation student sample (column 3, Tables 5-7). These results provide evidence to show that first-generation students benefit more from social technology competence in improving their digital collaboration, thus supporting the second hypothesis.

Table 7: Main Results based on the Aggregated Collaboration Measure			
	Full Sample	First-Gen	Non-First-Gen
Intercept	5.90**	6.36*	9.06*
	(2.64)	(3.43)	(4.81)
Gender_Male	-0.19	-0.15	-0.36
	(0.20)	(0.24)	(0.48)
Age	-0.19	-0.22	-0.35
	(0.14)	(0.18)	(0.27)
Employed	-0.25	-0.30	-0.10
	(0.19)	(0.23)	(0.40)
SmartPhoneYear	-0.10*	-0.10	0.03
	(0.06)	(0.06)	(0.15)
Household_Income	-0.003	0.07	-0.27*
	(0.08)	(0.12)	(0.15)
Social Media Frequency	-0.03	-0.10	0.03
	(0.08)	(0.09)	(0.25)
Social Media Duration	0.14*	0.17*	0.15
	(0.08)	(0.09)	(0.22)
Social Technology Competence	0.31***	0.29**	0.27
	(0.12)	(0.13)	(0.34)
N	106	88	18
Adj R^2	0.09	0.11	0.21

Standard errors are in parenthesis, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

DISCUSSION

The purpose of this research was to investigate the relationship between digital competence and digital collaboration among first-year college students and their peers, mainly at age 18 in their freshman year at college. The findings in our study provided sufficient evidence to show that a higher level of competence with social media technologies has a positive effect on levels of digital collaboration. As shown in the results based on the full sample and first-generation sample in Tables 5-7, the positive effect is consistently significant ($p < 0.05$).

These results are encouraging for first-generation students to develop their digital collaboration with social media technologies and to utilize the technologies to help them accomplish their academic tasks and engage in their college community. In this regard, these results offer important practical implications for higher education institutions to overcome one particular challenge facing first-generation students, which is their disengagement from academic and social experiences, including study groups, interactions with faculty, and extracurricular activities (Engle and Tinto, 2008). As the first-generation college students typically spend the majority of their time working and only take classes part-time, the amount of time that they spend on campus interacting with other students is limited, which inhibits their academic progress (Engle & Tinto, 2008). Having skills to use social media tools, they are more likely to benefit from the communication and information sharing features of social media platforms for online discussing and collaborating with their classmates on course assignments.

In addition, participants provided some examples on how they utilize social media platforms to seek help online from classmates and instructors and to collaborate with their classmates on course projects. These types of social media enabled activities were found beneficial to the college students in our study. This is illustrated in the following quotes:

> *Social media is somewhat helpful, because students can meet up with groups for group projects through social media.*

> *Social media like Snapchat does help social interactions at college because I use it to text people in my class to ask for help or sometimes people post events happening on campus so I know about it too.*

> *Yes, social media is helpful to my academic work. YouTube there are a lot of tutorials that can help with school work. There are a lot of education videos on YouTube. Facebook allows people to network in a click of a button. You can get in contact with clubs, organizations.*

Participants in our study are first-year college students between the ages of 17 and 21, resulting in an average age of 18.06. Our sample of participants is known as the Generation Z, which is the segment of the population born between 1995 and 2010. Growing up in a world of smartphones and free Wi-Fi, young adults of this generation are assumed to be Internet-savvy and proficient in information and communication technology (ICT), especially social networking applications such as Facebook, YouTube, Twitter, Instagram, and LinkedIn (Priestley, 2015). However, our study shows that not all of the Generation Z college students are equally competent at using social media technologies for academic work. Although about half of the participants (51.8%) in our data sample are confident about their technical skills in using social media technologies for learning and to create videos, digital stories, wikis, blogs, 41.5 percent of them take a neutral stance on this. The incoming generation of students has mainly relied on the Internet and technology throughout their entire lives and this has resulted in them becoming learners who rely on technology (Selwyn, 2012). Because of this, social technology use in higher education serves as a way to better engage the students in learning. Therefore, it is worth further studying the relationship between digital collaboration and this type of learning.

Our study contributes to the research on first-generation students by examining the role of social media technology as a useful resource for improving the college success of first-generation students. In addition, this study extends the research on computer-supported collaborative learning from the network of Internet technology to the social media platforms. As a social technology, social media is designed to facilitate human connection and communication. Moreover, our study has suggested that social media enabled the first-generation college students to access resources in the network of their college classmates and instructors, thus providing them with an educational affordance, as suggested by the Affordance Theory (Gibson, 1979).

This study also makes practical contributions to the design and implementation of social technology strategies in higher education. When one's peers are all communicating and interacting on social media, social media platforms will likely become a convenient tool for first-generation students to access and mobilize the resources available from peers in the college

learning environment. This suggests that it is time for higher education institutions to realize the new learning expectations of the new generation Z and consider incorporating social media tools and platforms into the academic program design (e.g., course delivery channel, instructor feedback mechanism) to promote student learning outcomes.

LIMITTATIONS AND FUTURE RESEARCH

We are encouraged by the findings of the research that higher levels of social technology competence would lead to more digital collaborations participated by first-generation college students. However, we need to acknowledge two limitations of the study. First, our findings may be limited by the organizational characteristics of the research site. Because our research site consisted of only one economically-diverse urban public university with a majority of first-generation undergraduate students, the generalizability of the study findings might be limited.. Thus, the findings of this study should be applied to other types of higher education institutions with caution. Second, in addition to the individual competence with social media technology and extent of social media use, other contextual and individual factors may also influence the level of digital collaboration. Future research on contextual factors such as institutional environment would provide potential useful results.

Nevertheless, collaborating with peers through social media is important for college students, especially first-generation college students who lack educational resources at home or in their own community. For the young first-generation students from Generation Z, they expect digital learning tools such as these to be deeply integrated into their education. For them, technology has always been a fully integrated experience into every part of their lives (Kozinsky, 2017). For future research, it would be useful to examine if and how the social technology competence influence college persistence of first-generation students throughout their college years. According to Dennis and colleagues (2005), support from peers, such as sharing notes, studying in groups, and sharing learning strategies, made the biggest impact upon first-generation college students' success in college. For the young generation of college students who are the first of their families to attend college, they should educate themselves on how to navigate social media tools so they can better capitalize on it as an educational resource in the digital learning environment.

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DECISION SCIENCES INSTITUTE

Understanding the Effects of Airbnb's Two-way Review System on Guests' Intention to Rebook

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"ABSTRACT"

Online reviews of products and/or services have long been recognized as a key driver for consumers' purchase intention. Together with the popularity of the sharing economy platforms, two-way review systems are also widely applied giving both service providers and users a chance to review each other. Psychologists point out that in those systems, people tend to give more positive reviews. Drawn on the heuristic systematic model, this paper focuses on investigating how such positive reviews of themselves form users' perceptions and their influence on the rebooking intention in sharing economy platforms.

KEYWORDS: Two-way review system, Sharing economy, Perceived enjoyment, Perceived helpfulness, Booking habit, rebooking intention

INTRODUCTION

In traditional and electronic commerce, (online) reviews are crucial drivers for business and the focus is always on the consumers and how products/companies are reviewed for the consumers' convenience and choices. Consumer reviews have been found to significantly influence purchase intention (Bae, Lee, Suh, & Suh, 2017; Sparks & Browning, 2011), willingness to buy (Wu & Gaytán, 2013) and to be the critical driver of sales (Ho-Dac, Carson, & Moore, 2013; Maslowska, Malthouse, & Viswanathan, 2017). Review characteristics are normally considered in terms of quality and quantity via the central (systematic) route or peripheral (heuristic) route respectively. While qualitative features of reviews, such as valence, argument strength (K. Z. Zhang, Zhao, Cheung, & Lee, 2014), normally require more efforts to judge, quantitative features, such as volume and rating, take less efforts.

In the new form of sharing economy, where service providers and service users join at a platform, both become the customers to the platform. Since all customers are created equal, peer to peer platforms need to protect both service providers and users equally via the reputation system (Jøsang, Ismail, & Boyd, 2007), or recently called two-way review system. The reputation system, first applied in the eBay, brought both sellers and buyers a chance to review each other after the completion of a transaction (Resnick & Zeckhauser, 2002). The system, however, was not utilized among users and gradually disappeared in 2006. Recently, when sharing economy becomes trendy, two-way review systems are once again introduced and widely utilized. The main purpose of this system is to give both service providers and service users an equal chance to review the provided service and the users' behavior, so that both sides will have more information for their next transaction decisions.

According to psychology, there is an interesting fact that knowing one can review and be reviewed at the end of the transaction, service users tend to behave differently, mostly in better manner while service providers tend to give milder or more positive reviews toward the users. This might generate two things among users, the enjoyment of being nicely reviewed and the perception of

helpfulness for their future bookings, especially when as many as 49% of the times service providers refused to sell their services to certain guests (Fradkin, Grewal, Holtz, & Pearson, 2015). Such enjoyment and helpfulness among the service users who receive positive feedbacks from service providers might potentially keep the users stay with the platform. Among the sharing economy businesses, accommodation tends to have lower competitive compared to transportation, online labor market, etc. (Petropoulos, 2017), thus retention of customers is more crucial to this type of platform.

From the literature review, we identified several research gaps. First, in sharing economy platforms, service providers and users are becoming equal, users can choose which service to buy, providers also have the right to accept or refuse one user. Thus, users care more about their profile quality for higher chance of acceptance by service providers. Previous studies have discussed this, such as how profile pictures influence the rental probability (Fagerstrøm, Pawar, Sigurdsson, Foxall, & Yani-de-Soriano, 2017), however, little research has been done on how reviews from previous hosts help users in their future bookings. Second, previous studies focused on online reviews of products or services and sometimes discussed the emotion embedded in the online reviews (Ullah, Amblee, Kim, & Lee, 2016), however limited research have investigated the impact of reviews about the consumers themselves and their emotions when being reviewed by others (Pettersen, 2017). Finally, shopping habit has been included in studies about online purchases and hotel booking, however, it has not been investigated in sharing economy context.

Within this study, we base on the dual process heuristic systematic model to hypothesize and answer the following research questions: *(1) How do service users perceive when receiving tend-to-be-more-positive reviews from reputable service providers? (2) Will users' aroused perception keep them retaining with the platform? and (3) How will users' booking habit influence their rebooking intention?*

To answer these questions, we conceptualize source reputation as the antecedent for perceived enjoyment via the heuristic route while review positivity influences the perceived helpfulness via the systematic route; perceived enjoyment and helpfulness, under the moderating effects of booking habit will influence users' intention to rebook on the platform. We expect that our research will contribute to the literature of online reviews, especially to new context of reviews of oneself via two-way review systems on sharing economy platforms. The rest of the paper is organized as follows. We first discuss the theoretical background, followed by the hypothesis development. We then use 180 data points collected from a self-reported online survey of Airbnb users to test our research model. Finally, we present our discussion of findings, contributions, limitations and suggestions for future research.

LITERATURE REVIEW

Heuristic Systematic Model (HSM)

This study elaborates on Heuristic Systematic Model – HSM (Chaiken & Eagly, 1989) to investigate the perception and behavior of the service users: how they process the information, bring out the evaluation, and form the decision via two different routes of processing. In systematic information processing, people consider all relevant information such as argument and validity, elaborate and form their judgement; while in heuristic information processing, people base on the information cues (even single cue) that take less efforts to elaborate and form the judgment such as volume and source credibility. When motivation for information processing is high, people tend to go through systematic processing, but they might at the same time go through the heuristic processing (Chatterjee, 2001). Heuristic systematic model has been applied in marketing and IS research to investigate the impact of reviews on purchase intention, system adoption or acceptance, and other intentional outcomes (Luo, Zhang, Burd, & Seazzu, 2013; K. Z. Zhang et al., 2014; K. Z. K. Zhang, Cheung, & Lee, 2014).

Within this study, we argue that, for an Airbnb user, the main effect of the two-way review system that one user considers is how the reviews can help them in their future booking, especially how

the positive content of the reviews would help; while being positively reviewed makes a user enjoyed as a side effect. We therefore conceptualize under the systematic route, the users perceive the helpfulness of the review system based on the consideration of the positive contents of the reviews; under the heuristic route, the reputation of the reviewers increases the enjoyment of the users. These perceptions then influence users' decisions of continuing to use the service.

HYPOTHESIS/MODEL

Source Reputation

Source credibility refers to the trustworthiness of the reviewers that the review readers perceive based on the provided reviewers' information (Li, Huang, Tan, & Wei, 2013) or consumers' perceptions over credibility in terms of the expertise and trustworthiness of the reviewer and review sources (K. Z. Zhang et al., 2014). In this study's context of the two-way review systems, reviewers are the hosts or service providers.

In online websites where consumers' reviews are allowed and displayed, any member can post their reviews, thus which reviewers on which websites to follow is critical to future purchase intention. In sharing economy platforms, instead of reading reviews about the products or services that they might consume, consumers are reading the reviews of their own past service usage written by previous service providers, thus the reviews become sensitive. In accordance with previous studies where the source reputation is decided by the number of reviews, ratings, etc. (Chua & Banerjee, 2015), the service providers' reputation in this case will be the rating, number of reviews they receive, or in simple term, their title of superhosts.

In this study, we argue that when receiving the reviews from previous hosts, the users will have higher perceived enjoyment if the reviews are from reputable hosts or superhosts. Thus, we propose the first hypothesis as follows.

Hypothesis 1: Hosts' reputation has positive influence on guests' perceived enjoyment.

Review Positivity

When discussing the quality of reviews, researchers focused on different dimensions, such as the depth of the reviews or the sidedness of reviews. There has been inconsistent conclusion whether negative reviews or positive reviews are more helpful to consumers. In most studies of the helpfulness of the online reviews, results showed that the more negative words in the review, the more helpful it will become (Baek, Ahn, & Choi, 2012; Sen & Lerman, 2007). Other research found that for products with high average rating, the positive reviews are more helpful and for low average rating products, negative reviews are more helpful (Yin, Mitra, & Zhang, 2016); or the usefulness increases when the reviews have extreme negative or positive contents (Park & Nicolau, 2015). In the context on hotel booking, Sparks and Browning (2011) found that the more positive reviews are more helpful for future booking of the hotel.

In the context of two-way review system, even though the hosts' reviews on guests are written for future hosts, they are reviewing the users themselves. Thus, users are concerned more about the positive contents rather the negative contents of the reviews. And for the sake of smooth future booking, the positive reviews will help to improve the quality of users' profile and increase the chance of acceptance by future hosts. In other words, the higher the positivity of the reviews, the more helpful they are. Based on this argument, we propose the next hypothesis as follows.

Hypothesis 2: Hosts' positive reviews have positive influence on guests' perceived helpfulness.

Perceived Helpfulness

Perceived helpfulness is defined as the extent to which service users perceive the previous service providers' review as being capable of facilitating their future usage of the service (Li et al., 2013). Perceived helpfulness and usefulness are found to have strong effects on intention to continue to use an information system (Bhattacherjee, 2001). In their study of the website socialness influence on intention to use the website, Wakefield, Wakefield, Baker, and Wang

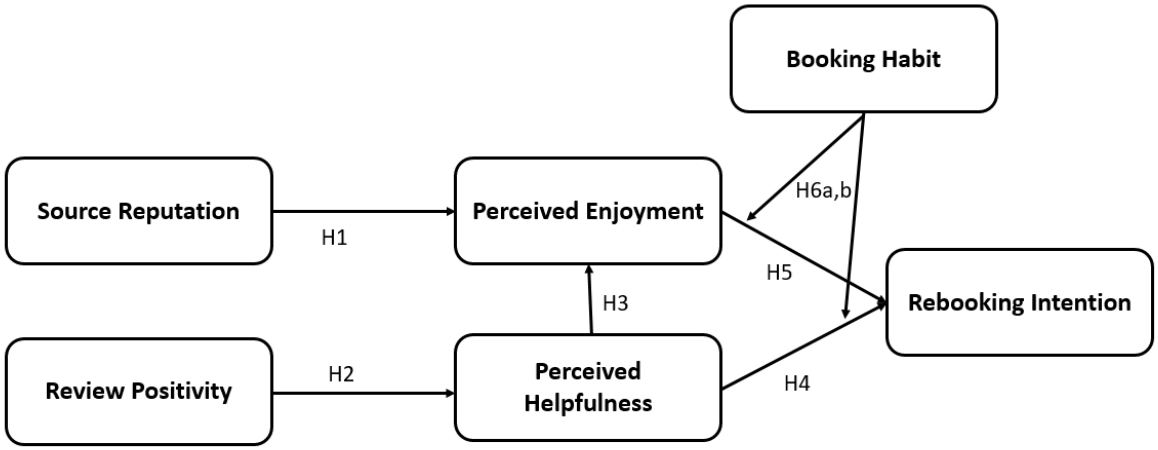
(2011) found that the perceived helpfulness leads to perceived enjoyment among website visitors and both perceived helpfulness and enjoyment then lead to the adoption of the website.
Applying to the Airbnb environment, knowing the positive reviews will increase their profile and their chance of being accepted for the future bookings, the perceived helpfulness will not only make users thrilled and enjoyed, but also strengthens their intention to rebook again. Therefore, we propose hypothesis 3 and 4 as follows.
Hypothesis 3: Guests' perceived helpfulness has positive influence on their perceived enjoyment
Hypothesis 4: Guests' perceived helpfulness has positive influence on their intention to rebook on the platform

Perceived Enjoyment
Perceived enjoyment refers to the extent to which the reviews from the reputation system are perceived to be enjoyable to the service users (Elwalda, Lü, & Ali, 2016). Quite a number of research has found the positive impact of perceived enjoyment on intention to adopt a new system (Dickinger, Arami, & Meyer, 2008) as well as repeating intention such as the repurchase intention (Koufaris, 2002), revisit intention (Reynolds & Ruiz de Maya, 2013), or online service usage intention (Kang, Hong, & Lee, 2009).
In the present study, we assert that when being reviewed by previous hosts, especially positively reviewed, service users will develop an enjoyable perception. Such enjoyment will make service users want to continue to book via the platforms. We then propose the next hypothesis.
Hypothesis 5: Guests' perceived enjoyment has positive influence on their intention to rebook on the platform.

Booking Habit
Habit is defined as "situation-behavior sequences that are or have become automatic… the individual is usually not conscious of these sequences" (Triandis, 1979). According to Chou and Hsu (2016), shopping habit refers to "individuals' general tendency of shopping online irrespective of which website they use for online shopping". Within this study, we define booking habit as the service users' general tendency of booking online irrespective of which platform they use for booking an accommodation.
Shopping habit has been examined in numerous studies both as the antecedent and moderator of purchase and repurchase intention. Khalifa and Liu (2007), in their study on online consumer retention, found that shopping habit has moderating effect on the relationship between satisfaction and online repurchase intention. Chiu, Hsu, Lai, and Chang (2012) examined the impact of trust and shopping habit in online stores found that shopping habit negatively significantly moderates the relationship between trust and repurchase intention. Other research also proposed the moderating effect of shopping habit on the relationships between satisfaction and trust on repurchase intention (Hsu, Chang, & Chuang, 2015).
Within this study, we argue that service users' booking habit moderates the relationship between their perceptions to intention to rebook at the platform. Thus, we propose the last two hypotheses as follows.
Hypothesis 6a: Guests' booking habit moderates the relationship between their perceived enjoyment and rebooking intention.
Hypothesis 6b: Guests' booking habit moderates the relationship between their perceived helpfulness and rebooking intention.

Figure 1 below illustrates our conceptual framework, how review positivity and source reputation influence guests' perceived enjoyment and helpfulness for their future bookings, which in turn will impact the intention to rebook at the platform in the future. Booking habit is proposed to moderate the relationships between perceived enjoyment and perceived helpfulness and rebooking intention.

Figure 1: Conceptual framework



METHODS

In this study, we generated a self-reported online survey questionnaire for data collection. The survey was developed based on literature review including source reputation, review positivity, perceived enjoyment, perceived helpfulness, booking habit, and rebooking intention. Table 1 below gives full details of all the measurements and sources for adaptation. To better capture the Airbnb renters' perception and intention, only users who have booked via this platform before and been reviewed by the previous hosts are eligible to participate in the survey. The survey was then distributed via travelling groups on Facebook to recruit participants and finally 180 valid responses were collected for data analysis.

Table 1. Variable Measurements

Variables	Code	Items	Sources
Review Positivity	PO1	The reviews of me from hosts on Airbnb are very good	(Cheung, Sia, & Kuan, 2012) (Yin, Bond, & Zhang, 2014)
	PO2	The reviews of me from hosts on Airbnb are very favorable	
	PO3	The reviews of me from hosts on Airbnb are very pleasant	
	PO4	The reviews of me from hosts on Airbnb includes positive comments	
Source reputation	*SO1*	*The hosts who reviewed me are reputable*	(Cheung et al., 2012) (Li et al., 2013)
	SO2	*The hosts who reviewed me are highly rated by other guests*	
	SO3	The hosts who reviewed me are good	
	SO4	The hosts who reviewed me are trust worthy	
	SO5	The hosts who reviewed me are reliable	
Perceived enjoyment	PE1	Reading the reviews of me from hosts on Airbnb is enjoyable	(Kang et al., 2009)
	PE2	Reading the reviews on me from hosts on Airbnb is pleasurable	

Table 1. Variable Measurements			
Variables	**Code**	**Items**	**Sources**
	PE3	I have fun reading the reviews of me from hosts on Airbnb	
Perceived helpfulness	PH1	The reviews of me from hosts is very helpful for my future booking on Airbnb	(Yin et al., 2014) (Liao, Tsou, & Shu, 2008)
	PH2	The reviews of me from hosts is very useful for my future booking on Airbnb	
	PH3	The reviews of me from hosts is very informative for my future booking on Airbnb	
	PH4	The reviews of me from hosts on Airbnb increase the quality of my profile	
Booking habit	*HA1*	*Booking at Airbnb is something I do frequently*	(Hsu et al., 2015) (Chiu et al., 2012)
	HA2	Booking at Airbnb is natural to me	
	HA3	Booking at Airbnb is something I do without thinking	
	HA4	Booking at Airbnb has become a routine for me	
	HA5	I have been booking at Airbnb for a long time	
Rebooking intention	IN1	I would like to continue booking at Airbnb	(Hsu et al., 2015) (Chou & Hsu, 2016)
	IN2	I plan to continue booking at Airbnb when I travel in the future	
	IN3	It is likely that I will continue booking at Airbnb in the future	
	IN4	I will consider Airbnb as the first choice to book in the future	

DATA ANALYSIS AND RESULTS

Among 180 respondents, 94 are male (52.2%); most of them are young users in their 20s (114 people, equals to 63.3%) and bachelor or master holders (49.4% and 37.2% respectively). For travel frequency, most people travel from 1 to 6 times per year, accounting for 85.6%. Regarding their Airbnb using habit, more than half of the respondents first booked in Airbnb more than a year ago, why the recency of the last booked varies. Most people book less than 5 times in Airbnb and as a result, receive less than 5 reviews from hosts. Details as in Table 2 below.

Table 2. Demographic Characteristics			
Control Variables	**Category**	**Frequency (N=180)**	**Percentage (%)**
Gender	Male	94	52.2
	Female	86	47.8
Age	Less than 20	2	1.1
	21-30	114	63.3
	31-40	47	26.1
	41-50	13	7.2
	Over 51	4	2.2
Education	High school and below	10	5.6
	Bachelor	89	49.4
	Master	67	37.2
	PhD and above	14	7.8
Monthly Income	Less than USD500.00	34	18.9

Table 2. Demographic Characteristics			
Control Variables	**Category**	**Frequency (N=180)**	**Percentage (%)**
	USD501.00-1,000.00	53	29.4
	USD1,001.00-1,500.00	36	20.0
	USD1,501.00-2,000.00	29	16.1
	More than USD2,001.00	28	15.6
How often do you travel every year?	Less than once	8	4.4
	1-3 times	115	63.9
	4-6 times	39	21.7
	More than 6 times	18	10.0
How long has it been since the FIRST time you booked on Airbnb?	Less than 3 months	26	14.4
	3 to less than 6 months	27	15.0
	6 months to less than 1 year	23	12.8
	More than 1 year	104	57.8
How long has it been since the LAST time you booked on Airbnb?	Less than 3 months	72	40.0
	3 to less than 6 months	54	30.0
	6 months to less than 1 year	28	15.6
	More than 1 year	26	14.4
How many times have you booked on Airbnb?	Less than 5 times	110	61.1
	6-10 times	50	27.8
	11-15 times	15	8.3
	More than 16 times	5	2.8
How many reviews have you received from your previous hosts on Airbnb?	Less than 5 reviews	127	70.6
	6-10 reviews	39	21.7
	11-15 reviews	11	6.1
	More than 16 reviews	3	1.7

In the present study, we applied consistent Partial Least Squares (PLSc) to analyze the data. PLS is a component-based structural equation modeling technique, where PLS is most suitable for model with formative variables and PLSc is more suitable for model with all reflective variables. The data was analyzed in two stages: measurement model, followed by structural model.

Measurement Model

To check the validity of the measurements, we first assessed the factor loadings of each item and the construct convergent validity via Cronbach's Alpha, Composite Reliability (CR) and Average Variance Extracted (AVE). As rules of thumb, Cronbach's Alpha value should be greater than 0.7, CR values greater than 0.7, and AVE values greater than 0.5 (Fornell & Larcker, 1981). After factor analysis, three items including SO1, SO2, and HA1 were deleted because of low factor loadings (smaller than 0.7). The rest of the items were good and included in analysis as shown in Table 3. All Cronbach's Alpha, CR, and AVE values for all constructs well satisfy the requirements, which means the measurements in this study have good convergent validity.

Table 3. Descriptive statistics of constructs				
Variables	**Items**	**Loading**	**Mean**	**S.D**
Source reputation (SO)	SO3	0.872	5.922	1.077

Table 3. Descriptive statistics of constructs				
Variables	**Items**	**Loading**	**Mean**	**S.D**
Cronbach's alpha = 0.894 CR = 0.894 AVE = 0.738	SO4	0.863	5.706	1.250
	SO5	0.842	5.822	1.141
Review Positivity (PO) Cronbach's alpha = 0.943 CR = 0.944 AVE = 0.808	PO1	0.861	5.878	1.177
	PO2	0.929	5.833	1.267
	PO3	0.937	5.906	1.168
	PO4	0.866	6.072	1.197
Perceived enjoyment (PE) Cronbach's alpha = 0.896 CR = 0.897 AVE = 0.745	PE1	0.916	5.561	1.270
	PE2	0.863	5.511	1.302
	PE3	0.806	5.339	1.399
Perceived helpfulness (PH) Cronbach's alpha = 0.909 CR = 0.907 AVE = 0.712	PH1	0.816	5.644	1.315
	PH2	0.836	5.633	1.286
	PH3	0.756	5.461	1.335
	PH4	0.954	5.761	1.412
Booking habit (HA) Cronbach's alpha = 0.895 CR = 0.895 AVE = 0.685	HA2	1.006	4.650	1.641
	HA3	0.754	4.017	1.848
	HA4	0.745	4.011	1.792
	HA5	0.778	4.389	1.771
Rebooking intention (IN) Cronbach's alpha = 0.903 CR = 0.906 AVE = 0.707	IN1	0.769	4.700	1.729
	IN2	0.854	5.689	1.284
	IN3	0.831	5.594	1.324
	IN4	0.903	5.700	1.264

Next, we conducted two tests to confirm the discriminant validity of the constructs, first the confirmatory factor analysis and then the correlations between constructs. Table 4 shows that all items have higher loadings on the constructs that they belong to and Table 5 shows that no two constructs have higher correlation coefficients than the square AVE. These results confirmed the discriminant validity of all constructs.

Table 4. Confirmatory factory analysis with PLS						
	SO	**PO**	**PE**	**PH**	**HA**	**IN**
SO3	**0.872**	0.779	0.633	0.632	0.324	0.507
SO4	**0.863**	0.752	0.633	0.610	0.364	0.512
SO5	**0.842**	0.693	0.573	0.648	0.364	0.539
PO1	0.746	**0.861**	0.637	0.594	0.281	0.412
PO2	0.806	**0.929**	0.653	0.638	0.320	0.485
PO3	0.806	**0.937**	0.658	0.669	0.302	0.480
PO4	0.743	**0.866**	0.615	0.601	0.293	0.452
PE1	0.661	0.700	**0.916**	0.694	0.290	0.386
PE2	0.608	0.613	**0.863**	0.716	0.290	0.339
PE3	0.576	0.524	**0.806**	0.674	0.343	0.314

Table 4. Confirmatory factory analysis with PLS						
	SO	**PO**	**PE**	**PH**	**HA**	**IN**
PH1	0.583	0.598	0.685	**0.816**	0.338	0.394
PH2	0.632	0.589	0.654	**0.836**	0.399	0.412
PH3	0.507	0.469	0.672	**0.756**	0.381	0.413
PH4	0.733	0.679	0.709	**0.954**	0.436	0.523
HA2	0.457	0.413	0.352	0.460	**1.006**	0.660
HA3	0.324	0.230	0.291	0.333	**0.754**	0.538
HA4	0.250	0.187	0.261	0.318	**0.745**	0.611
HA5	0.292	0.238	0.261	0.404	**0.778**	0.558
IN1	0.398	0.283	0.283	0.364	0.725	**0.769**
IN2	0.517	0.478	0.362	0.455	0.558	**0.854**
IN3	0.513	0.436	0.324	0.443	0.573	**0.831**
IN4	0.591	0.501	0.378	0.475	0.565	**0.903**

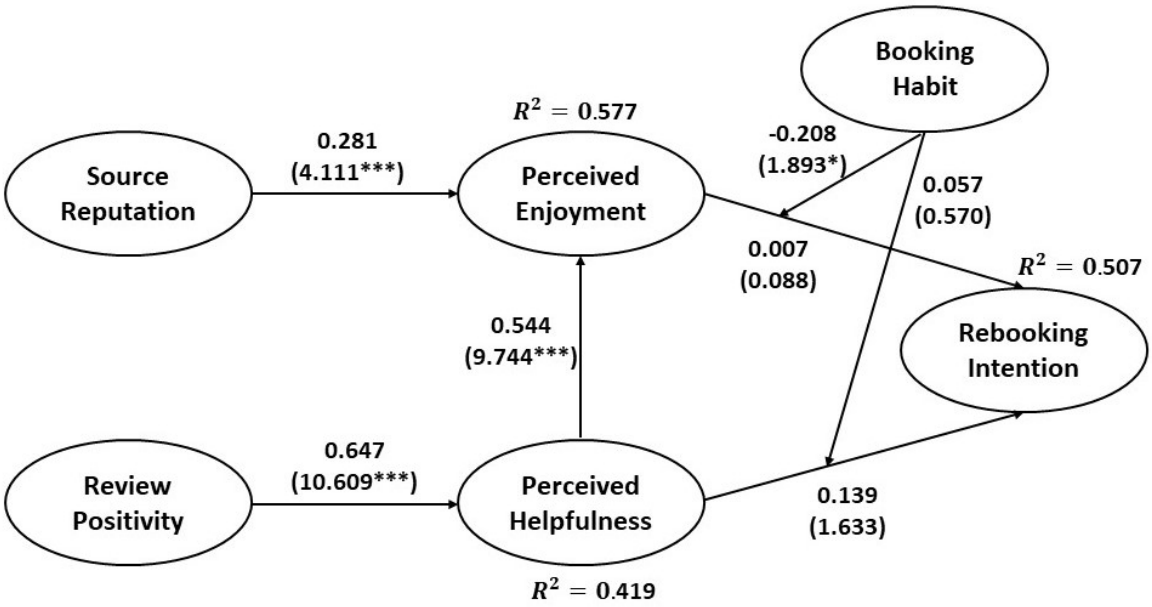
Table 5. Correlations of constructs						
	SO	**PO**	**PE**	**PH**	**HA**	**IN**
SO	**0.863**					
PO	0.859	**0.899**				
PE	0.714	0.713	**0.863**			
PH	0.733	0.697	0.805	**0.844**		
HA	0.408	0.333	0.354	0.462	**0.828**	
IN	0.604	0.510	0.402	0.519	0.715	**0.841**

Note: The bold diagonal values are square roots of AVEs

Structural Model

To test hypotheses and overall model, we conducted consistent bootstrapping with the resampling of 1000. Figure 2 below illustrates the paths' beta values and t-values, and R-square values of dependent variables. Source reputation positively significantly influences the perceived enjoyment among users with beta value of 0.281 and t-value of 4.111. Thus hypothesis 1 is supported. Review positivity also significantly influences the perceived helpfulness with beta value equals to 0.647 and t-value to 10.609, which confirms hypothesis 2. Hypothesis 3 that predicts the impact of perceived helpfulness on perceived enjoyment is also supported with good indicators (beta value equals to 0.544 and t-value to 9.744). However, both perceived enjoyment and perceived helpfulness of users weakly influence their rebooking intention (both t-values are lower than critical level, equal to 0.088 and 1.633 respectively), even though t-value for path between perceived helpfulness and rebooking intention is close to critical level, both hypothesis 4 and 5 are not supported. For the moderating effects, booking habit weakly moderates the relationship between perceived helpfulness and rebooking intention, while significantly moderates the relationship between perceived enjoyment and rebooking intention but in the reverse way. This suggests that when the users have long history of and frequent booking habit on Airbnb, they tend to care less about the reviews and such enjoyment will even less likely to influence their rebooking intention. Thus, hypothesis 6a is supported but not hypothesis 6b.

Figure 2. Structural model



Note: Beta values and t-statistics (in the brackets) are reported; * p<0.1; ** p<0.05; *** p<0.01

DISCUSSIONS, CONTRIBUTIONS AND LIMITATIONS

Discussions

This paper tries to investigate the influence of two-way review systems on sharing economy platforms on users' perception and intention to continue to use the platforms. Based on the heuristic systematic model, we hypothesize the heuristic route of source reputation leading to perceived enjoyment and the systematic route of review positivity to perceived helpfulness. The results show that the more reputable the hosts are, the more enjoyable the users perceive when being positively reviewed of the past behavior. On the other hand, the positive reviews are perceived to be helpful to the users for their coming bookings, which is contrary to some of the previous studies where negative reviews were found to be more helpful to readers (Baek et al., 2012). The users are also more enjoyed when they have high helpfulness perception of the reviews they received. However, none of the perceived enjoyment or perceived helpfulness significantly leads to the intention to rebook at the platform in the future. This might be explained that when users read the reviews about themselves from the two-way review system, they might only develop perceptions about the two-way review system, and it will take more factors to bridge to the rebooking intention from there. Finally, to our surprise, users' booking habit has little moderating effect on the relationship between perceived helpfulness and rebooking intention, while significantly weakens the relationship between perceived enjoyment and rebooking intention. This implies that frequent booking users might not be amazed by the positive reviews they got from the system.

Contributions

Theoretically, our findings contribute in several ways. First, this study enriches the literature of online reviews. While most studies focus on the influences of online reviews for products/services that consumers are interested in, limited research have discussed the online reviews about the consumers themselves and their past behavior. Based on the facts that people tend to behave better in places that are not their home and others tend to give more positive comments for

strangers, the findings once again confirm that such psychological inclinations exist and do bring enjoyment and helpfulness to users. Second, the booking habit is once again found to be a significant moderator that leads to rebooking intention. Finally, even though the main purpose of the two-way review system is not to amaze users, it is found to have potential impact on users' intention to continue to use the platform's services.

Practically, it seems both service providers and service users know that the reviews tend to be too positive and there exists the reliability of these reviews in particularly and the trustworthiness of the reputation system in general. Platforms should have diverse measures to build a precise reputation system for the good of both service providers and service users.

Even though perceived enjoyment does not directly influence the rebooking intention among users, but when interacting with users' booking habit, it does influence users' intention. The impact of perceived helpfulness of this reputation system is almost significant, which also implies some potential importance. Platforms should promote this system further as a mean to attract users' retention.

Limitations and Future Research

This study does have some limitations. First, regarding to the theoretical framework development, the heuristic systematic model discusses the influence of aroused judgments on the acceptance of the system. However, in this study, instead of investigating the acceptance of the reputation system, we focus on the rebooking intention, which might be loosely related and the reasons why perceived enjoyment and perceived helpfulness do not significantly lead to rebooking intention. Thus, future research can focus on finding the bridging factors that mediate such relationships.

Second, methodology wise, this study uses self-reported survey to collect data for analysis, which poses several limitations. For example, among all the hosts and reviews that one user received, there should be more reputable hosts and less reputable, and more favorable reviews and less favorable. Therefore, respondents might be confused and do not know which hosts or which reviews to base on for their judgments. Or their responses might not objectively present their behaviors. In future research, other methods should be used to have a comprehensive understanding of the issue; such as experiment can be used to manipulate the source credibility, review valence to explore more of their affects. Text mining techniques and real data exploration on users' behavior might also bring better understanding of the issue.

Finally, there are limitations in the data collection. The sample size in this study is rather small (180 samples) and only focus on Airbnb users. Future research can expand the sample size and test it in other platform users.

CONCLUSIONS

Sharing economy is becoming an important trend and the reputation systems, operationalized as the two-way review systems, help both service providers and users in making decisions. Our study suggests that the positive reviews from reputable service providers strongly enhance users' perceived enjoyment and perceived helpfulness, which while interacting with users' booking habit have potential influence on intention to continue to use the services. Thus, this study contributes to the literature of online reviews of the service users themselves both theoretically and practically.

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DECISION SCIENCES INSTITUTE
Understanding What Drives Bitcoin Trading Activities

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ABSTRACT

Cryptocurrencies have gained tremendous popularity over the past few years. The purpose of this study is to try to understand the factors that are driving cryptocurrency-related trading activities. Focusing on the well-established cryptocurrency called Bitcoin, we find that online search popularity and the volume of trade in unrelated stock markets positively and negatively, respectively, influence Bitcoin trading volume. We also find no statistical evidence that the underlying sentiment behind relevant financial news influence Bitcoin trading volume. We believe these results might be of great value to investors interested in cryptocurrencies and might instigate further research on this topic.

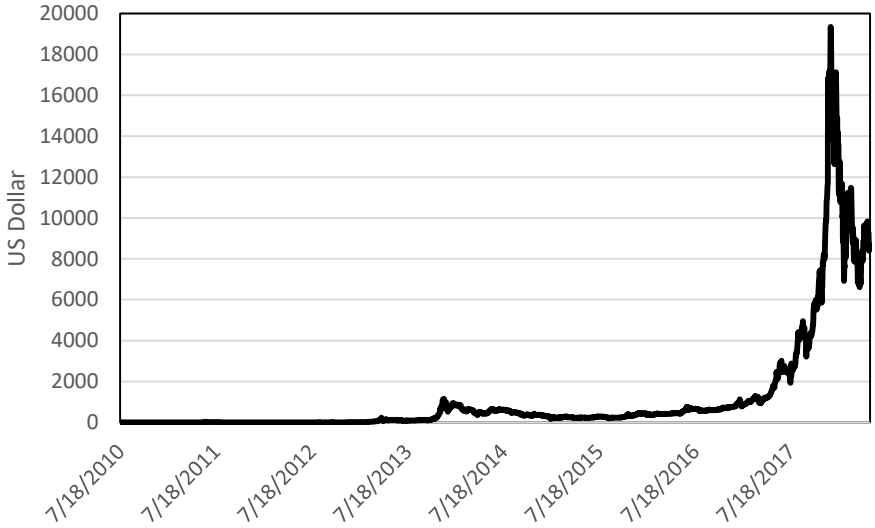
KEYWORDS: Bitcoin, Cryptocurrency, Regression

INTRODUCTION

The year of 2009 saw the birth of a revolutionary concept, namely the online, fully decentralized currency called *Bitcoin* (Nakamoto, 2008). As a payment system, the transactions involving bitcoins are recorded in a public, distributed ledger that requires no intermediaries such as a central bank. That distributed ledger, called *Blockchain*, is heavily dependent on concepts and ideas from the cryptography field, which makes it a member of a new family of information technologies called cryptotechnologies. Due to a similar reason, Bitcoin is now considered a member of a family of currencies called *cryptocurrencies*.

Since its first release, Bitcoin has gained tremendous popularity over the years and exploded in its valuation. For example, Figure 1 shows the value of one Bitcoin in US dollar from July 18th, 2010 to May 15th, 2018. One can immediately see that there was a huge spike in prices in 2017. In particular, Bitcoin price peaked at $ 19,343.04 on December 16th, 2017.

Figure 1. Bitcoin Prices in US Dollar from July 18th, 2010 to May 15th, 2018.



Following the success of Bitcoin, several other cryptocurrencies raised money through initial coin offerings (also known as ICOs) and are now publicly available for trading. As of May 18th, 2018, the website *coinmarketcap.com* listed a total of 1,593 cryptocurrencies having a combined market cap of $369,691,771,684. In all fairness, after the current hype around cryptocurrencies dies down, it is unlikely that all those cryptocurrencies will stand the test of time. The question that arises is then: which cryptocurrencies will survive? Answering this question is crucial for low-risk-tolerance investors and/or investors considering long-term cryptocurrency investment strategies.

One way of determining whether a certain cryptocurrency will stand the test of time is by looking at trading volume. In particular, one can take inexistent or very low trading activities as a proxy for the lack of interest in the underlying cryptocurrency. In this paper, we try to understand some of the factors that might influence trading activities associated with cryptocurrencies. Specifically, we focus on the potential factors that drive Bitcoin trading volume due to the same being currently the most well-established cryptocurrency.

Since cryptocurrencies are online coins, it might be just natural that trading volume is partially driven by the online popularity of a cryptocurrency. Our proxy for online popularity is the frequency with which online searches include the name of a cryptocurrency. As we elaborate on later, we use data from Google Trends to measure search frequency. That said, our first hypothesis is:

Hypothesis #1: *online search frequency positively correlates with Bitcoin trading volume*.

We next hypothesize that other trading activities might influence the volume of cryptocurrency-related trade. For example, one can argue that when a certain market (*e.g.*, a stock market) is attractive, then less resources might be allocated to other trading activities. To test this idea, we measure how the trading volume associated with the stock market index known as the Dow Jones Industrial Average (DJIA) influences Bitcoin trading volume. Our second hypothesis is then:

Hypothesis #2: *the trading volume in non-cryptocurrency financial markets negatively correlates with Bitcoin trading volume*.

Our last hypothesis relates to the influence of financial news on the trading volume concerning cryptocurrencies. It comes as no surprise that financial news heavily influence investors (Barber & Odean, 2007; Fang & Peress, 2009; Engelberg & Parsons, 2011). Recent financial news have mixed feelings when it comes to cryptocurrencies. On the one hand, there are positive news around the acceptance of cryptocurrencies and their valuation gains. On the other hand, there are also several reports on how the anonymity aspect of some cryptocurrencies are making them very suitable to be used for the payments of illegal actives. Since the sentiment behind the underlying news is mixed and, generally speaking, cryptocurrencies are growing in value, we then hypothesize that financial news have no influence on the trading volume of cryptocurrencies. To test this hypothesis, we analyze how the sentiment behind the news published on the Facebook page called *Bitcoin Chart* affects Bitcoin trading volume. Our formal hypothesis is then:

Hypothesis #3: *the sentiment behind cryptocurrency-related news does not significantly affect Bitcoin trading volume*.

In the following section, we explain how we collect the data relevant to the testing of the above hypotheses. This is followed by an explanation of how we analyze the collected data. We finally conclude by elaborating on the implications of the obtained results and how they relate to the relevant literature.

DATA COLLECTION AND PREPARATION

The central variable in our study, henceforth called *Bitcoin_Volume*, measures Bitcoin trading volume. We collected its values from the website *blockchain.info* (Blockchain, 2018). The collected data covers the period of time between July 24th, 2017 and April 19th, 2018, which captures the moment in time when Bitcoin exploded in valuation (see Figure 1 and 2). The resulting 270 observations correspond to the number of daily confirmed Bitcoin transactions. To test Hypothesis 1, 2, and 3, we also collected data from Google Trends, DJIA, and Facebook, as we explain next.

Figure 2. Number of Daily Confirmed Bitcoin Transactions.

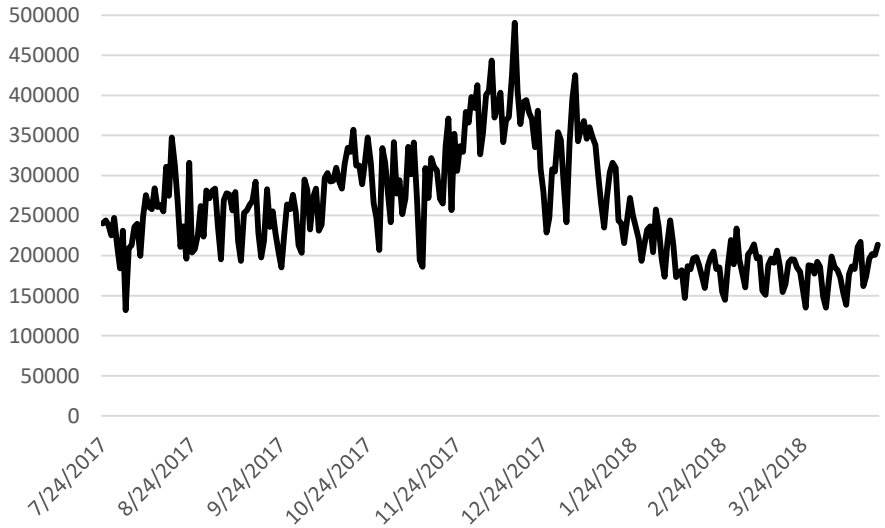
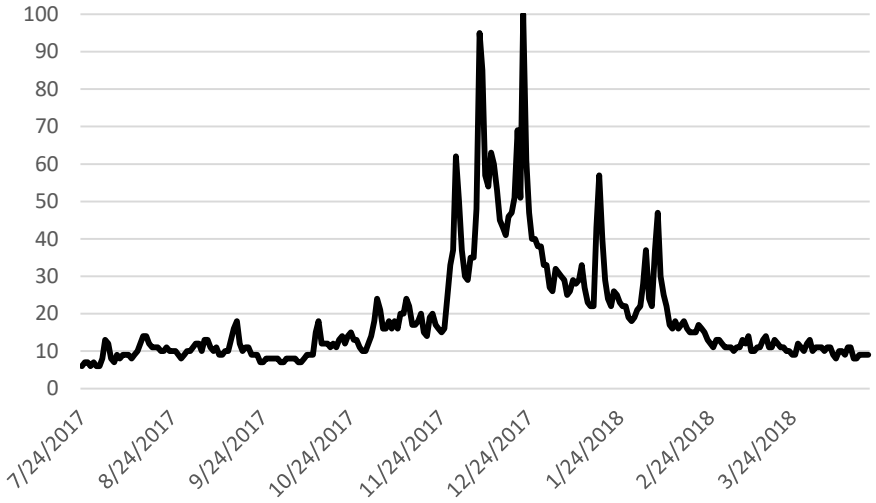


Figure 3. Google Trends Regarding the Term 'Bitcoin'.



Google Trends

The next source of data is Google Trends (*trends.google.com*). The purpose of the collected variable, henceforth called *Gtrend*, is to determine the online popularity of the term "Bitcoin" over time. Specifically, Google Trends determines the "interest over time" for a specific search term by dividing the number of searches of that term by the total number of all searches done on Google at a given point in time. The resulting numbers are then scaled on a range of 0 to 100 based on the term's proportion to all searches on all topics. In our work, we consider daily searches done by users in the United States of America. That said, we obtained 270 values between 0 and 100 that correspond to how popular the term 'Bitcoin' was during the period of time between July 24th, 2017 and April 19th, 2018. Figure 3 illustrates the obtained data.

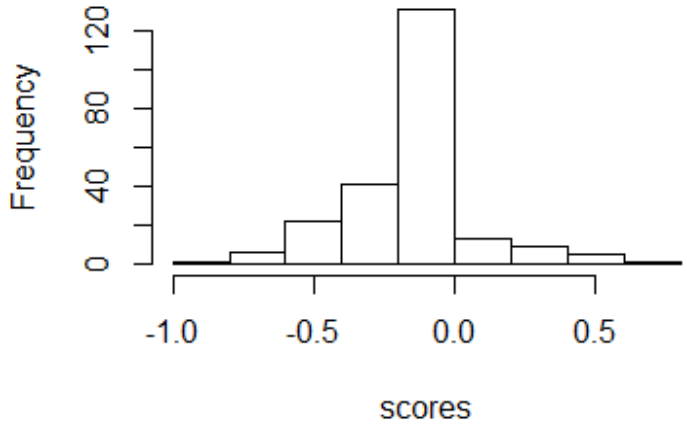
Dow Jones Industrial Average

The next variable we collected, henceforth called *DJIA_Volume*, is about values representing daily trading volumes associated with the Dow Jones Industrial Average (DJIA) index. This data set was collected from Yahoo Finance (Yahoo, 2018). DJIA determines how 30 major American companies have traded on the NASDAQ and NYSE stock markets. Such an index includes very diverse companies, *e.g.*, Apple, Boeing, Caterpillar, Goldman Sachs, IBM, Nike, Walmart, among others. Since the underlying stock markets are officially closed on the weekends, we were only able to collect 187 values during the period of time between July 24th, 2017 and April 19th, 2018.

Facebook

We finally collected financial news related to Bitcoin published on the Facebook public page called *Bitcoin Chart* (Facebook 2018). At the time of writing, that page has the highest number of followers among open Bitcoin pages on Facebook with a total of 402,562 followers. In total, we collected 694 Bitcoin-related snippets across 229 different days between July 24th, 2017 and April 19th, 2018. After collecting the snippets, we estimated the sentiment behind the underlying texts by using a service from the IBM Watson family (Ferrucci *et al.*, 2010; Ferrucci *et al.*, 2013) called Natural Language Understanding. Each resulting sentiment score ranges from -1 to 1 (*i.e.*,

Figure 4. Histogram of the Sentiment Scores Associated with Bitcoin Snippets.



negative sentiment to positive sentiment). Since many snippets were posted on the same day, we averaged the sentiment scores of all snippets published in a day so as to have a single score per day. In our analysis, we denote the resulting variable by *Scores*. Figure 4 plots a histogram of the obtained sentiment scores. One can immediately see that most snippets associated with Bitcoin are either negative or neutral. For the sake of illustration, consider the snippet *"Unpacking five of the biggest cryptocurrency scams to have hit the crypto world.*", which was posted on April 2018th, 2018. The resulting sentiment score of -0.74 returned by IBM Watson is very negative due primarily to the role of the word "scams" in that sentence.

Final Merged Data

We note that the first two collected variables, *Bitcoin_Volume* and *Gtrend*, have a total of 270 values, whereas the last two, namely *DJIA_Volume* and *Scores*, have, respectively, 187 and 229. After grouping all variables by day and removing the incomplete cases, we ended up with a data set containing 160 observations and 4 variables. Table 1 illustrates the final data set, which in turn is used in our analysis described next.

DATA ANALYSIS

After collecting and preprocessing the data, we next analyze the final data set so as to understand how different variables influence Bitcoin trading activities. In our analysis, we start by reporting some descriptive statistics and correlation matrix in, respectively, Table 2 and 3. From Table 2, one can immediately see that sentiment scores are on average negative, as we already mentioned in the previous section, meaning that most of the collected financial news about Bitcoin are negative in nature. Moreover, the minimum (*6*) and maximum (*85*) *Gtrend* values illustrate that some of the original data points we collected before were lost after merging all the data sets and removing missing data. From the variables *Bitcoin_Volume* and *DJIA_Volume*, one can see that the number of daily Bitcoin transactions is rather small when compared to the number of transactions involving stocks in the DJIA index.

Table 1. Sample of the Final Data.

Bitcoin_Volume	*Gtrend*	*DJIA_Volume*	*Scores*
347393	29	341470000	-0.761442
337959	33	346830000	0

Table 2. Descriptive Statistics Concerning the Final Data Set.

Variable	*Mean*	*St. Dev.*	*Min*	*Max*
Bitcoin_Volume	262,529.9	69,505.58	131,875	490,644
Gtrend	18.881	14.234	6	85
DJIA_Volume	370,958,500	106,743,091	118,610,000	823,940,000
Scores	-0.117	0.235	-0.761	0.665

Table 3. Correlation Matrix.

	Bitcoin_Volume	*Gtrend*	*DJIA_Volume*	*Scores*
Bitcoin_Volume	--	0.614***	-0.235**	-0.010
Gtrend	0.614***	--	0.214**	0.025
DJIA_Volume	-0.235**	0.214**	--	-0.026
Scores	-0.010	0.025	-0.026	--
Note: ** = p-value < 0.01; *** = p-value < 0.001				

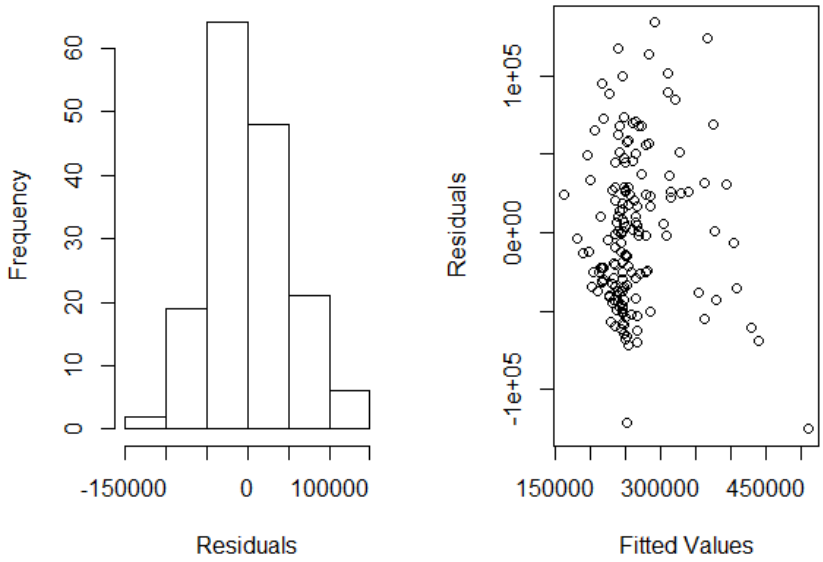
Focusing now on Table 3, one can see that *Gtrend* and *DJIA_Volume* significantly correlates with *Bitcoin_Volume*. While the former is a positive association, the latter is a negative correlation. This indicates that online popularity, as measured by Google Trends, and Bitcoin trading activity tend to move in the same direction, whereas trading activity associated with the DJIA index and Bitcoin trading activity move in opposite directions. Another interesting fact is that the variable *Scores* is not correlated with any other variable. We return to this point later in the paper. Finally, it is noteworthy that *Gtrend* also positively correlates with *DJIA_Volume*. Recall that the variable *Gtrend* measures the popularity of the term 'Bitcoin' over time. That said, we believe that its positive correlation with *DJIA_Volume* might just be spurious since it seems to contradict the facts that the variables *DJIA_Volume* and *Gtrend* are, respectively, negatively and positively correlated with *Bitcoin_Volume*.

We next extend the above univariate and bivariate analyses by developing a multiple linear regression model where *Bitcoin_Volume* is the dependent variable and all the other variables are independent variables. As one can see from Table 3, the independent variables are not highly correlated, which means that a regression model is unlikely to suffer from multicollinearity issues. Table 4 shows a summary of the obtained regression model. The coefficients in Table 4 confirm what we previously suggested. First, holding everything else constant, Bitcoin trading activities are expected to increase when Bitcoin's online popularity (*Gtrend*) increases. Second, when the number of transactions involving stocks in the DJIA index (*DJIA_Volume*) goes up, the number of Bitcoin transactions are expected to go down. Finally, there is no significant relationship between sentiment scores related to Bitcoin news (*Scores*) and Bitcoin trading activities. The R^2 and F-statistic values suggest that our model fits the data well. In particular, it is rather surprising that the three independent variables can explain 51.9% ($R^2 = 0.519$) of the variance in the amount of daily trading activities associated with Bitcoin.

Table 4. Summary of the Multiple Linear Regression Model.

	Coefficient	*Standard Error*	*P-value*
(Intercept)	289909.95	14,245.510	< 0.001
Gtrend	3403.46	277.846	< 0.001
DJIA_Volume	-0.00025	0.000037	< 0.001
Scores	-11132.59	16,445.560	0.499
$R^2 = 0.519$ F-statistic = 55.997 (df = 3, 156; p-value < 0.001)			

Figure 5. Validating the Assumptions behind the Linear Regression Model. (LEFT) Distribution of the Residuals. (RIGHT) Validating Homoscedasticity.



It is important to highlight that we carefully validated the assumptions behind the linear regression model. First, there is strong evidence that the mean of the residuals is equal to zero (one sample t-test; null hypothesis: $\mu = 0$; p-value > 0.999). Second, the distribution of the residuals resembles a normal distribution (see the left part of Figure 5). Finally, the assumption of homoscedasticity seems to hold true (see the right part of Figure 5). Although some observations are flagged as outliers according to traditional guidelines based on Cook's distance, we nonetheless obtained qualitatively the same results when removing those outliers.

DISCUSSION

Cryptocurrencies promise to disrupt many traditional industries and the way humans perceive and handle (virtual) money. Given the abundance of cryptocurrencies currently available to the public, it is just natural that only a limited number of virtual coins will eventually prevail. In this paper, we studied some of the factors that might make some coins more popular than others. Specifically, we took the number of daily transactions as a proxy for popularity. This allows one to understand and potentially predict which coins will stand the test of time. Our initial study was focused on Bitcoin since the same is currently the most popular and well-established cryptocurrency. We then investigated how online popularity, trading volume in an unrelated financial market, and financial news influence Bitcoin trading activity.

Our first hypothesis was that online popularity positively correlates with Bitcoin trading volume. Using Google Trends as a proxy for online popularity, we confirm that our first hypothesis is true. Although it was found before that Google Trends values can partially explain Bitcoin prices (Kristoufek, 2013; Kristoufek, 2015), to the best of our knowledge this is the first paper to establish that online popularity also drives Bitcoin trading volume.

Our second hypothesis was that trading volume in non-cryptocurrency financial markets negatively correlates with Bitcoin trading volume. We used the trading volume regarding stocks in the Dow Jones Industrial Average index as a proxy when testing that hypothesis. Our results

confirm that the second hypothesis is true in that DJIA trading volume negatively correlates with Bitcoin trading volume. To the best of our knowledge, this is the first work to establish such a relationship between non-cryptocurrency financial markets and cryptocurrency trading volume.

Our last hypothesis was that financial news do not significantly affect Bitcoin trading volume. After collecting data from the most popular Bitcoin public page on Facebook and estimating the sentiment behind the underlying posts using IBM Watson, we confirm that the third hypothesis is also true, *i.e.*, there is no significant relationship between sentiment scores and Bitcoin trading volume. It is fair to acknowledge that the lack of relationship might be due to the fact that, despite having hundreds of thousands of followers, the Facebook page we collected data from might not be influential enough and/or the published news might be somehow biased, *e.g.*, too negative. In hindsight, we recognize that it would be valuable to collect Bitcoin-related news from more than one Facebook page and/or other news sources so as to tackle the abovementioned issues.

We conclude this paper by returning to the discussion in the introductory section, namely how can one know which cryptocurrencies will stand the test of time? Our results suggest very practical guidelines to answer this question. First, one can use Google Trends to track the online popularity of a cryptocurrency over time. When this popularity measure starts going down, then our results imply that trading activities involving the cryptocurrency is also expected to go down and, consequently, the public might be losing interest in the cryptocurrency. Second, one can track the trading volume in different non-cryptocurrency financial markets. When these numbers start going down, then it is expected that trading activities involving cryptocurrencies will go up, meaning that the public might be more interested in cryptocurrencies.

Clearly, the above guidelines rely on the assumption that the results we obtained in this paper are valid for all cryptocurrencies, which is unwise to claim without extra data analyses. That said, besides replicating this study for cryptocurrencies other than Bitcoin, we believe it would be of great value to study how generalizable our results are. For example, would one obtain qualitatively the same results when using stock market indexes other than DJIA or different sources of cryptocurrency-related news? Is there any other way of measuring the online popularity of different cryptocurrencies that perhaps complements Google Trends? We argue that answers to the above questions might be of great value to investors considering to trade cryptocurrencies.

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DECISION SCIENCES INSTITUTE
Use of Electronic Medical Records: An Application of UTAUT Model

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ABSTRACT

Little is known about factors affecting adoption of Online Medical Records (OMR). We examined associations of vulnerability perception, usefulness, ease of use, visit frequency and provider encouragement with use of OMR and moderating effects of these variables using National Cancer Institute (NCI) data. Usefulness and provider encouragement played important roles.

KEYWORDS: Electronic Medical Record, Vulnerability, UTAUT, Security, Privacy

INTRODUCTION

Electronic health information provides many advantages. Accessibility and availability of electronic health information beyond providers' offices enhance persons' ability to manage their health and to make informed decisions. In the last few years, availability of electronic health information has expanded significantly (AHA 2016); as such, availability not only provides access to health related data but also facilitates routine tasks regarding health care and helps communicate with providers. According to a report published by The Office of the National Coordinator for Health Information Technology (ONC), about 54% individuals who were offered online medical records (OMR) viewed it at least once in a year (Patel 2018). With rapid increases in availability of electronic health information and Internet use (Pew Research 2018), it is important to understand the factors that facilitate or impede the use of electronic health information by individual patients.

Prior studies on online medical records adoption mainly focused on providers or the organizations; the existing literature has not much discussed patients' medical record adoption. OMR often comprises individuals' clinical records such as medical history, test results, medication information, and health behavior data that may be static and/or interactive in nature (Pagliari et al. 2007). From the patient perspective, OMR have a high potential to improve care if adopted and used by the consumer (Yamin et al., 2011).Tang et al. (2006) concluded that the main reason to adopt OMR by a patient was easy access; credible information and knowledge helped with healthcare and disease management and improved communications with providers. Although beneficial, OMR adoption is often limited to some groups (e.g., racial/ethnic minority and low-income users) (Yamin et al., 2011). Existing studies have discussed the key challenges of OMR adoption by consumers. Liu et al. (2011) discussed various usability challenges of patients' OMR adoption such as functionality, familiarity, and comfort during access of OMR, data accuracy, as well as privacy, security, and trust on the related system. Greenhalgh et al.

(2010) noted ease of use and usefulness as important factors for OMR adoption. In some studies, privacy and security of OMR were shown as major concerns related to OMR adoption. Pagliari et al. (2007) noted that the key challenge of OMR adoption was to find an optimal solution to balance utility and security. The increased frequency of data breaches may have increased concerns about the security of OMR among users. On the other hand, in spite of strong architectural security (such as advanced encryption standards), users often are concerned about unauthorized data access or privacy. While discussing the desirable characteristics of OMR, Mandl et al (2001) specifically mentioned 'confidentiality' as one of the important characteristics along with accessibility, comprehensiveness, and accountability of OMR. Simon et al. (2009) conducted a focus group prior to launching a community-wide electronic health information system in Massachusetts; one of the main concerns for the stakeholders, specifically patients, was about health information privacy and security. This paper aims to find the factors that influence the use of OMR. Using the theoretical framework of the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003), this research investigates performance expectancy, effort expectancy, social influence, and facilitating conditions as well as the direct and moderating influencing factors. In addition, this study examines an important construct, "vulnerability," which is defined as the privacy and security of the OMR. As discussed above, privacy and security might be key factors for users while using OMR. We utilized data from a nationwide survey conducted by National Cancer Institute (NCI-USA). The contributions of this study include understanding of factors that are important to patients many of who are chronic disease patients, including cancer survivors and generating insight that can be projected to the US population.

LITERATURE REVIEW

Unified Theory of Acceptance and Use of Technology (UTAUT) and Adoption of Online Medical Record

Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003) was used as a reference framework. Venkatesh et al.(2003) integrated concepts from several models and theories such as TRA (Theory of Reasoned Action), TAM (Technology Acceptance Model), TPB (Theory of Planned Behavior), MM (Motivational Model) in UTAUT to put forth elements of technology adoption. The four key elements of UTAUT are performance expectancy, effort expectancy, social influence, and facilitating conditions. Performance expectancy is the degree to which the users believe that a system will help to perform a specific task. This definition is similar to Davis et al. (1989) definition of perceived usefulness. This variable was included in our research to capture the users' perspective about the usefulness of the OMR websites/applications. Effort expectancy, as defined by Venkatesh et al. (2003), is the degree to which a system is easy to use to perform a task. This definition is similar to Davis et al. (1989) definition of perceived ease of use and this construct is adapted in our study to understand whether ease of use is helpful for OMR adoption/use. The third major element of UTAUT is social influence, which means someone's believe that the important people he/she knows think he/she should use the system (Venkatesh et al., 2003). This construct is similar to what Ajzen (1991) was mentioned as subjective norm. In this current study, we define provider (including physician and nurse) encouragement as 'social influence' because in health related concerns, physicians probably are the most trusted persons to the patients and physicians' encouragement to adopt OMR may significantly influence the patients. Facilitating conditions in

UTAUT is the organizational infrastructure that the users believe facilitates a specific technology adoption (Venkatesh et al., 2003). As this study examines factors affecting individuals' use, here we adapt this definition that is consistent with the aim. In this study, facilitating condition is defined as frequency of visits by a patient to a provider facility; i.e., our rationale is if the patient visits providers' facility more frequently, it may reflect a higher need on the patient's part and thus the patients may feel more strongly to adopt and use OMR.

Information Vulnerability and Adoption of Online Medical Record

As we discussed earlier, in the context of OMR adoption by patients, privacy and security may play critical role. Even with a sense of urgency, many consumers are reluctant to use online medical records because of privacy and security (Archer et al. 2011; Libert et al. 2015). In prior work, privacy and security was conceptualized in terms of maintaining confidentiality, integrity, availability (CIA) of online medical records such that it can be accessed by authorized users only, protected from unauthorized changes, and retrieved and used by owners/users when they like (Dehling et al. 2014). The major issue relating security and privacy of online medical record usage includes authorized access, relevancy, ownership, infrastructure, and archiving and auditing patients' information. Therefore, Tejero et al. (2012) noted that dependable architecture and reliable implementation policies are required to address these issues; electronic health record systems suffer from lack of protection to sensitive information, data theft, phishing, etc. that may result in higher susceptibility to privacy and security. In this research, we defined technology vulnerability as the consumers concerns about security and privacy with regard to using online medical records. Here privacy is individuals' right to determine whether their personal health related information should be revealed to others as well as to which extent and where the information can be used (Westin et al. 2003). In this research, security is defined as sense of assurance of information safeguard (Anderson 2003). Although there is an ongoing debate on the distinction between privacy and security (Smith et al. 2011), health information privacy is implemented through information security and indeed, the concept of privacy is non-existent without security practices (Lafky et al. 2011). As both security and privacy are important for the protection and appropriate use of health information that resides in online medical records, we considered them as a single construct. Our rationale is that most patients, arguably not tech-savvy, may not consciously distinguish between these two concepts but rather more be concerned about unwarranted events occurring due to any of security breaches or privacy violation.

THEORETICAL DEVELOPMENT/MODEL

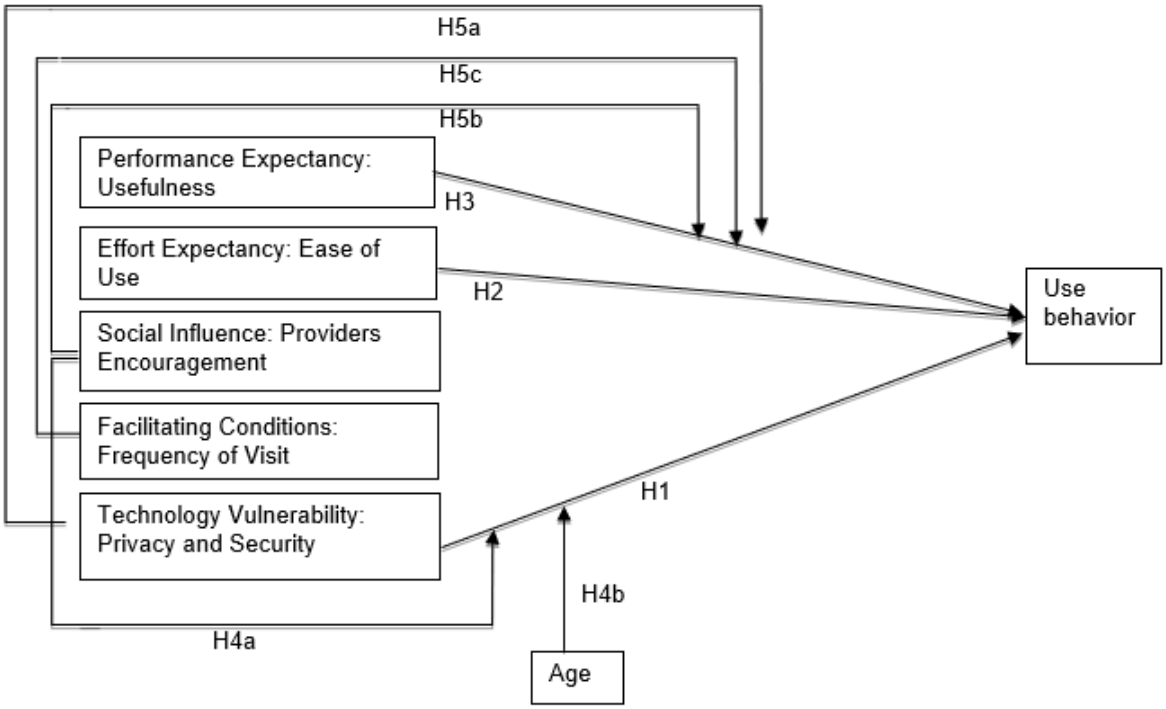

Figure 1: Research Model and Hypothesis

Figure 1 depicts proposed relationships among constructs. Following hypotheses were examined:
H1) Vulnerability is negatively associated with use of health information technology.
H2) Ease of use positively is associated with use of health information technology.
H3) Usefulness is associated positively with use of health information technology.
H4a) The effect of vulnerability on use of health information technology is moderated by physician encouragement.
H4b) The effect of vulnerability on use of health information technology is moderated by age.
H5a) The effect of usefulness on use of health information technology is moderated by perceived vulnerability.
H5b) The effect of usefulness on use of health information technology is moderated by physician encouragement.
H5c) The effect of usefulness on use of health information technology is moderated by frequency of visit.

METHODOLOGY

Data Source

The National Cancer Institute's Health Information National Trends Survey 5 (HINTS 5), Cycle 1 data were used for the study. This survey was conducted between January and April of 2017 and was a single-mode mail survey of noninstitutionalized individuals living in the United States using the Next birthday method. Two-stage sampling design was chosen. First, a stratified sample of addresses was selected from a file of residential addresses and in the second-stage, one adult person was selected from each sampled household. The sampling frame of a database of addresses was provided by Marketing Systems Group (MSG). Responses were obtained from 3,285 subjects, representing 247.8 million US populations.
The focal topic of this Cycle was interoperable (i.e., connected) health care system in the United States and thus, the survey from this cycle deemed suitable for the study objectives in addition to the fact that HINTS data were used in studying Internet search behaviors and technology use (Xiao, 2014 and Heffner and Mull, 2017). Since the focus of the study was to examine those who used the Internet-based health technology, subjects who used the Internet for a variety of reasons, including communication or have a smartphone or tablet were included. In addition, patients who were between 30 and 75 years and had a physician visit in recent years (<2 years) were considered. Such restrictions were thought to improve the validity and relevance of this work. The final study sample had 765 respondents representing 48.7 million US populations.

Measurement of Variables

All variables/measures used in this study came or were constructed from the HINTS 5, Cycle 1 questionnaire.

Dependent variables

The primarily dependent variable used in this study is the extent of online medical record use. In other words, the variable of interest is post-adoption continuance of use and intended to capture actual usage with regards to frequency and/or depth of use (Zheng et al. 2013). Respondents were asked as to how many times they accessed their online medical record in the last 12 months. Response options included: 0, 1-2, 3-5, 6-9, and ≥10 times. Since this study subjects were restricted to adopters, respondents only could select the last four options. Thus, this variable was measured on a 4-point ordinal scale.

Independent variables

Vulnerability: HINTS asked two questions regarding one's concerns and confidence about privacy and safety of online medical records. First, how confident are you that safeguards (including the use of technology) are in place to protect your medical record from being seen by people who aren't permitted to see them? Response options were: 1= very, 2=somewhat, and 3=not confident. Second, if medical information is sent electronically – that is, by computer – from one health care provider to another, how concerned they are that an unauthorized person would see it with a similar 3-point scale. There two items were related and jointly address both

security and privacy issues. Responses on these two items were summated to estimate vulnerability.
Usefulness: this measure came from a single-item question. In general, how useful is your online medical record for monitoring your health? There were 5 options: 5=do not use, 4=not at all, 3=not very, 2= somewhat, 1=very useful. The item was reverse coded for this study. The people choosing 5 were excluded from analysis.
Ease of use: It was measured with a single question. How easy or difficult was it to understand the health information in your online medical record? There were 4 options: 1=very easy, 2= somewhat easy, 3= somewhat difficult, and 4=very difficult.
Provider encouragement: This was a dichotomous scale and measured by asking if health care providers, including doctors, nurses, or office staff ever encouraged one to use an online medical record.

Other variables

The extent literature of technology adoption (Venkatesh et al. 2003) proposed facilitating condition as an important predictor. The extent of online medical use, i.e., facilitating condition, can potentially be directly related to frequency of visits that one made in the recent past. For the frequency effect, a single 6-point Likert scale was used. In the past 12 months, not counting times you went to an emergency room, how many times did you go to a doctor, nurse, or other health professional to get care for yourself? Zero through 4 means the respective numbers of visits and 5=5-9 visits, and 6 meaning ≥10 visits. In addition, demography related variables (age, race/ethnicity, and gender) were used as control variables.

Statistical Analysis

Analyses of survey respondents need to adjust for complex sampling design and nonresponse and noncoverage biases; such an approach is necessary to ensure estimation of correct standard errors needed for valid inference (see HINTS 5 Cycle 1 Methodology Report for calculation of sample weights and replicate weights). Briefly, weights were derived by adjusting for the probability of selecting the household and household nonresponse and finally these initial weights were calibrated to US population counts. Replicate weights were derived using the delete-one jackknife procedure. We provide unweighted descriptions of study subjects and corresponding population-level counts and proportions with use of weights as well. For hypothesis testing, we used simple regressions, main-effects only multiple regressions, and multiple regression with additional interaction effects. For each of these analyses, we accounted for sampling design issues by using weights as advised by the HINTS methodology report.

Table 1: Demography

Variable	N=765	%	Weighted N= 48.7 million	Weighted %
Age			50.9*	0.41**
Gender				
Male	280	36.7	20.7	42.5
Education				
High school or less	100	13.1	9.7	19.9
Some college	218	28.5	15.6	32.1
College graduate or higher	446	58.4	23.3	47.9
Race and ethnicity				
White	523	70.6	32.7	69.1
African American	83	11.2	5.1	10.9
Hispanics	62	8.4	5.0	10.6
Other	73	9.9	4.4	5.9
Occupation				
Employed	473	62.7	32.8	68.3
Retired	185	24.5	7.2	14.9
Other	96	12.7	8.1	16.8
Smart Phone	695	90.8	45.2	92.9
Electronically contacted physician	560	73.4	35.1	72.3
Made electronic appointment	448	58.6	28.6	58.9
Chronic disease#	380	52.7	23.2	49.9

* Mean in years; ** Standard error
# Cardiovascular diseases: diabetes, heart disorders, hypertension, and chronic or obstructive lung diseases
Weighted estimates account for complex sampling design and project to the US population

Results

Table 1 describes the study subjects. The mean age of them are about 50 years with 36.7% being male. They come from diverse social segments with regards to race (e.g., 70.6% white), education (e.g., 58.4% college degrees), and occupation (e.g., 62.7% employed). Over 52% reported having a chronic disease such as diabetes, heart problems, high blood pressure, and chronic lung diseases. About 50% of these subjects used online medical records 1-2 times. We followed the analytic strategy in Xiao et al. (2014). We ran a simple regression on each of vulnerability, ease of use, and usefulness. We hypothesized that vulnerability is negatively associated with use; the association was not found significant (β= -0.06, P=0.285). However, ease of use (β= -0.2, P=0.005) and usefulness (β= 0.28, P=<0.001), were significantly associated with use of online medical records. In addition, the effects of frequency and physician encouragement were significant (P<0.01) as well.

Next, we ran a series of multiple regressions, which included all of the above variables as well as control variables and results were presented in Table 2. The results from the main-effects model did not show association (β= 0.03, P=0.63) between vulnerability and use; however, ease of use became marginally significant (β= -0.16, P=0.072) while usefulness remained strongly significant (β= 0.26, P=0.001). Thus, H2 and H3 were supported while H1 was not.
Next, we examined the interaction effects of vulnerability and usefulness separately in two models. None of interaction effects of vulnerability with age (β= -0.00, P=0.619) and provider encouragement (β= -0.13, P=0.236) were significant. While interaction between usefulness and vulnerability was not significant (P=0.658), that with provider encouragement (β= 0.37, P=0.001) and frequency (β= 0.07, P=0.035) were. Thus, H4a, H4b, and H5a were not supported and H5b and H5c were supported.

DISCUSSIONS

This study investigated factors that affect online medical records use among adopters. A nationally representative sample was used to examine the hypotheses. To the best our knowledge, this is the first study to investigate online medical records use among a nationally-representative pool of subjects, many of who have been suffering from chronic diseases; indeed some (15%) of these patients also suffer from multiple chronic diseases. A number of our hypotheses have been supported. In particular, usefulness was found to have a strong and persistent effect on online medical records use after controlling for frequency of provider visits and other variables. However, surprisingly we did not find the effect of vulnerability concerns on use. Several potential reasons can be speculated. These subjects already adopted the system and thus, they might have thought over and worked out on such concerns before actually starting to use online records. It is also possible that an implicit trust dynamics was at play since they made a decision to use online records. The empirical evidence of physician encouragement on online medical records use further supports such a plausible reason. That is, patients might have derived trust implicitly since their providers encouraged them to use the system or having seen their providers use the system themselves as many physician practices in the US started using health IT such as EPIC. Furthermore, there was lack of information on system designs (e.g., login features). It would be reasonable to assume that there were heterogeneity and that might have led to confounding of the vulnerability effect. Alternatively, the effect of vulnerability is less predominant among adopters and unfolding such an effect requires much larger sample size that that was available for this study.

Table 2: Linear Regression of Online Medical Records Use

Parameter	Main effects model		Interaction model[1]		Interaction model[2]	
	Estimate (SE)	P-value	Estimate (SE)	P-value	Estimate (SE)	P-value
Intercept	0.25 (0.43)	0.557	0.17 (0.44)	0.694	1.70 (0.52)	0.002
Vulnerability	0.03 (0.06)	0.630	0.08 (0.13)	0.545	0.11 (0.15)	0.469
Ease of use	-0.16 (0.08)	0.072*	-0.15 (0.08)	0.081*	-0.13 (0.09)	0.136
Usefulness	0.26 (0.07)	**0.001**	0.26 (0.07)	**0.001**	-0.20 (0.15)	0.192
Provider encouragement	0.29 (0.10)	**0.007**	0.49 (0.22)	**0.033**	-0.94 (0.32)	**0.006**
Frequency of Provider Visits	0.20 (0.04)	**<.001**	0.19 (0.04)	**<.001**	-0.05 (0.11)	0.677
Age	0.00 (0.00)	0.709	0.00 (0.01)	0.563	0.00 (0.00)	0.842
Male	0.20 (0.10)	0.052*	0.19 (0.10)	0.057*	0.20 (0.10)	**0.048**
Race and ethnicity						
African American	-0.07 (0.18)	0.704	-0.07 (0.18)	0.697	-0.07 (0.19)	0.713
Hispanics	-0.39 (0.16)	**0.017**	-0.39 (0.16)	**0.019**	-0.39 (0.15)	**0.013**
Other	-0.03 (0.15)	0.817	-0.04 (0.15)	0.769	-0.04 (0.14)	0.784
Vulnerability X Age			0.00 (0.00)	0.619		
Vulnerability X Provider encouragement			-0.13 (0.11)	0.236		
Usefulness X Vulnerability					-0.02 (0.05)	0.658
Usefulness X Provider encouragement					0.37 (0.11)	**0.001**
Usefulness X Frequency of Provider Visits					0.07 (0.03)	**0.035**

* Significant at the level of 0.1; bold are significant at the level of 0.05; SE: standard error
Model estimates were weighted to account for complex sampling design
1: Interaction effects with vulnerability; 2: interaction effects with usefulness

The extant research on technology adoption demonstrates consistently the effect of ease of use on adoption. This study found an interesting pattern of effects of ease of use on online medical records use. In particular, while ease of use appeared strongly related to use in the simple regression model such an association became noticeably weaker or disappeared in the multivariable analyses. Ease of use may be confined to some segments of patients; thus, once those effects (e.g., demography, visit frequency, etc.) are accounted for, the impact of ease of use decreases. It is also possible that experiential learning mitigates ease of use.

Implications for Theory

There has been extensive research on technology adoption and less so on drivers of continuous use of technology. Our work focused on the later and directly extends the literature. In particular, while past studies have predominantly focused on ecommerce our work extends to health care. With a growing older population and segment suffering from chronic diseases early on their life, such a work is considered timely and beneficial to society. In light of our findings demonstrating effects of usefulness and, to some extent, ease of use, this study holds promise of an integrative theory of adoption and continued use.
Subjective norm has played a key role in the theory of planned behavior (TPB). Researchers have also used TPB in the context of e-commerce. In our study we found a consistent and strong effect of provider encouragement. A close construct is social influence as is conceptualized with the framework of UTAUT. While provider encouragement is not subjective norm in the sense subjective norm has been operationalized in the e-commerce literature or social influence, our operatonalization of social influence as provider encouragement is close to normative influence in that provider encouragement provides assurance and probably conveys expectations implicitly. This study provides grounds for extending or re-conceptualizing normative social influence when researchers need to investigate health IT use.

Implications for Practice

Chronic conditions-especially, multiple chronic conditions-impacting people's life are on the rise and they are affecting early on (Butorff, Ruder, and Bauman, 2017). OMRs create a patient-centric platform with the potential ability to support patient-provider information sharing and collaboration, improve health care outcomes and reduce costs at the individual and system levels. From the health care systems or policy makers' perspective, this study provides an understanding of how patients can possibly be persuaded to use OMRs. For example, consistent effects of provider encouragement imply that physician or nurses can be a strong stakeholder helping patients adopt and use OMRs and they should discuss with their patients or enquire about this when an opportunity arises.
This study has implications for developers and vendors of OMRs. Among many drivers of use of OMRs, usefulness was investigated extensively. Usefulness was found to drive use alone and in conjunction with other variables. This also found that there are attributes of OMRs that drive the perception of usefulness. Thus, developers or vendors should attempt to enhance these features and engage with patients to help understand patients' needs and expectations.
Although not predominant, but there remain some concerns for ease of use at least for some patients. These patents may belong to some demographic strata. For example, race and gender showed some effects on use of OMRs. It is possible that needs and expectations are different in these patients. An adequate understanding of these issues will help develop features and messages targeted to these patients that will increase the likelihood of further use.

Limitations and Future Research

The study findings should be interpreted with caution because of a few limitations. First, unlike standard measures used in studying constructs affecting technology adoption such as usefulness, ease of use, HINTS data provide a single item measures for ease of use and usefulness. While a single-item measure may be unambiguous, if properly designed, a validated multi-item measures tend to generally better capture a construct. As some were used in previous waves (e.g., online records use), it may be speculated that measures have been subject of methodological rigors undertaken by the sponsor. In addition, prior research investigated post-adoption technology use with single-item measures (Zheng, Zhao, Stylianou, 2013). Future research should address the issues related to measures. Second, because data came from a cross-sectional study design, it precludes the causality between independent and dependent variables. Third, respondents' personalities, attitudes or skills may affect online records use. For example, a person with confidence in his or her ability to manage health technology may utilize online records more frequently. Fourth, there is limited information on the design feature of online medical records. Thus, system design issues or characteristics embedded in security and/or privacy concerns and their relationships with continued use of online records are not fully understood and left for future research. Finally, the impact of online records use on patients' health care outcomes should be examined in the future.

CONCLUSION

A national survey on health technology adoption provides insightful information on healthcare consumers' use of online medical records. Predominantly, usefulness drives the extent of use, which is also strongly affected by a need reflecting factor, frequency of visits. In addition, the effects of usefulness, are moderated by frequency and provider encouragement. Developers and vendors should work with patients and their healthcare providers to reinforce usefulness perceptions.

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DECISION SCIENCES INSTITUTE
Using Big Data to Explore Third World Markets

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ABSTRACT

Third world countries remain an unexplored market. Those markets can be as profitable as those of Europe and America if few barriers can be overcome. The main purpose of this study is to show how companies can use big data and its analysis tools successfully for business in developing countries. Businesses could achieve competitive advantage by gathering data from those countries, analyzing and using them to improve decision making. Moreover, big data tools can generate reliable measures to increase profitability in an environment that does not always depend on technology in ordinary business transactions.

KEYWORDS: Big data, IT tools, Third world markets, Technology, competitive advantage, Digital divide, Information Technology, Developing nations, Developing countries, Third world countries, Development

INTRODUCTION

Compared to the rest of the world, third world countries use technology less in business transactions even though people in those areas are catching up with other nations in daily use of technology for other life aspects. The marginal used of technology in business transaction can be attributed to the high cost of technology. As a result many third world countries cannot afford the technology necessary to efficiently run a business; even though some businesses in those areas could compete on the global market with technology. Moreover, companies looking to expand their market share may see the need to venture into third world areas. With the current globalization, expanding to third world countries might be a necessary leap that most companies will need to remain competitive.

However, since third world countries are not well known to incoming businesses, there should be a thorough analysis and understanding of the population needs, the environmental restrictions and the market limitations. Finding data on these markets may be a big challenge for businesses willing to analyze and improve their chance of success in those markets. The challenge will be to find data to analyze for these markets. The next step will be using the various big data tools to analyze those data. To accomplish these tasks the current paper focuses on how technology can help in getting and analyzing big data for developing countries; and therefore, increase a change of success. It is important to review existing literature to understand the technology available in third world areas, as well as the analysis tools.

LITERATURE REVIEW

The use of technology and its applications has significantly increased around the world in the recent years. This increase can be attributed to the fact that, information technology, especially mobile technology has become affordable even for people in third world countries. Analyzing the technologies available in different parts of world can help understand how business can used technology to grow and conquer new markets.

Importance of Technologies in Third World Countries

The use of the technology may not give businesses significant advantage in developed countries; however some third world countries having access to technology can make a big difference. The availability of technology can help businesses find or create new or better opportunities. Technology can help businesses and governments offer services otherwise not possible without technology (Heeks & Stanforth, 2015). Businesses may use technology to improve efficiency and effectiveness. Third world countries are clearly at a disadvantage when it comes to technology, but businesses in those areas can still see its benefits (Jimba, 1999). Governments are relying more and more on new technology and applications to resolve various problems and issues faced by third world countries (Heeks & Stanforth, 2015). Currently, by the means of online connectivity through mobile technology such as smart phone, laptops as well as social media application, businesses can reach customers in remote areas.

The recent progression of technology in developing countries has seen the growth of social media and the internet which allowed businesses to reach their customers (Jimba, 1999). Companies in developing countries are gradually beginning to advertise their products and services online. The progress of online shopping has increased the technology requirements for businesses. Those businesses are now able to communicate with their customers and better understand their needs and preferences; which has not always been the case in third world countries (Jimba, 1999). Without technology, businesses and governments in developing countries faced obstacles and difficulties in communicating with people and collecting information about their preferences and opinions. Moreover, with the help of technology, those businesses could collect and share data and information with each other as well as with the government. The collection of data can successfully be achieved today with the availability of large data storage, advanced technology tools and applications (Gonzalez-Brambila, et al., 2016). However, those countries are still at a disadvantage when it comes to technology compared to developed areas.

Limitations of Technology in Developing Countries

In developing countries it is very difficult for businesses to fully take advantage of technology as businesses do in developed countries. In third world countries, businesses are confronted with a variety of obstacles (Heeks & Stanforth, 2015). Those obstacles include but are not limited to: poverty, illiteracy, capital requirements and technology transfer. As a result, many businesses suffer from low returns, which lead to high rates of bankruptcy (Gonzalez-Brambila, et al., 2016).

Poverty: Countries are characterized as third world mainly because of the high level of poverty. Poverty is the primary reason most third world countries' government, businesses and citizens are behind in technology usage. Gonzalez-Brambila, et al. (2016) reports that the requirement associated with the latest technologies may rise higher for third world countries because of the high cost to adapt to the low technological environment. The cost of the required powerful

equipment need for some technology can grow higher than many countries can afford. In addition adapting new technology to poor infrastructures may prove more costly than the total cost of the same technology in rich countries because of the capital required.

Capital Requirements: By comparison to developed nations, many third world countries lack the basic equipment required to successfully install and use most technologies. Those requirements include among other things, electricity, internet connectivity, computer equipment. As a result, companies or individuals attempting to invest in new technology may be face with a high price tag not only of the technology cost, but also the necessary equipment to make the new technology functional. Heeks & Stanforth (2015) argue that the cost can rise so high that it most businesses cannot afford it. The cost can also rise since developing countries have to import all the required technology from developed nations (Shahidullah, 1999); because almost nothing is manufactured locally.

Technology Transfer: Technology used in third world countries are for most created for developed countries, those technologies may sometime be too advanced and not adapted. It costs more to customize the transferred information technology to suit business in developing areas because the way businesses are conducted in third world countries is very different from that of developed countries. To be successful, technology destined for third world nations should take into account among other things the customs, the location, the language, the existing technology, the government rules and regulations, the method of payment, the population skills. The market for products and services in developed areas is very competitive especially with the advanced in information technology compared to third world countries which have limitation as far as technology is concerned. With the need to increase their market shares most companies are compelled to establish a global presence and explored new markets. Those new markets are for most in developing nations especially with the growing needs of the population triggered by the internet and social media and other information technologies. Global connectivity is creating a lifestyle change in developing countries to mimic that of people in developed nations.

Targeting the third world countries create a big opportunity for companies around the world to sell their products and services. However, success in those areas will be determined by the ability to collect and analyze data and provide useful information for business to incorporated in their decision making. Businesses are acquiring big data analysis tools to understand the need of those areas and strengthen their position in those markets. Many tools with the capability of organizing and grouping the data can be used to help companies gain competitive advantage (Anonymous, 2017).

Characteristics of Big Data

Vast amounts of data are collected daily around the world whether intentionally or not. Those data come from multiple sources including browsing histories, bookmarked websites, GPS histories, shared data in social media, web searches and more (Anonymous, 2017). By their simple nature, those data can be classified into different categories (Kuner et al., 2012). They can be structure and organized in table and other prearranged form, or unstructured and needing to be well-arranged before use (Nunan, & Di Domenico, 2017). Combining all these complex data is what is simply called Big Data. Kuner, et al. (2012) defines Big Data as huge volumes of data that can't be analyzed using normal analysis tools intended for small data; since the tools designed to convert big and complex data into understandable pattern were not available (Nunan & Di Domenico, 2017). Conventionally, data with similarities were grouped in

categories very convenient for analyses. They consist of all the data available around the world that can be transformed in a useful format and analyzed by businesses to make informed decisions and gain competitive advantage. The very nature of Big Data makes such grouping nearly impossible. Some data are difficult to collect, save, process, and analyze because of their massive volume (Jain, 2016). To effectively engage in big data analyses, it is important to first understand its massiveness and complexity. The complexity of Big Data can be divided into three basic sets known as the 3Vs: volume, variety, and velocity (Lee, 2017).

Volume: Jacobson (2013) claims that, about 2.5 quintillion bytes of data are created every day. The volume of big data can be characterized as large amount of data generated at a very fast pace (Lee, 2017); which made it challenging to process due to its massive size. For instance, the cost associated with big data would have been very high because data storages used to be very expensive (Sivarajah, et al., 2017). Luckily, today progresses in technology, lead to the creation of affordable data storage which alleviate the cost of collecting and storing large volume of data and therefore making big data analysis possible.

Variety: Big data consist of multiple types of data. Sivarajah, et al. (2017) state that big data includes pictures, texts, videos, graphics, charts, tables and much more. Those data can be structured and/or unstructured according to Nunan & Di Domenico (2017). The structured parts of the data are organized in database table and can easily be analyzed using the traditional data analysis tools. The unstructured portion of the data on the other hand, can be hard to categorize because of their unconventional nature; they may include texts, photos, videos, social media, audio, etc.

Velocity: velocity refers to how fast data is being generated and processed. Jacobson (2013) reports that, almost 90% of data available today, have been generated in the last few years. It used to be easy to process and analyze data because it was generated at a slow rate (Sivarajah, et al., 2017). Today however, data is being generated so fast that, as to necessitates high capacity analysis tools to keep up with the fast pace, which as some may characterize it, almost in real time. Big Data include any type of data that can be analyzed to return benefits.

Benefits of Big Data

Businesses invest in Big Data for different reasons. New businesses want to know the ideal location to establish the new company, what customers like, and how to gain competitive advantage. Existing businesses need to identify new products or venues that can be profitable; to enhance the business processes and to understand the market environment. Big Data may help companies attain their desired outcomes (Kuner, et al., 2012). The sought after outcomes may include among other things: reducing costs of operations, making better decisions, and providing customers with better products and services. Big Data can help businesses achieve efficiency and effectiveness in their operations by predicting the right demand of products and services (Lee, 2017). This ability to predict come develops by keeping close communications with the customers as well as collecting data from various sources to help learn about customers' needs and preferences, the prices they are willing to pay. Gandomi and Haider (2015) suggest that Big Data can help businesses identify the necessary medications for their processes to remain competitive in the market place. Therefore, Big Data tools might be beneficial and help forecast the future trends in the market.

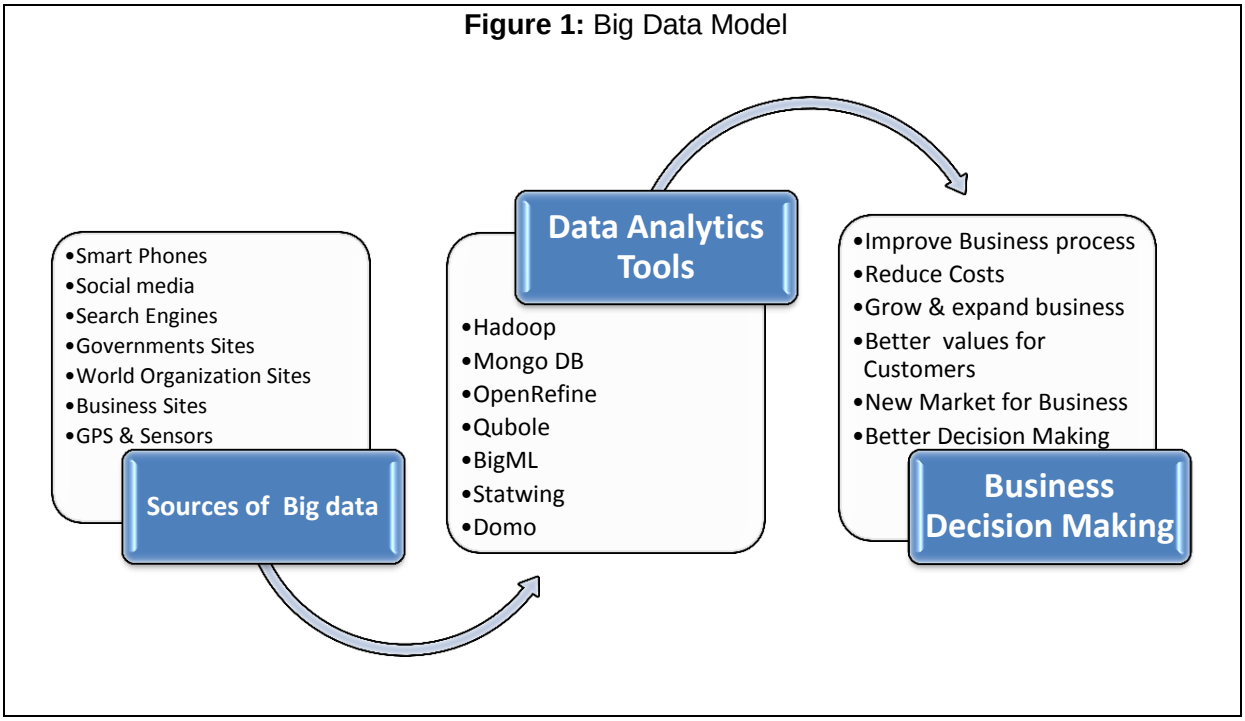
RESEARCH METHODOLOGY

The literature suggests that, in third world countries, big data and its tools can help local business trying to maximize their profits and international companies looking to invest in new markets. This study proposes a model showing how businesses can use big data analysis tools to secure their position on today global market.

Model

The model in this study shows how businesses can use Big Data and its analysis tools to gain competitive advantage in developing nations and maximize their profits in today's global market. First, data should be collected data from the many sources forming Big Data. Then the data will be analyzed using the appropriate big data analytics tools. Finally companies can use the result of their analysis for decisions making.

Figure 1: Big Data Model



Sources:

Today, data is continuously being collected from different sources on almost every aspect of our environment, our society and our life. All those data sources contribute to Big Data. The data sources include but are not limited to social media, public and private websites, google, smart phones apps, Government publications and committees, GPS, and sensors.

(1) Government Agencies: accurate and reliable information are found on government websites (Marr, 2015); including information about the people, culture, crimes, markets and industry.

(2) International Organizations: is a great source for information about countries history, education, markets, economy and much more (Marr, 2015).

(3) Public Websites: provide information about the news, weather, currency, and more; which, can indirectly affect businesses.

(4) Company Website: can notify companies about customers visiting their website, the number of views of specific products, the number of visitors and feedback from customers.

(5) Social Media: It is a great place for businesses to collect data, communicate with customers and learn about them. It includes Facebook, Twitter, LinkedIn, Skype, YouTube, Pinterest…

(6) Smart Phones Applications: when customers sign up for Apps, companies can collect data such as their names, age, location, preferences, emails, etc...

(7) GPS: By using the GPS, in driving, flying, navigating or walking, generate data that can be essential for business decisions.

(8) Sensors: sensors are use almost everywhere and can generate a huge amount of real-time data as their technologies have improved tremendously.

(9) Search Engine: including Google can be considered as one of the biggest sources of information. Individuals and businesses can use them to know about many things.

Tools:

After data gathering comes the analysis phase which required big data analysis tools used for simplifying and making data understandable. Those tools include: Hadoop, MongoDB, OpenRefine, Qubole, BigML, Statwing, and Domo.

(a) Apache Hadoop: open source software used to store and organize large amounts of data.

(b) MongoDB: big databases that can handle frequently changing big data. It is reliable for real-time data.

(c) OpenRefine: open source software that organizes chaotic data in big data for effective use.

(d) Qubole: tool that uses data platforms based on clouds technology to process big data.

(e) BigML: tool that uses machine learning to simplify the big data gathered from multiple sources and generate useful models for decision making.

(f) Statwing: tools that organize the big data in a way that can easily be manipulated to generate new information.

(g) Domo: tool that saves, processes, and converts companies' databases, into charts and other visualization outputs.

Research Design

Some data sources such as GPS, sensors, and some Government publications are limited only to develop nations. Most third world countries have unreliable GPS and maps due to the poor quality of infrastructures. Table 1 presents the availability of the sources to businesses in the Third World Countries and the Developed Countries where (Y: Available, N: Unavailable).

Table. 1: Availability of Sources

Sources		Google	GPS	Sensors	Smart Phones	Websites	Social Media	Government
	Developed Countries	Y	Y	Y	Y	Y	Y	Y
	Third World Countries	Y	N	N	Y	Y	Y	Y

Regardless of the size of the company, most data sources are available online and are excellent places to get input for the big data analysis tools (Marr, 2015). Data from different sources are fed to big data tools which will organize them and process them into information. Moreover, data analytics tools enable businesses to present the information into visualizations forms including charts, tables, graphs and much more. As a result, businesses have access to information they can use in decision making. Companies can use these outcomes from big data analysis as a powerful tool to succeed in business in third world countries. These analyses can help companies understand third world the market and the need of potential customers. Firms in developed countries can take decisions based on real time information available in the big data to gain competitive advantage in the global market.

On the other hand, businesses from the third world countries may also benefit from the analyses and improve their processes, products, prices, and communications with current and potential customers. Third word areas businesses can also compete to a certain degree on the global market and attract customers around the world. However high capitals investment required may be overwhelming for businesses in the third world countries. In any case business in third world markets lack advanced technologies which may limit their access to big data and its analysis tool. Therefore, big data and its tools will mostly benefit businesses in developed nations. Businesses in developed nations, especially the big ones, will incur lower costs than in using big data and its tools that any business in third world nation. This advantage is due to the fact that in most developed nations, large companies have already been using big data and its tools to compete nationally as well as in some international markets.

SUMMARY AND CONCLUSION

To be competitive in today's global market, businesses can adopt information technology as an integral part for their process. The current paper suggests that big data and its analysis tools could help businesses compete in third world countries. With globalization, businesses in third world countries could overcome the limitations due to the lack of advanced technology that can secure competitiveness and maximize profits. Although big data tools are expensive for third world nations, they can be very beneficial and rewarding for the businesses. In the long-run, the benefits of investing in big data and it technology will outweigh the costs; and businesses in both developed countries and third world countries can enjoy the benefits. The next step in this research will be to analyze the different big data tools and determine the most appropriate for different regions.

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DECISION SCIENCES INSTITUTE
Using Recurrent Neural Network for Cloud Masquerade Attack Detection

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ABSTRACT

There is an increasing trend to use cloud for data storage and applications. However, the security and privacy issues in the cloud environment become the major concerns for cloud users and organizations. Masquerade attack is one of the most critical attacks in the cloud. To exploit the sequential feature of the masquerade attack dataset, we propose to use Recurrent Neural Network (RNN) with Long Short-Term Memory (LSTM) to detect masquerade attacks. We also applied word vector to preprocess the dataset to provide more exploitable information for prediction. Experimental results showed that the proposed RNN methods obtained better performance than the traditional multilayer perceptron methods. Moreover, the RNN with word vector method showed promising performance in identifying both the normal and masquerade records.

KEYWORDS: Recurrent neural network, Cloud computing, Masquerade detection, Multilayer perceptron

INTRODUCTION

Research in cloud computing has been receiving a lot of attention from both academic and industrial worlds. According to Amazon (Amazon, 2017), “Cloud computing is the on-demand delivery of compute power, database storage, applications, and other IT resources through a cloud services platform via the internet with pay-as-you-go pricing.” However, the security and privacy issues concerning the storage of data in the cloud have been the major concerns for many organizations. Compared with traditional IT solutions, cloud computing has different threats concerns (Oktay and Sahingoz, 2013). According to (Ramteke, et. al, 2013), masquerade attack is one of the most critical attacks in the cloud. A masquerader is an attacker who authenticates as a legal user by stealing its credentials or by violating the authentication service (Kholidy, et. al. 2015). Several datasets are currently used to evaluate masquerade detection techniques, namely, SEA (Schonlau, 2017), Greenburg (Greenberg, 1988), Purdue

(Lane and Brodley, 1997), and CIDD (Kholidy and Baiardi, 2012). We used the dataset SEA to evaluate our masquerade detection algorithms in this paper.

Data in SEA contains username and the commands issued by those users. Compared with regular users, the commands issued by masqueraders have some sequential patterns, for example, changing users' privilege, accessing root directory and/or users directory, copying/deleting files, etc. Therefore we propose to use recurrent neural network (RNN) with Long short-term memory (LSTM) to detect masquerade attacks. RNN is a type of deep learning neural networks that can process sequential information using their internal state (memory). LSTM enables RNN to learn sequences containing longer-term patterns of unknown length. RNN with LSTM has been successfully applied in abnormal detection (Malhotra, 2015; Bontemps, et. al. 2016), network intrusion detection (Staudemeyer, 2015), human action recognition (Baccouche, M. et. al. 2011), etc. However, to the best of our knowledge, there has no research applying it to masquerade detection yet. To improve the performance of RNN, we adopted the method of preprocessing text data in text mining to transform the command list into word vectors. Experimental results showed that the modified RNN with Word Vectors (RNN-WV) performed well in detecting both the normal and masquerade records.

The contribution of the paper is twofold. Firstly, we innovatively applied RNN in masquerade detection to exploit the sequential patterns of user commands. Secondly, we used word vector to preprocess the commands to provide more exploitable information for prediction. The rest of the paper is organized as follows. We briefly review some related work in masquerade detection. Then we introduce the algorithms used for masquerade detection, including Multilayer Perceptron, RNN, and RNN-WV. Experiments, results and discussion are presented in the following section. The paper concludes with highlights and future work.

RELATED WORK

There has been many masquerade detection methods developed in the literature. Most of them are based on data mining algorithms. For example, Szymanski and Zhang (Szymanski and Zhang, 2004) used a SVM classifier to detects masqueraders. They first discovered frequent patterns in the sequence of user commands, encoded them with unique symbols, and then rewrote the sequence with the new coding for classification. Maxion and Townsend (Maxion and Townsend, 2002) applied a Naïve Bayes classifier to classify commands into either normal or masquerade. Naïve Bayes was also used in (Dash et al. 2005) to extract meaningful episodes from a long sequence of commands. Then a Naïve Bayes classifier was utilized to identify these episodes either as masquerade or normal.

Camina et. al. compared task-based Masquerade Detection System (MDS) with object-based MDS (Camina et. al. 2014). In order to evaluate the usefulness of the task abstraction, they designed some experiments with two different classifiers: Markov chains and Naïve Bayes. They found that a task-based MDS was as powerful as an object-based one. They also found that Markov chains outperformed Naïve Bayes, because it accounted for event temporal relationships.

Kholidy et. al. proposed a Data-Driven Semi-Global Alignment (DDSGA) approach for detecting masquerade attacks (Kholidy, et. al. 2015). In this approach, the user active session sequence was aligned to the previous ones of the same user and it labeled the misalignment areas as anomalous. A masquerade attack was signaled if the percentage of anomalous areas is larger

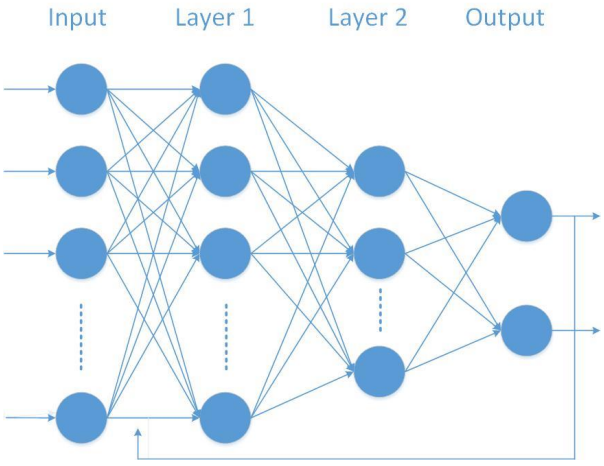
than a dynamic, user dependent threshold. Compared with SGA and other masquerade methods, DDSGA obtained higher hit ratio percent and relatively lower false positive percent. However, it could not effectively identify new masqueraders based on the commands of the existing users.

MASQUERADE DETECTION ALGORITHMS

Multilayer Perceptron (MLP)

A Multilayer Perceptron (MLP) was one types of the most frequently used artificial neural network (Rosenblatt, 1961). An MLP consists of at least three layers of nodes, an input layer, one or more hidden layers, and one output layer. Each layer consists of one or more neuron-like nodes. A node in one layer connects to nodes in the next layer. Except for the input nodes, each node is a neuron that uses a nonlinear activation function. MLP utilizes backpropagation for training. MLP can distinguish data that is not linearly separable. MLP was a popular machine learning solution in the 1980s, which has been successfully applied in the fields such as speech recognition, image recognition, and machine translation (Wasserman and Schwartz, 1988). Figure 1 shows the architecture of a MLP. In this paper, we use MLP as a baseline masquerade detection algorithm.

Figure 1: A Multilayer Perceptron (MLP)

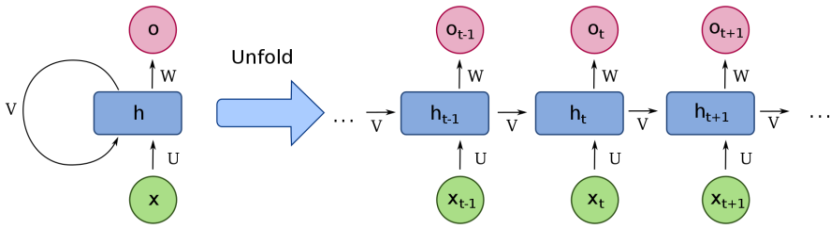


Recurrent Neural Network (RNN)

A Recurrent Neural Network (RNN) is neural network where connections between nodes form a directed graph along a sequence (Prasad, S. C. and Prasad, P., 2014). This allows it to exhibit dynamic temporal behavior for a time sequence. RNNs can use their internal state (memory) to process sequences of inputs. Basic RNNs are a network of neuron-like nodes, each is connected to other nodes in the next layer. Each node has a time-varying real-valued activation. Each connection has a modifiable real-valued weight. Like MLP, RNN usually is composed of an input layer, multiple hidden layer, and an output layer. For supervised learning in discrete time settings, sequences of real-valued input vectors arrive at the input nodes, one vector at a time. As shown in Figure 2, at any given time step, each non-input unit computes its current activation (result) as a nonlinear function of the weighted sum of the activations of all units that

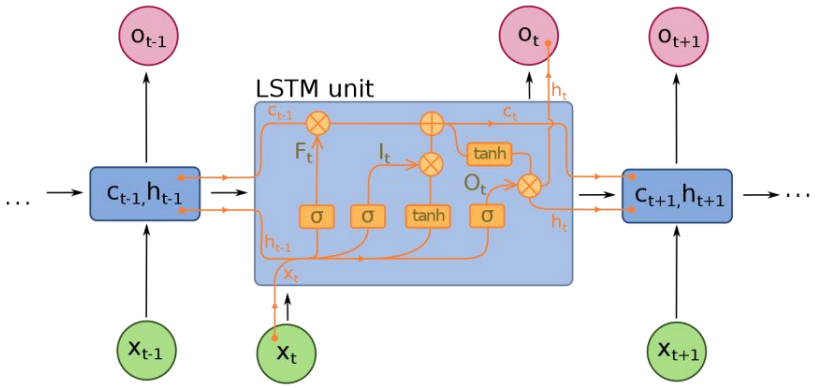
connect to it. Each sequence produces an error as the sum of the deviations of all target signals from the corresponding activations computed by the network. For a training set of numerous sequences, the total error is the sum of the errors of all individual sequences.

Figure 2: Unfolded basic recurrent neural network[1]



Long Short-Term Memory (LSTM) is used to avoid the vanishing gradient problem (Hochreiter and Schmidhuber, 1997). LSTM prevents backpropagated errors from vanishing or exploding. Instead, errors can flow backwards through unlimited numbers of virtual layers unfolded in space. That is, LSTM can learn tasks that require memories of events that happened thousands or even millions of discrete time steps earlier. LSTM works even given long delays between significant events and can handle signals that mix low and high frequency components. A long short-term memory unit is depicted in Figure 3.

Figure 3: Long short-term memory unit[1]



In this project, given a sequence of commands, we need to predict whether they are from a legitimate user or a masquerader. By applying RNN with LSTM, we utilize its memorizing feature to remember the signature command sequence from legitimate users and from masqueraders.

RNN with Word Vectors (RNN-WV)

To preprocess the commands to be fed to RNN with LSTM, instead of using a command stream, we adopted the method of preprocessing text data in text mining to transform the command list into word vectors. We built a command index and mapped each command to an

[1] By François Deloche - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=60109157

integer between 0 and the index size. Thus each command became a word vector and the command block became a input matrix. We believe this 2-dimentional structure provide more exploitable information for prediction.

EXPERIMENTAL RESULTS AND DISCUSSION

We conducted experiments to evaluate the performance of the proposed RNN methods for cloud masquerade detection.

Neural Network Setup

To compare the performance of the three neural networks mentioned before, we built the neural networks with similar structure. Figure 4 shows the architecture of MLP used in the experiments. It consists of three layers. The input layer has 100 nodes, which can input one block of 100 commands at a time. It has full connection to Layer 1, which also has 100 nodes. Layer 2 has 10 nodes, all of which connect to the output layer. The output layer has two nodes, which are used to denote whether the input block is a regular block (Class 0), or a masquerade block (Class 1).

Figure 4: MLP architecture used in experiments

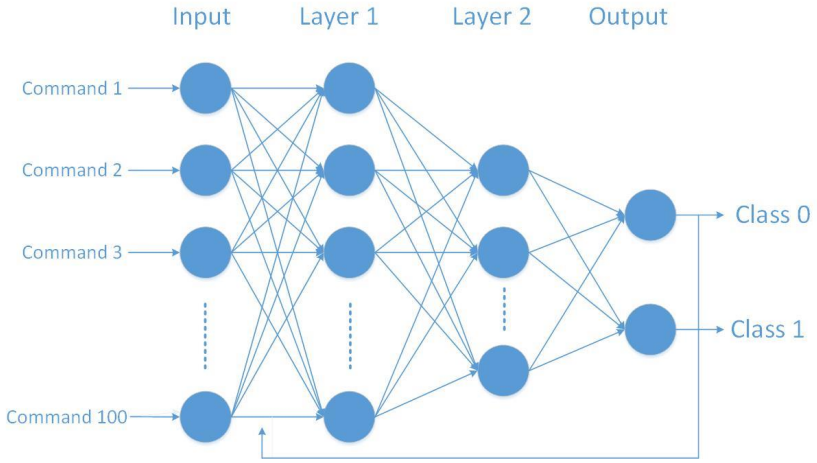
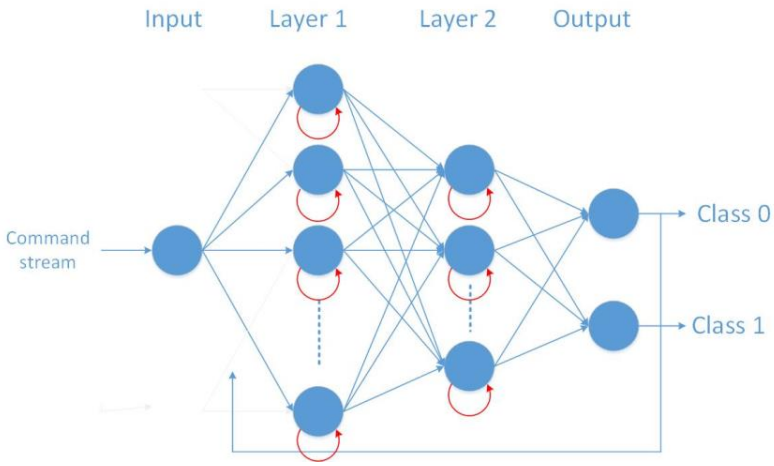


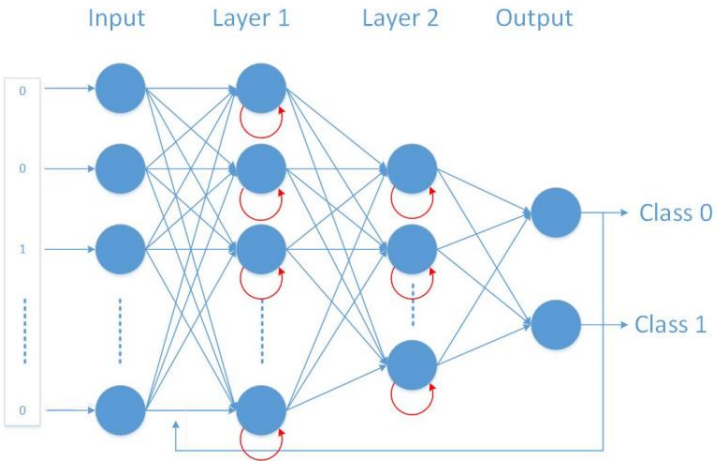
Figure 5 shows the architecture of RNN used in the experiments. It also consists of three layers. The input layer has only one node. The command block is considered as a univariate time series, which is input to the network one command per time step. It also has 100 nodes in Layer 1 and 10 nodes in Layer 2. The red circle under each node in these two layers represent the LSTM unit in the node.

Figure 5: RNN architecture used in experiments



The architecture of RNN with word vector is shown in Figure 6. It has the same Layer 1, Layer 2, and Output Layer as the one in Figure 5. The only difference lies in the Input layer. It has multiple input nodes in this layer, and the number of input nodes depends on the number of commands in the dataset. The input is also considered as a time series data, but at each time step one word vector will be input to the network.

Figure 6: RNN with word vector used in experiments



Dataset

In this paper, we used SEA dataset (Schonlau, 2017), which was used by most papers on masquerader detection. SEA consists of commands collected from UNIX account audit data. Among all the fields of audit data only the username and the command were taken. The data describe 50 different users each issuing 15000 commands. The first 5000 commands are considered genuine. The remaining 10000 commands of each user are divided into 100 blocks of 100 commands each. These blocks are seeded with masquerade users. There is a 1% probability that a block is a masquerader and, in this case, there is a probability of 80% that the following one is a masquerader too. As a result, approximately 5% of the test data contain masquerades.

Metrics

We used the following metrics to measure the performance of the masquerade detection algorithms. We used *tp* to represent the number of true positive records, *tn* to represent the number of true negative records, *fp* to represent the number of false positive records, and *fn* to represent the number of false negative records.

Accuracy is the percentage of correctly predicted records over the total number of records.

$$Accuracy = (tp + tn) / (tp + tn + fp + fn)$$

Precision is the number of correct positive results divided by the number of all positive results.

$$Precision = tp / (tp + fp)$$

Recall is the number of correct positive results divided by the number of positive results that should have been returned.

$$Recall = tp / (tp + fn)$$

F_1 *score* can be interpreted as a weighted average of the precision and recall, where an F_1 score reaches its best value at 1 and worst at 0.

$$F_1 = 2 \cdot Precision \cdot Recall / (Precision + Recall)$$

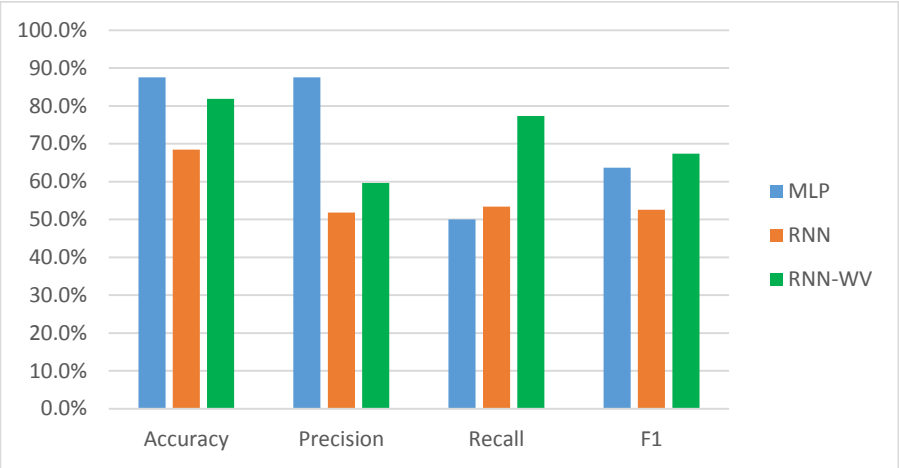
Performance Evaluation

We evaluated the performance of the masquerade detection algorithms in two scenarios, which are described below.

Scenario 1

In this scenario, we divided the data of each user into two parts, the training part and the testing part. We collected the training part data of all the users to train the neural networks, and then used the testing part data from all users to evaluate the prediction accuracy. The purpose of this scenario was to evaluate the performance of the predicting algorithm in identifying the masquerade behavior of existing cloud users. As only about 3% of the original dataset contains masquerade data, we under-sampled the dataset by removing the first 50 blocks of genuine data from each user. The performance of the masquerade detection algorithms was compared using the same under-sampled dataset.

Figure 7: Comparison of masquerade detection algorithms in scenario 1



As shown in Figure 7, RNN-WV performed better than RNN. Its overall accuracy is 81.9% while the accuracy of RNN is only 68.5%. The recall of RNN-WV is also more than 20% higher than RNN. Although MLP obtained better results than RNN and RNN-WV in accuracy, precision, and F_1, it actually failed the test. It was not able to identify any masquerade record. In other words, its recall is 0. We compared the recall results of all three algorithms in Table 1. Recall-Normal represents the percentage of the normal records that was correctly predicted, while Recall-Masq represents the percentage of the masquerade records that was correctly predicted. MLP reached 100% in Recall-Normal, which means it can correctly identify all the normal records. But on the other hand, its Recall-Masq value is 0%, which means it does not qualify for the masquerade detection task, as it cannot detect any masquerade record.

One reason MLP did not perform well was because the dataset was severely skewed, although the dataset was under sampled, the ratio of normal records to masquerade records was still 7:1. Another reason may be that the architecture of MLP was not sophisticated enough to handle this classification task. For comparison reason, we used the same hidden layers (Layer 1 and Layer 2) for all three neural networks. Table 1 also shows that the performance of RNN-WV was very promising. It successfully identified 82.5% of the normal records, and 72.2% of the masquerade records, which made it a good candidate for the masquerade detection task.

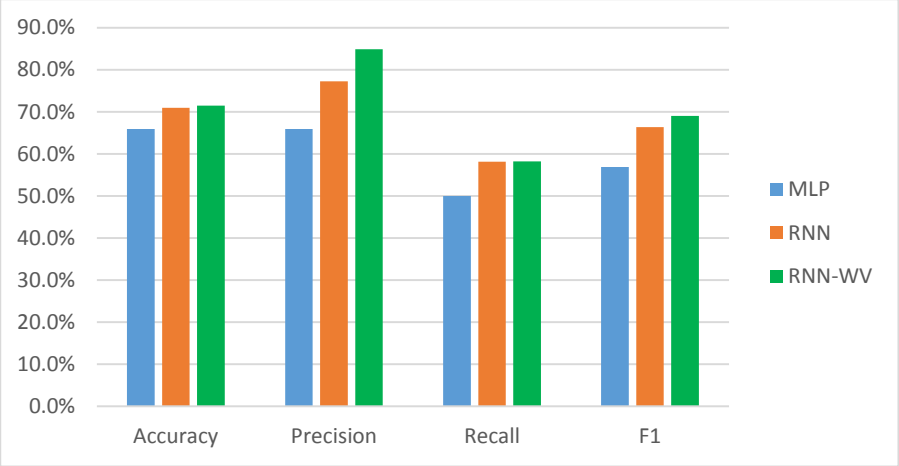
Table 1: Comparison of recall values in scenario 1

Measure	MLP	RNN	RNN-WV
Recall-Normal	100%	73.4%	82.5%
Recall-Masq	0%	33.3%	72.2%

Scenario 2

In this scenario, we divided the users into two groups, the training group and the testing group. We used the data from the training group to train the neural networks, and then used the data from the testing group to evaluate the prediction accuracy. This scenario was used to evaluate the performance of the predict algorithm in identifying the masquerade behavior of new cloud users. As in scenario 1, we under-sampled the dataset by removing the first 50 blocks of genuine data from each user. The performance of the masquerade detection algorithms was compared using the same under-sampled dataset.

Figure 8: Comparison of masquerade detection algorithms in scenario 2



RNN-WV still performs better than RNN and MLP in this scenario. Its overall accuracy is 71.5%. The performance of RNN is close to RNN-WV. And again, MLP classified all the records as normal records and failed to identify any masquerade records. Predicting the new user's behavior based on the behavior of the current users may be more difficult than predicting the future behavior of the existing users based on their previous behavior. That may be the reason why the performance of the three prediction algorithms was not as good as in scenario 1. As shown in Table 2, both RNN and RNN-WV could identify most of the normal records, but the accuracy of identifying masquerade records was below 20%. We will improve both algorithms to keep the current accuracy in predicting normal records and boost the accuracy in predicting masquerade records in our future work.

Table 2: Comparison of recall values in scenario 2

Measure	MLP	RNN	RNN-WV
Recall-Normal	100%	98.3%	100%
Recall-Masq	0%	18.0%	16.4%

CONCLUSION AND FUTURE WORK

Masquerade attack is one type of the critical attacks on the cloud. To detect masquerade attacks, we proposed to use RNN with LSTM to exploit the sequential feature of user commands. We also used word vectors in preprocessing to improve the prediction performance. The experiments showed that the RNN based methods outperformed the traditional MLP methods. Furthermore, the RNN with word vector method showed promising performance in identifying both the normal and masquerade records, which made it a good candidate for the masquerade detection task.

The experimental results also showed that the performance of predicting new masqueraders from the behavior of existing ones needed to be improved. We will modify the current algorithms to find a better solution.

One of most critical defects of dataset SEA is that SEA neglects command arguments and parameters. We will create a dataset with user profiles containing not only more detailed information about user commands, but also other user information such as login time, location, session, IP address, etc. We believe the new dataset will help build the masquerade detection system that can be applied to real-world cloud environment.

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DECISION SCIENCES INSTITUTE
Value creation networks for Industry 4.0: best practices in German manufacturing industries

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ABSTRACT

While Industry 4.0 can open new business models by fulfilling vastly individualized customer requests, the design and implementation of value creation networks is challenging: the role of the focal firm as principal coordinator becomes increasingly decentralized, interface standards are missing, and big data analysis for the necessary real-time coordination bears algorithmic challenges. This paper presents results of a longitudinal meta-study on development and current state of Industry 4.0 in the German manufacturing industries. The author derives lessons learned and best practices for designing and implementing value creation networks in Industry 4.0 settings.

KEYWORDS: Industry 4.0, platforms, manufacturing industries, internet-of-things, value creation networks

INTRODUCTION

While Industry 4.0 can open new business models, the technical implementation and especially the value creation network design and the operations strategies for providing highly individualized products and services are challenging. The concept of Industry 4.0 no longer grounds in the idea of value creation networks as linear processes with specified beginnings, pre-determined process steps and a specific end. In its place, it requires full flexibility of value creation set-ups in order to fulfil vastly individualized customer requests (batch size of 1). To achieve this flexibility not only requires a set of actors that come together to bring that particular product or service to market, but their selection from a larger set of potential actors on a one-on-one basis. In particular, the role of the focal firm as coordinator and central decision maker becomes increasingly decentralized.
The objective of this paper is therefore to illustrate the origins of the Industry 4.0 concept and to investigate its evolution in the German manufacturing industries in the past five years. A case study on automobile manufacturing and interviews with industry executives provide insight on real-world challenges as well as lessons-learned from the introduction of industry 4.0 and related best practices for value creation network design and operations strategies.

LITERATURE REVIEW

The concept of industry 4.0

Origins
The term Industry 4.0 (I4.0) was coined by the German government in a high technology strategy project to address the increasing global competition on product quality and production costs faced by the German manufacturing industry (Lee et al. 2015; Müller et al. 2017; Rodriguez et al. 2018). I4.0 was first presented to the public at Hannover Industrial Fair 2011 as part of the High-Tech Strategy Action Plan 2020 (Helmold & Terry 2016). Germany's very

important manufacturing sector suffered through the relocation of production facilities towards aspiring countries, which had managed to close the productivity and quality gap while keeping labor costs comparatively low. At the same time, established manufacturing companies had to recognize that customers were no longer willing to pay large price premiums for incremental quality improvements and demanded customized products and fast delivery (Brettel et al., 2014; Helmrich 2017). Consequently, manufacturing companies started to exploit new business potentials and opportunities through emerging technologies such as digitalization, the internet of things (IoT), internet of services (IoS), or cyber-physical systems (CPS). Against this backdrop, Germany launched the Industrie 4.0 initiative as part of its high-tech strategy to establish itself as a leader of integrated industry. Since then, I4.0 has received growing attention (even keeping the original German spelling for the spelled-out variety of the term) and was recorded on the 2016 World Economic Forum's agenda (Hofmann & Rüsch 2017).

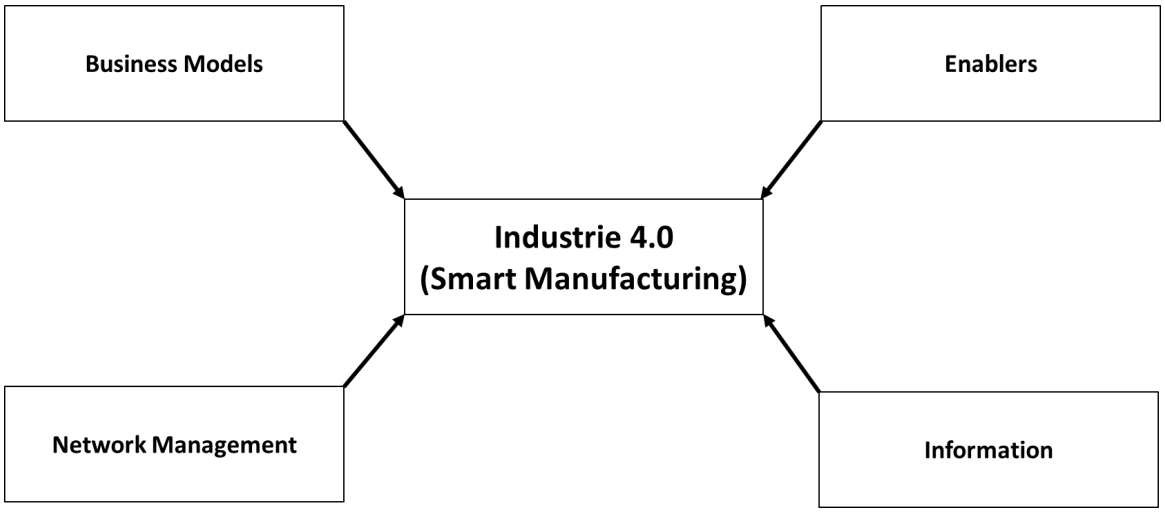
Definition

Most remarkably, although the concept Industrie 4.0 has been widely discussed for quite some time, there is still no generally accepted understanding of what it comprises, neither in academia nor in practice (Hofmann & Rüsch, 2017; Vogel-Heuser & Hess (2016), Xu et al., 2017). Interviews with practitioners commonly reveal a fuzzy image of I4.0 regarding the actual objectives, the relevant technologies, or the applicability for different industrial sectors. Similarly, academics have not developed a sound conceptual and terminological foundation of I4.0, which consequently hampers scientific research (Hermann et al., 2016).

Based on Spath et al. (2013), Bauernhansl et al. (2014) and Müller et al. (2017) this paper defines Industrie 4.0 as a concept in which companies, machines, devices and computers cooperate through digital technologies in horizontal and vertical networks to manufacture highly-individualized products. These networks continuously share information in real-time by connecting plants, equipment, machines, products and workpieces through information and communication technologies (ICT) into cyber-physical systems. As the concept of smart manufacturing conveys the same ideas as I4.0 (Kusiak 2017) both terms will be used interchangeably in this paper.

The author proposes to capture the I4.0 concept through four components: business models, enablers, information, and network management (see figure 1), which are subsequently explained.

Figure 1: Components of the Industry 4.0 concept



Business Models

From a business model perspective I4.0 either addresses cost reductions or capturing new business opportunities such as innovative products and services. Currently most manufacturers focus on the former while business model innovations are moving at a slower pace (Ernst & Young, 2017; Goschy & Rohrbach 2017; Rodriguez et al., 2018). Similarly, business models involving the creation platforms markets are still pursued with lower priority (Staufen AG 2018). The majority of new business models involve some form of data analytics. For analytic and predictive maintenance, the collected data is analyzed to offer customers improved information on process status or replacement suggestions for their equipment, hence adding a service component to the pure product (Staufen AG, 2018). Extended models move to a full service offer where the customer no longer buys the equipment, but only pays for equipment use (e.g. by volume or time). Essentially a service now replaces the product offer (everything as a service, XaaS).

From a cost reduction perspective, I4.0 is regarded as a means to improve processes or for increasing production flexibility and adaptiveness, faster reaction times, or an improved overall effectiveness of manufacturing equipment (Buer et al., 2018, Liao et al., 2016; Lu 2017).

Network Management

A major challenge is to determine the best real-time combination of actors regarding objectives such as timing, cost, quality levels, etc. for each individual order. Such a multitude of objectives can only be achieved through extended vertical, horizontal, and lateral collaborations resulting in growing complexities of value creation settings with multi-level competition and ensuing transaction costs (Baumann et al., 2016, Dietl et al., 2009, Holweg et al. 2014). As a result, actors face a trade-off between installing efficient value creation networks for particular products while being flexible enough to be part of alternative value creation networks for required product differentiations (Baumann et al., 2017, Brusoni et al., 2009, Jia et al. 2017, Pullman et al., 2010, Stevenson et al., 2017). In addition, the role of the focal firm as principal coordinator becomes increasingly decentralized in I4.0 settings. These challenges add to those discussed in the value creation network design and operations strategy literature (Holweg et al., 2014, MacCarthy et al., 2016, Pashaei et al., 2017).

Enablers

I4.0 grounds in a variety of enablers, which are briefly described in the following passage. A more detailed description and evaluation of I4.0 enablers can be found, for example, in Schebek et al. (2017) or Plattform Industrie 4.0 (2016).

Cyber-physical systems (CPS): CPS are systems that connect computation with physical processes. In the context of manufacturing this refers to monitoring and controlling the processes via computer networks (through the use of multiple sensors, actuators, control processing units, and communication devices) and synchronizing information related to the shop floor (Lee et al., 2015; Mosterman & Zander, 2016). Technologies such as RFID (radio-frequency identification) tags allow unique identification, while multiple sensors and actuators not only provide storage and data analytics, but are fully network compatible (Hermann et al., 2016). So-called manufacturing execution systems (MES) are the critical module that function as interoperational, real-time-enabled, and web-enabled connector between enterprise resource planning (ERP), production planning and control (PPC), and the actual shop floor, thus ensuring the connection of all network participants (Obermaier & Kirsch, 2017). Consequently, manufacturing equipment will turn into CPPS, Cyber-Physical Production Systems, which know their state, their capacity and their different configuration options and are also able to take decisions autonomously. In the I4.0 concept the shop-floor will become a marketplace of

capacity (supply) and demand for which multi-agent systems (self-)organize allocation (Almada-Lobo, 2016).
Internet of Things (IoT): The idea of smart, connected products is considered an initiator of Industry 4.0. IoT refers to a setting where essentially all (physical) things can turn into so-called smart things by featuring RFID tags, sensors, actuators, or small computers that are connected to the internet (Keskin & Kennedy, 2015). Through unique addressing schemas, these components interact with each other and cooperate with their neighboring 'smart' components in order to reach common goals (Hermann et al., 2016). IoT is at the heart of business models relying on new functionality, improved reliability, higher product utilization and capabilities (Greiner, 2015; Hofmann & Rüsch, 2017).
Internet of Services (IoS): The idea behind IoS is to make services easily available through web technologies (such as service-oriented architecture (SOA) or software as a service (SaaS)). allowing companies and consumers to create new kinds of value-added services. These services provide access to the resources of another party in order to perform a prescribed function and receive a related benefit. Resources may be human workforce and skills, technical systems, information, consumables, land, etc. (Hofmann & Rüsch, 2017).
Smart factory: The idea of the smart factory conveys a decentralized production system that is made up of a network of human beings, machines and resources that communicate with each other as naturally as in a social network (Yin et al., 2017. The existing production logic with a central steering entity changes towards smart products that navigate their way independently through production processes and are easily identifiable and locatable at any time. Digital connectivity enables an automated and self-optimized production of goods and services including delivering without human interventions (self-adapting production systems based on transparency and predictive power) (Hofmann & Rüsch, 2017). Besides these changes in production processes also the roles of employees are expected to alter with employees taking on more supervising tasks with greater responsibility (Spath et al., 2013). They are supported by smart technologies such as wearables (e.g. smart watches, glasses, or gloves), augmented reality applications, autonomous vehicles (incl. drones) and distributed ledger systems (e.g. the blockchain) (Xu et al., 2018). Data analytics amalgamates the information from these connected systems to provide decision support to both machines and humans (Ainin et al, 2015; Ba & Nault, 2017).

Information
I4.0 depends on extensive data analytics (Yin et al., 2017) and, increasingly, concepts of Artificial Intelligence (AI) and Machine Learning (ML) (Staufen AG, 2018; Wunck & Baumann, 2017). In a first process step data is being collected via multiple devices equipped with sensors. Data analytics then inspects, cleanses, transforms, and models data in order to discover patterns, extract relevant information, and support decision-making. Typical techniques involve data mining, which mostly focuses on data analysis for predictive purposes, and statistical applications, which focus on discovering previously unknown facts, structures, or evidence (Ba & Nault, 2017). Other common techniques are data visualization and data dissemination (Ainin et al, 2015). Big Data, i.e. data that is challenging through its volume, variety, velocity, and/or veracity, proves particularly challenging in data analytics, as these big data sets typically exceed the capabilities of traditional data-processing application software (Baumann & Eulenstein, 2014). Furthermore, it is important to evaluate the information processing chain regarding the value added by its process steps. A reference process model for industrial IoT applications can compare the value propositions of competing solutions (Wunck & Baumann, 2017).

DESIGN/METHODOLOGY/APPROACH

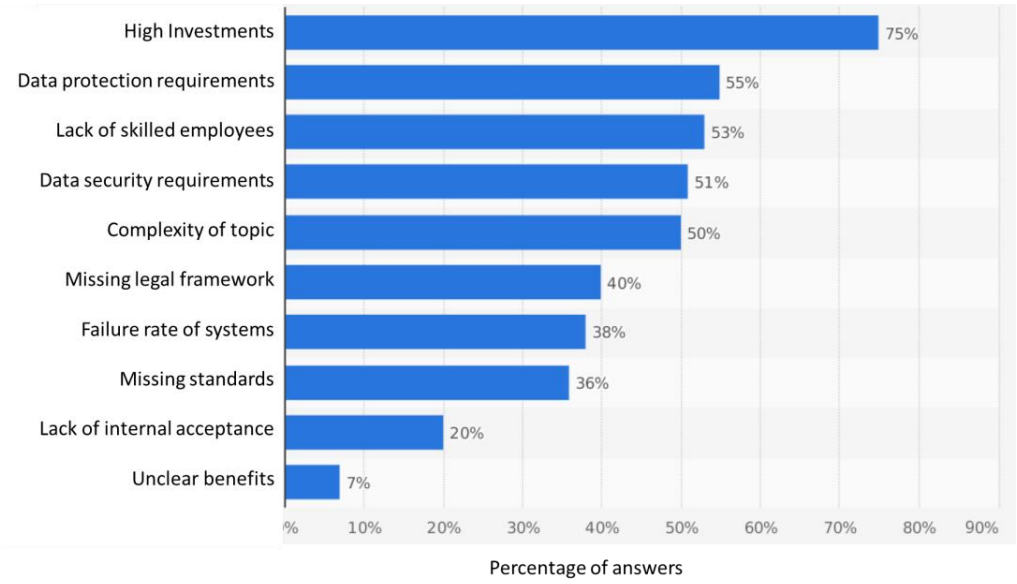
In a longitudinal meta-study, the author traces the development of the Industry 4.0 concept and its implementation in the German manufacturing industry over a period of five years based on archival data, case studies from the automobile industry and a medium sized (plastics) manufacturer, semi-structured interviews, and field observations. Germany was selected as the concept originates in this country. This paper focuses on presenting a condensed overview of the results of the meta-study and the automobile industry case study.

RESULTS

Industry 4.0 lessons learned from German industry

Optimistic studies estimate German manufacturers on average can nearly double their operating profit through smart manufacturing (Cap Gemini Consulting, 2018). At the same time manufacturers become gradually aware that technological changes do not only bear great potential, but do come with considerable risks of disruption. Almost 60% of manufacturers anticipate disruptive attacks in the next ten years (Goschy & Rohrbach, 2017). Consequently, increasing investment into I4.0 technologies is expected for the near future, particularly for SME. On average 5% of turnover will likely be invested, primarily for personnel and ICT. In terms of outcomes the highest potential is expected for increasing flexibility in production and logistics (Ernst & Young, 2017), predictive maintenance on both the production and product side (Goschy & Rohrbach, 2017), and the development of new business models (Bundesministerium für Wirtschaft und Energie, 2015; Helmrich, 2017).

Figure 2: Impediments to I4.0 for German manufacturers (Bitkom Research, 2018)



Surprisingly, the majority of German companies do not yet have a digitalization strategy (Gelowicz, 2018) and only a quarter have an advanced digitalization state of their vertical and horizontal value creation chains (Budak et al., 2018). Studies into reasons why I4.0 is not implemented a faster rate (see figure 2) reveal that German SME in particular shy away from the extensive investments into technology and personnel (Ernst & Young, 2017) and are more

concerned about the costly complexity of the tasks and data security issues than larger organizations. SME have limited available resources and also have to address integration of their legacy equipment into I4.0 scenarios (Bundesministerium für Wirtschaft und Energie, 2015, Staufen AG 2018).

So what are the success factors for I4.0 and what lessons can be learned from German industry? The first lesson is about *customer focus* and *service-oriented business models*. Companies need to satisfy vastly heterogeneous customer needs while balancing the trade-off in realizing scale effects along the value chain through standardization and mass production (Baumann et al., 2017). An efficient implementation of I4.0 supports the move towards mass customization that focuses on the production of personalized mass products, mostly through flexible processes, modularized product design and integration between supply chain members along the value chain. Otherwise high-wage countries such as Germany cannot compensate their inferior labor cost structure when barriers to entry diminish for new competitors (Brettel et al., 2014; Helmrich, 2017) and boundaries between producers, suppliers and customer become increasingly blurry (Ernst & Young, 2016). In addition, new businesses emerge that complement the traditional sale of machinery and products with smart services such as predictive maintenance (Goschy & Rohrbach, 2017).

The second lesson concerns the *design of collaborative production and supply networks*. It is vital to accommodate the strategic planning level decisions of shifting added-value creation from one factory or company towards integrated production and supply networks with an ensuing complexity of products and processes. This involves the design of the aggregated flows of materials and products among suppliers and facilities not only from a procurement point of view, but also from a distributional perspective towards customers (Altmann, 2015). These value creation networks offer a number of advantages: risk sharing, pooling of resources, expansion of market opportunities, and overall a more agile adaptation to volatile markets and shortened product lifecycles. However, the decoupling and spatial separation of production processes comes with high costs for coordination, synchronization, and cross-company data sharing and integration (Baumann et al., 2017; Brettel et al., 2014; Lödding et al., 2017). Furthermore, different mentalities towards information and cost-sharing as well as opportunistic behavior can deteriorate or even destroy the benefits of the collaboration network. Therefore, adequate control measures across all production- and supply-related actors need to be operationalized by formal safeguards to manage the complexity of the networks (Dietl et al., 2009).

The third lesson lies in *Data Management*. The success of I4.0 scenarios depends on the availability, adequate processing and distribution of the necessary information for the efficient steering of the collaboration networks. These data come from ERP-systems, product sensors, machine data as well as production information (e.g. runtime, capacity usage, order status) across all network partners (Wunck & Baumann, 2017). The value, however, does not lie in collecting the data, but in amalgamating and analyzing it for the entire network in order to propose the best possible combination of network partners for a particular customer request (Baumann et al., 2017). Likewise powerful analyses are needed for real-time predictions, e.g. for predictive maintenance or system status, to provide smart services to the customers. However, algorithmic challenges inhibit data exploitation, in particular in settings with polynomially or exponentially growing run-time (Baumann & Eulenstein, 2014).

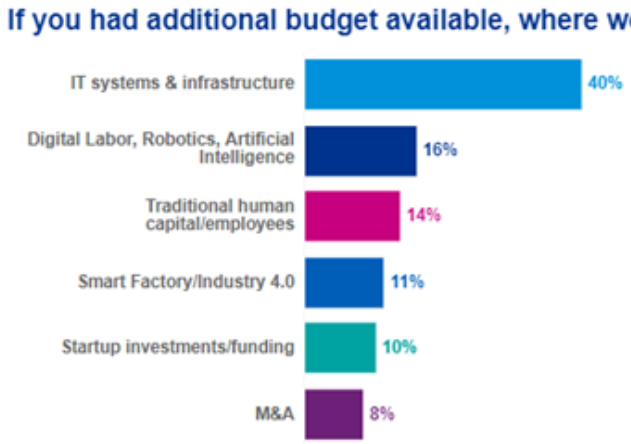
Finally, it has to be noted that the major challenge of I4.0 is not the technology, but the *management of the digital transformation process* including the design of value creation networks (Mason & Wagner, 2005). Managers often underestimate the speed of the transformation and as a result necessary organizational structures and cultures are not being implemented with adequate speed (Goschy & Rohrbach, 2017, Staufen AG, 2018). Even more seriously, the majority of German manufacturing companies have not even started to develop an I4.0 roadmap that is grounded in a cross-functional and agile digitalization strategy

(Sniderman et al., 2016). Neither, are the benefits of collaboration networks explored in depth nor those of innovative business models (Bundesministerium für Wirtschaft und Energie, 2015; (Goschy & Rohrbach, 2017); Plattform Industrie 4.0, 2016).

Case Study: Industrie 4.0 in automobile manufacturing

The automobile industry is among the most important industrial sectors in Germany and hence has a strong influence on overall economic development. Its competitive environment is characterized by increasing dynamics and volatility combined with a market saturation in voluminous core markets (USA, Europe or Japan) as well as an intensifying price competition. Furthermore, the industry experiences shorter product life cycles and growing customer demand for individualized products (Gölzer & Fritzsche, 2017; Hung Vo, 2016) which leads to a high diversification of products through variants and customer-specific fittings. Manufacturers have addressed these challenges by reducing vertical integration and shifting activities to their suppliers (Reinhart et al., 2017). Consequently, both product and process complexity have vastly expanded within the automotive industry (Hung Vo, 2016). In addition, market developments such as shared-ride and car sharing models have demonstrated the disruptive power of digital business models. This setting calls for I4.0 scenarios and it is hardly surprising that the automotive industry is one of the forerunners. Almost all German companies in this industry already work with smart manufacturing concepts or explore digital additions to their business models (Goschy & Rohrbach, 2017).
Current car buyers expect they can configure all possible features of their automobile ranging from color to seats, engines, tires and audio-visual equipment. Digitization will soon allow customers to change the color of their vehicle up to the moment the car body enters the paint shop. Digital features will change future user experiences with the car reminding the driver that the next inspection is due based on actual wear and tear or the manufacturer being able to keep in touch via personalized audio-visual messaging. Sensors will provide manufacturers with extensive data sets on actual car usages and performance which can be analyzed to improve future car design (Helmrich, 2017). Data analytics also provides entirely new business models around upstream data usage, offering paid services during the product-lifetime. This is particularly interesting for the high-volume manufacturers that have lower profit margins in the traditional point of sales model (KPMG, 2018).

Figure 3: Investment in the automotive industries (KPMG, 2018, p. 8)



Production systems at German automobile manufacturers are being redesigned to handle the complexity induced by the market (Dunckern, 2017). Other requirements are to further improve productivity of production (e.g. costs, time, quality), but also an increased flexibility to produce more variants and to address the ensuing complexity (Reinhart et al., 2017). However, it is important to note that German automobile manufacturers do not expect a batch size of 1 as propagated by I4.0 purists. Manufacturers perceive it as either irrelevant or not feasible for implementation in their current market environments (Goschy & Rohrbach, 2017). They also have no intention of deviating from the focal firm concept, contrary to what is propagated for I4.0.
All I4.0 enablers and technologies such as IoT, CPS, artificial intelligence, human-robot-collaboration, virtual and augmented reality, driverless transport systems, RFID, additive manufacturing or drones have or are about to become standards in German automobile production (Brettel et al., 2014). IoT in particular is regarded as an important enabler for information sharing across participants in collaboration networks (Tietze et al, 2017). Every new car is now a part of the IoT and vehicles are communicating with each other, and sending and receiving data via the cloud. The technology supports, for example, lane compliance, parallel parking or setting insurance premiums according to driver capability.
Looking ahead it is interesting to note that a surprisingly high share of automobile executives (40%) would invest into IT systems & infrastructure rather than into I4.0. However, this could also be an indicator that executives perceive a homogenous IT as necessary prerequisite for I4.0 to be fully implemented (KPMG, 2018, Staufen AG).

CONCLUSION

The results of the meta-study show that the implementation of the Industry 4.0 can vary depending on the industry and the size of the company. Large automobile manufacturers are fairly advanced in collaborating with suppliers, yet real-time routines for assessing and integrating actors into the supply network are still underdeveloped. Beyond that, SME also struggle considerably with understanding the implications for their business models. Fully adaptive value creation design consequently still lags behind the original propositions as do real-time data exploitations. Most notably, many existing studies do not or only superficially address the business model level, thereby neglecting the question of how the considerable costs of realizing Industry 4.0 can be recouped from increased sales.
This paper adds knowledge on designing value creation networks and operations strategy for Industry 4.0 settings when moving away from focal firms to more decentralized procedures, including competitive challenges in and between networks. Current findings indicate, however, that executives do not regard full decentralization of decision making as an option, but prefer to manage networks in focal position for the relevant segments of their value creation networks.

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Value or Volume?
A Comparison of Two Risk Sharing Approaches

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ABSTRACT

We compare a sales volume-based agreement and a value-based cost-effectiveness rebate between a payer and manufacturer to deal with uncertainties in new and expensive pharmaceutical products. We find the conditions in which the two parties agree or disagree on the preferred contract. Our study suggests that the contract preferred by the two parties depends on a combination of factors such as the drug price, treatment eligibility, etc. To our knowledge, our study is the first modelling paper on the direct comparisons between the two contracts which generates important insights and provides foundations for future design and selection of the contracts.

KEYWORDS: Risk-sharing, Price volume agreement, Cost-effectiveness, Drug costs, Pharmaceutical promotions

INTRODUCTION

The large proportion of pharmaceutical spending in both health expenditures and gross domestic product is a big concern in many countries. For example, 20% of health expenditures were spent on pharmaceuticals in Organization for Economic Co-operation and Development (OECD) countries in 2013 (Organisation For Economic & Development, 2015). Many payers use a formulary (a list of drugs that will be reimbursed by the payer) to manage and contain pharmaceutical spending (Gershon, 2011; Zaric & Xie, 2009).

However, when making formulary listing and reimbursement decisions, there are several uncertainties such as the sales volume or the effectiveness of new drugs. Sales volumes could be larger than originally anticipated due to factors such as poor forecasts, off-label usage, expansion of indication, and marketing effort by the manufacturers (Zhang, Zaric, & Huang, 2011). The effectiveness of new drugs in real clinical practice could be lower than the efficacy in clinical trials which usually have targeted patients with higher adherence level (Antonanzas et al., 2011). To deal with these uncertainties many payers have adopted risk-sharing agreements under which the reimbursement for a pharmaceutical product is related to its performance in real-world settings (Adamski et al., 2010).

Although the uncertainties in both sales volume and health outcome co-exist in many situations, we are not aware of any direct theoretical comparisons between sales volume-based and health outcome-based contracts. Our study intends to fill an important gap by comparing the performance of a sales volume-based agreement and a cost-effectiveness-based agreement to provide theoretical foundations for selection and decision making in the future. We focus on the comparison between a sales volume-based agreement and a value-based cost-effectiveness rebate.

To control financial expenditure, a price volume agreement (PVA) uses a sales threshold, and manufacturers must pay partial or full rebate to payers for excessive sales over the threshold. These contracts are widely used in Australia and many European countries (Adamski et al., 2010). To manage the uncertainties in health outcomes, a value-based cost-effectiveness rebate (CER) specifies a cost-effectiveness threshold and manufacturers have to pay rebates to payers if the drug fails to meet the benchmark (Adamski et al., 2010). A well-known example of this type of plan was in the listing for Multiple Sclerosis drugs in the UK (Palace et al., 2015).

Several studies have investigated the performance of a PVA (Zaric & O'Brien, 2005; Zhang & Zaric, 2011, 2015; Zhang et al., 2011) and some examined the efficiency of a CER (Antonanzas et al., 2011; Barros, 2011). Limited studies compared different types of risk sharing agreements. For example, Zaric and Xie (2009) compared two cost-effectiveness-based agreements and showed that the optimal agreements for the two parties depend on several factors and neither of them is always preferred by either party (Zaric & Xie, 2009). Levaggi (2014) compared the welfare of a listing through an uncertain bargaining process and a value based pricing agreement with risk sharing, and showed that the total welfare is always better under a value-based pricing scheme but the distribution of the benefits between consumers and the manufacturer depends on the rebate rate (Levaggi, 2014).

We are not aware of any direct comparisons between a sales volume-based and a health outcome-based agreement. In this study, we build a model which consists of a manufacturer and third-party payer to compare the desirability of a PVA and a CER. It should be noted that the two contracts under comparison are not always applicable in reality. For example, a CER is not an option when outcome is not measurable or there is generic alternative available. However, our study intends to provide insights into situations where both contracts are available options and need to be compared. We model the manufacturer's marketing efforts explicitly as it can significantly affect both the cost-effectiveness and the sales volume of a new drug. To our knowledge, our study is the first modelling paper on the theoretical comparison of the two risk-sharing approaches.

MODEL

We develop a model to analyze interactions between a public third-party payer (payer) and a pharmaceutical manufacturer (manufacturer). We assume the manufacturer has received regulatory approval to sell a new drug and has applied to the payer to list the drug on the formulary. To manage the uncertainties in the sales volume and health outcome of the new drug, the payer is considering one of two risk-sharing agreements (i): a price volume agreement ($i = PVA$), and a value-based cost-effectiveness rebate ($i = CER$). All model notation is summarized in Table 1.

Without loss of generality, we normalize the size of the patient population to one. Let β be the incremental health benefit for a patient using the new drug compared with the current standard

Table 1 Summary of notation

Decision	
Manufacturer	
m	Marketing effort
Payer	
i	Index for the two contracts, $i = PVA, CER$
Parameters	
β	Incremental health benefit per patient under the new drug compared with the current standard treatment
$\underline{\beta}, \overline{\beta}$	Lower bound and upper bound of β
$f(\cdot), F(\cdot)$	PDF and CDF of β
λ	Payer's willingness to pay threshold
y	Threshold (lower bound) of treatment eligibility for the new drug
ϵ	A random variable for heterogeneity in prescribing behavior
$\underline{\epsilon}, \overline{\epsilon}$	Lower bound and upper bound of ϵ
$g(\cdot), G(\cdot)$	PDF and CDF of ϵ
k	Parameter of the efficiency of the marketing effort in the cost function
p	List price of the new drug
c_M	Manufacturer's marginal production cost per unit of drug
c_P	Payer's non-drug related cost per unit of drug
a_P^i	Payer' implementation cost of contract i per unit of drug
x	Volume threshold for rebate in a PVA
Calculated quantities	
Q	Expected total sales of the new drug.
B	Expected total health benefit of the new drug
S^i	Expected total rebate in contract i
π_M^i	Manufacturer's expected profit
π_P^i	Payer's expected payoff
Other notation	
$*$	Superscript for optimal value

of treatment. The units of β could be quality-adjusted life years (QALYs), life years (LYs) or any other units that the payer cares about. We assume patients are heterogeneous in β between $\underline{\beta}$ and $\overline{\beta}$ according to a probability density function (PDF) $f(\cdot)$ and a cumulative distribution function (CDF) $F(\cdot)$. (i.e., different patients derive different levels of benefit relative to the standard of care). This captures the variability across patients that can be attributed to patient characteristics or other factors. Let λ be the payer's willingness to pay for each unit of β.

We assume that there is a threshold of treatment eligibility y such that all patients with $\beta \geq y$ will be treated with the new drug, and patients with $\beta < y$ will be treated with the current standard of care. The parameter y is exogenous and specified in clinical or formulary guidelines and is thus interpreted as a rule that only patients expected to derive a minimal level of benefit will be prescribed the new drug. We assume that physicians can observe β for each patient prior to the prescribing decision, and that each patient consumes one unit of the new drug if prescribed.

There is heterogeneity in prescribing decisions which can be caused by physicians' inability to perfectly observe β, differences in interpretations of guidelines, situations which are not adequately captured by the guidelines, off-label use and "indication creep" (Cabana et al., 1999;

Lugtenberg et al., 2009; Riggs & Ubel, 2015). Therefore, some physicians may prescribe the new drug to patients who are not eligible according to clinical guideline whereas others may prescribe the new drug more strictly. Let ϵ be a random variable distributed between $\underline{\epsilon}$ and $\overline{\epsilon}$, with a PDF $g(\cdot)$ and CDF $G(\cdot)$, that captures heterogeneity in prescribing behavior. In addition, the manufacturer exerts marketing effort $m > 0$ at a cost of km^2 to increase demand, where k is the parameter of the efficiency of the marketing effort. Typical marketing effort include detailing, giving free samples to physicians and advertising in medical journals (Hébert & Stanbrook, 2007; Mizik & Jacobson, 2004). The cost function is similar to those used in some other studies on advertising (Bagwell, 2007; Tirole, 1990) and has the following properties: 1) marketing effort can only increase sales, 2) there is diminishing marginal returns on marketing effort, 3) no cost will occur without marketing effort. We assume that the mechanism of the marketing effort is to cause physicians to prescribe the new drug to some patients who are not eligible according the original clinical guideline, which has the effect of reducing the treatment threshold to $y - m$. The combined effect of heterogeneity in prescribing decisions and manufacturer promotional effort is that the actual treatment eligibility is $y - m + \epsilon$. Thus, the total sales quantity of the drug is $q = \int_{y-m+\epsilon}^{\overline{\beta}} f(\beta)d\beta$, the total health benefit of the drug is $b = \int_{y-m+\epsilon}^{\overline{\beta}} \beta f(\beta)d\beta$, the expected total sales quantity over ϵ is $Q = \int_{\underline{\epsilon}}^{\overline{\epsilon}} q\, g(\epsilon)d\epsilon$, and the expected total health benefit of the drug is $B = \int_{\underline{\epsilon}}^{\overline{\epsilon}} b\, g(\epsilon)d\epsilon$.

Let p and c_M, $p > c_M > 0$, be the price and the manufacturer's marginal production cost per unit of drug, respectively. Let c_P be the payer's non-drug related incremental cost per unit of drug which could be positive or negative. A negative c_P indicates that the new drug causes a reduction in non-drug healthcare expenditures. For example, the drug may prevent or delay expensive surgeries, or prevent infections that are expensive to treat. A positive c_P indicates that the new drug causes an increase in non-drug healthcare expenditures. For example, it may be necessary to administer the drug in hospital, or spend time in hospital to treat a drug reaction. Let a_P^i be the administration cost for implementing contract i which is assumed to be fully borne by the payer. The payer's monetary benefit is $MB = \lambda b - (p + c_P + a_P^i)q$. The first term λb denotes the monetary value that the payer attached to the total incremental health benefit of the new drug. The second term $(p + c_P + a_P^i)q$ is the total costs incurred by the payer.

Let s^i be the rebate from the manufacturer to the payer under contract i. In a PVA, a sales threshold x is predetermined in the contract and we assume that the manufacturer must pay full rebate to the payer for the excess of sales, i.e. $s^{PVA} = \max\{0, p(q - x)\}$. In a CER, there is no rebate when $MB \geq 0$, and the manufacturer must fully compensate the payer's loss if $MB < 0$, i.e. $s^{CER} = \max\{0, (p + c_P + a_P^{CER})q - \lambda b\}$. Let S^i be the expected value of s^i over ϵ.

Let π_P^i and π_M^i be the payer's and the manufacturer's expected payoff under contract i which are calculated as follows

$$\pi_P^i = \lambda B - (p + c_P + a_P^i)Q + S^i \quad (1)$$

$$\pi_M^i = (p - c_M)Q - km^2 - S^i \quad (2)$$

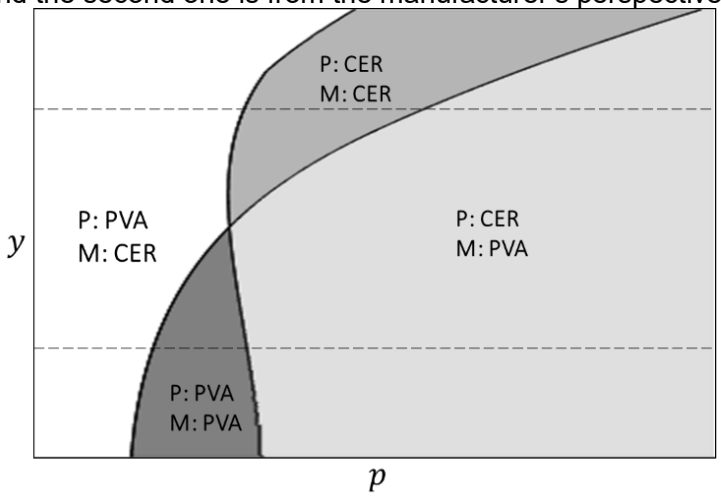
We assume that the payer first chooses the optimal risk-sharing agreement i to maximize her expected payoff and then the manufacturer chooses the optimal marketing effort m to maximize his expected payoff. The payer will choose a PVA if the expected payoff in a PVA is greater

than the payoff in a CER, i.e. $i_P^* = PVA$ if $\pi_P^{PVA*} > \pi_P^{CER*}$, and vice versa. Similarly, the manufacturer prefers a PVA if the expected payoff in a PVA is greater than the payoff in a CER, i.e. $i_M^* = PVA$ if $\pi_M^{PVA*} > \pi_M^{CER*}$, and vice versa. We do not consider any participation constraint for the payer as her payoff is always non-negative in a CER according to the setup of the rebate, and therefore π_P^{CER} could be considered as the reservation payoff for the payer. Thus, the payer will not choose a PVA if $\pi_P^{PVA} < 0$.

ANALYSIS

We made some additional assumptions in order to derive analytical solutions. We assume β is uniformly distributed between 0 and 1 and ϵ is uniformly distributed between $-\overline{\epsilon}$ and $\overline{\epsilon}$, $\overline{\epsilon} > 0$. Later we perform a robustness check and find that the main results also hold for normal distributions. We assume that the rebate threshold in a PVA is exogenously set equal to the expected sales (i.e. $x = Q$) since many PVA's set the sales limit based on anticipated expenditure (sales) (Adamski et al., 2010). With these additional assumptions, we find the optimal marketing effort (m^*), the payer's and the manufacturer's expected payoff in contract i (π_P^{i*} and π_M^{i*}, respectively) which are summarized in Table A1 and Table A2 in the appendix. We present the findings numerically using parameter settings $\lambda = 50000, \overline{\epsilon} = 0.1, c_M = 5000, c_P = 500, a_P^{PVA} = 200, a_P^{CER} = 1000$ and $k = 10000$. We also perform a robustness check on different values of the administration costs as it is one the major concerns of implementing a risk-sharing agreement (Adamski et al., 2010) and find that our results are qualitatively similar over a wide range of possible values.

Figure 1: Two-way policy graph of the contracts preferred by the payer and the manufacturer (the first contract in the labels is the optimal contract from payer's perspective and the second one is from the manufacturer's perspective)



In Figure 1, we present a two-way policy graph for the contract preferred by each party for different combinations of the drug price p (horizontal axis) and the treatment eligibility y (vertical axis), as preliminary analysis demonstrates that the optimal solutions are sensitive to these two parameters. The lower dashed line is for a small value of y which corresponds to a broad treatment eligibility, and the upper dashed line is for a large value of y which corresponds to a targeted treatment eligibility. With a sufficiently low price, the payer prefers a PVA, but the manufacturer prefers a CER. When price is sufficiently high, the payer prefers a CER, but the

manufacturer prefers a PVA. For intermediate prices, the two parties may prefer the same contract depending on the combinations of parameters. In this numerical example, both parties prefer a PVA when treatment eligibility is broad (i.e., y is low); and both prefer a CER when treatment eligibility is targeted (i.e., y is high). When prices are very big or very low the two parties disagree on the preferred contract.

To explain the logic behind Figure 1, we present additional details in Figures 2 and 3 corresponding to combinations of p and y shown along the two dashed lines in Figure 1. Figures 2 (a) and (b) show that with both broad and targeted treatment eligibility, the marketing effort in a PVA is greater than in a CER, and the marketing effort in a PVA is increasing in the drug price whereas the marketing effort in a CER is non-monotonic (increasing then decreasing) in the drug price. Figures 2 (c) to (f) show that the expected total sales and total health benefit of the new drug have the same trend with the optimal marketing effort. These trends are interrelated with the changes in the optimal rebate which are explained in the next paragraph.

Figures 2 (g) and (h) show that in the optimal solution, there is always a positive expected rebate in a PVA. This is because the manufacturer has to pay a rebate to the payer when there are excessive sales but does not receive any reward from the payer if the total sales is below the sales limit. The manufacturer is able to increase the marketing effort as the rebate is relatively small, and the increased profit from the increased marketing effort outweighs the marketing cost and rebate. In a CER, when price is sufficiently lower than the payer's willingness to pay, there is a higher chance that the monetary value of the total health benefit λb exceeds the payer's costs $(p - c_P - a_P^{CER})q$ and thus the optimal rebate is zero. This is because the relationship between the two quantities is dominated by the large difference of the drug price and the willingness to pay. The relative change in the total sales and total health benefit is relatively small as both quantities have same trends as shown previously (Figures 2 (c) to (f)). As a result, the manufacturer could increase the marketing effort to increase drug sales and profit without concern about the rebate in this price range. When price is sufficiently high, the optimal rebate in a CER starts to increase in the drug price. This is because the payer's costs are more likely to exceed the monetary health benefit which is again dominated by the relationship between the price and the payer's willingness to pay. Thus, the manufacturer makes a trade-off between the increased sales and rebate, and the optimal marketing effort is decreasing in the drug price in this price range.

Figure 3 shows the two parties' payoffs as a result of the combined effect of the aforementioned optimal quantities. Let $\tilde{p}_P$ be the switching price where the payer's preferred contract switches from a PVA to a CER and let $\tilde{p}_M$ be the switching price where the manufacturer's preferred contract switches from a CER to a PVA. Figures 3 (a) and (b) show that the payer prefers a PVA with a sufficiently low drug price ($p < \tilde{p}_P$). This is because the rebate in a PVA is positive but the rebate in a CER is zero (as shown previously in Figures 2 (g) and (h)) and this difference in rebate outweighs other differences between the two contracts such as monetary health benefit and profit from marketing effort and total sales. When price is sufficiently high ($p \geq \tilde{p}_P$), the payer prefers a CER as the rebate in a CER is increasing rapidly with price and exceeds the rebate in a PVA. Similarly, Figures 3 (c) and (d) show that the manufacturer prefers a CER with a low drug price ($p < \tilde{p}_M$) and prefers a PVA with a high drug price ($p \geq \tilde{p}_M$). Define the switching patients as those who are treated with the new drug but who would not be treated without marketing effort. With a broad treatment eligibility, the incremental health benefit from the switching patients is small, which reduces the manufacturer's switching price and creates a range for a PVA to be preferred by the two parties. With a targeted treatment eligibility, the incremental health benefit from the switching patients is large. This allows a health outcome-

Figure 2 Optimal values when y is small (the lower dashed line in Figure 1) and y is large (the upper dashed line in Figure 1)

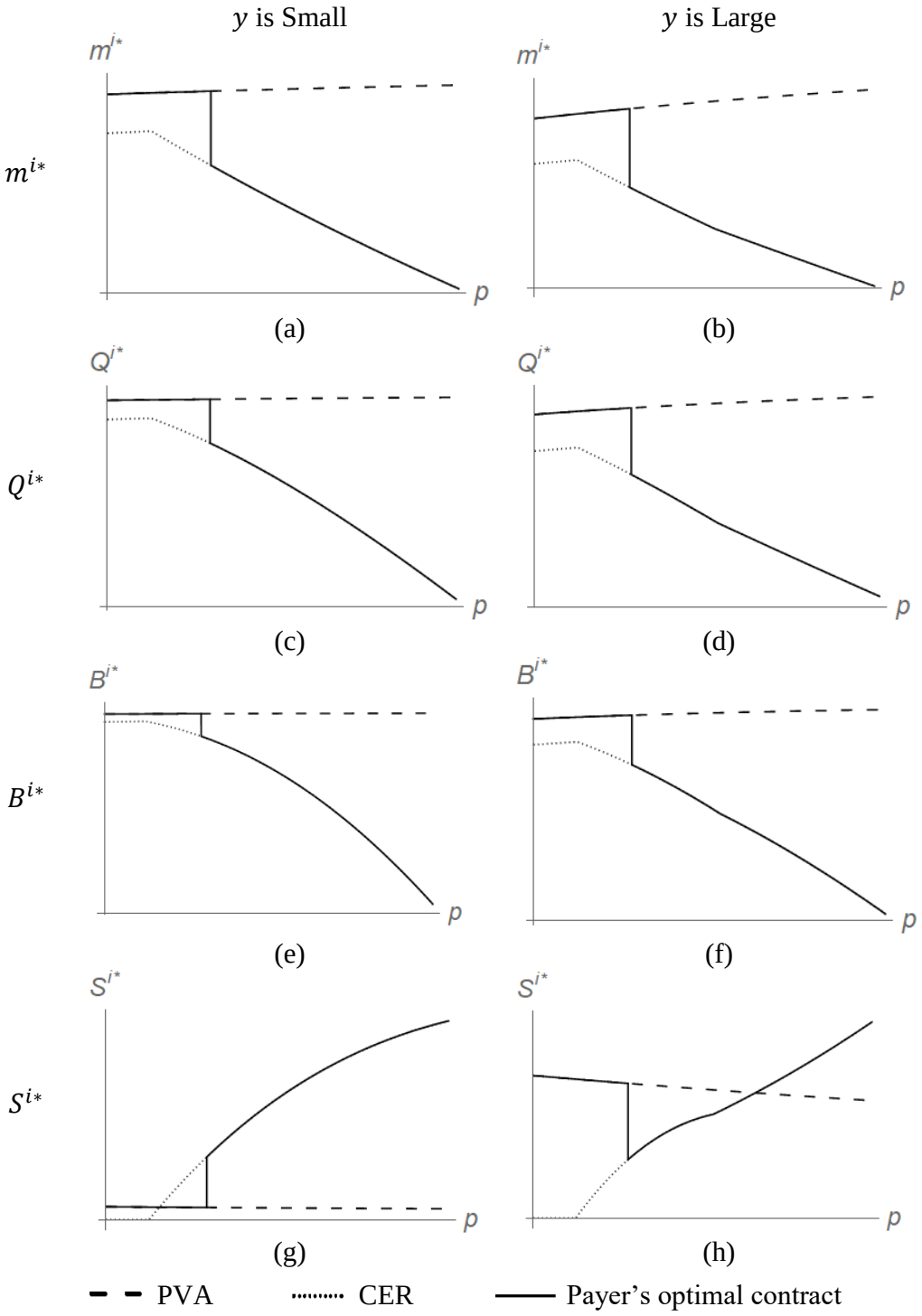
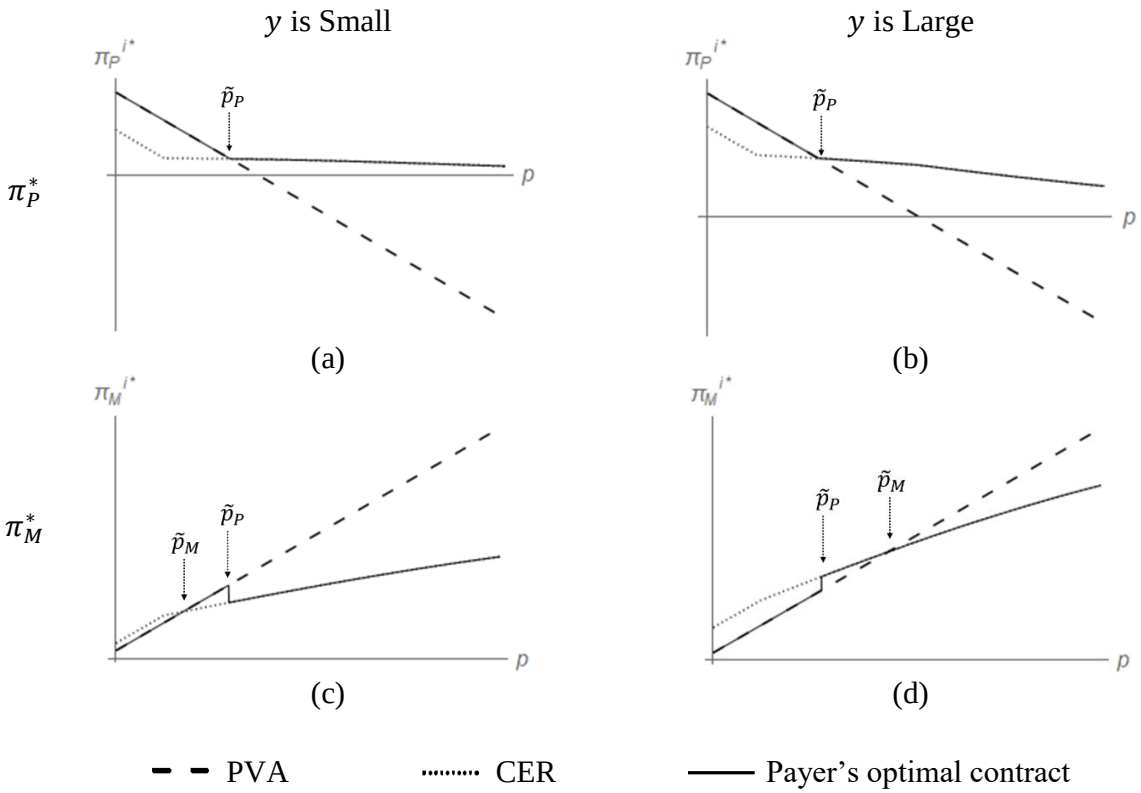


Figure 3 Optimal payoffs when y is small (the lower dashed line in Figure 1) and y is Large (the upper dashed line in Figure 1)



based contract to be preferred by the manufacturer up to a higher price and creates a range for a CER to be preferred by the two parties.

We perform robustness checks on the assumptions made for model tractability. When relaxing the assumption on a bounded uniform distribution and assuming a normal distribution for β and ϵ, the general insights are the same as presented here. If the administration cost is sufficiently high, then there is no region where both parties prefer a PVA, and the general insights for the other three regions remain the same.

CONCLUSION AND DISCUSSION

In this article, we compare the performance of a sales volume-based agreement and a cost-effectiveness-based contract between a payer and a manufacturer as uncertainties in sales volume and cost-effectiveness co-exist in many situations. We find the conditions on when the two parties agree or disagree on the preferred contract. Our study suggests that neither of the two risk-sharing agreements is always preferred by both parties. In general, the payer prefers a PVA but the manufacturer prefers a CER when price is much lower than the payer's willingness to pay. With a sufficiently high drug price, the payer prefers a CER but the manufacturer prefers a PVA. When price is intermediate, the two parties may prefer the same contract depending on the combinations of parameters. For example, both parties may prefer a CER with a broad treatment eligibility and prefer a PVA with a targeted treatment eligibility.

As observed, the two parties may prefer the same contract under certain circumstances. When choosing properly under these circumstances, a risk-sharing agreement can re-distribute risks between the two parties and create an all-win situation: for the payer, both the total health benefit and the cost to the health care system are taken into consideration and maximized; for the manufacturer, market access is accelerated, profit and the resulting incentives for future investment in new drug development are protected; for the patients, as some payer may only list a drug on the formulary with a risk-sharing agreement (Morgan, Thomson, Daw, & Friesen, 2013) due to unforeseeable risks and health budget constraints, such a contract also accelerates patients' access to new drugs and improve patients' welfare.

There are some limitations in this study and future research could consider the following extension directions accordingly. We compared a value-based risk-sharing agreement (a CER) and a volume-based risk-sharing agreement (a PVA) in this model. However, these two types of contracts are not always applicable to both parties. For example, a CER is not an option when outcome is not measurable or there is generic alternative available. Future research could consider other types of risk-sharing agreements to increase options for the two parties such as Patient access schemes (e.g. free drugs, price cap, etc.). We assumed the price is set exogenously, but it could be negotiated between the two parties or a decision variable of either party depending on their power. We assumed all parameters are publicly known and did not consider any information asymmetry. However, some key parameters of the health benefit could be one party's private information. For example, the manufacturer may have better knowledge on the type of the distribution of health benefit through clinical trial, or the payer may have better knowledge on the information though investigation or research. We assumed the sales limit in a PVA is set equal to the expected sales. However, it could take other forms or be either party's decision.

To our knowledge, this study is the first to compare a value-based and a volume-based risk-sharing contract between a payer and a manufacturer. We provide important insights into the conditions which determine when the two parties agree or disagree on whether a value-based or a volume-based contract is more desirable. As pharmaceutical spending keeps increasing, continued research on this topic is necessary for future design, selection and implementation of those contracts.

APPENDIX

Derivation of the optimal solutions

With the assumption of uniform distribution, the total sales and total health benefit are given by $q = 1 - (y - m + \epsilon)$ and $b = \frac{1-(y-m+\epsilon)^2}{2}$.
As uniform distribution has boundaries, there are two cases:
(1): $y - m - \bar{\epsilon} > 0$, i.e., the lowest value for the actual treatment eligibility is positive.
(2): $y - m - \bar{\epsilon} \leq 0$, i.e., the lowest value for the actual treatment eligibility is zero (actual treatment eligibilities with $y - m + \epsilon < 0$ are out of the defined boundary for ϵ and therefore the values for them are zeros).

Case 1 ($y - m - \bar{\epsilon} > 0$, i.e., $m < y - \bar{\epsilon}$):

The expected totals sales and the expected total health benefit are $Q = 1 + m - y$ and $B = \frac{1}{6}(3 - \bar{\epsilon}^2 - 3(y - m)^2)$.

1 - a. PVA:
With the assumption $x = Q$, the rebate occurs when $p(q - x) = -p\epsilon > 0$, i.e., when $\epsilon < 0$.Thus, $S^{PVA} = \int_{-\bar{\epsilon}}^{0} p(q - x)g(\epsilon)\, d\epsilon = \frac{p\bar{\epsilon}}{4}$. The manufacturer's payoff is concave ($\frac{d^2\pi_M^{PVA}}{dm^2} = -2k < 0$). The first derivative of π_M^{PVA} with respect to m is $\frac{d\pi_M^{PVA}}{dm} = p - 2km + c_M$.The first order necessary condition for m^{PVA*} is $\frac{d\pi_M^{PVA}}{dm} = 0$. With the condition for case i, the optimal marketing effort is shown in Table A1. The two parties' optimal payoffs are calculated by plugging in m^{PVA*} and shown in Table A1.

1 - b. CER:
The rebate occurs when $(p + c_P + a_P^{CER})q - \lambda b > 0$, i.e., when $\epsilon \leq \epsilon^{CER} = \frac{2(p+c_P+a_P^{CER})}{\lambda} - 1 + m - y$. We compare ϵ^{CER} with the boundaries of ϵ and obtain three cases:
(a) $\epsilon^{CER} < -\bar{\epsilon}$; (b) $-\bar{\epsilon} \leq \epsilon^{CER} \leq \bar{\epsilon}$; (c) $\epsilon^{CER} > \bar{\epsilon}$.

1 - b - i. $\epsilon^{CER} < -\bar{\epsilon}$
The condition for this case is $m < 1 - \bar{\epsilon} + y + \frac{2(p+c_P+a_P^{CER})}{\lambda}$. The rebate never occurs and thus $S^{CER} = 0$. The optimal values are solved with the same manner and shown in Table A2.

1 - b - ii. $-\bar{\epsilon} \leq \epsilon^{CER} \leq \bar{\epsilon}$
The condition for this case is $1 - \bar{\epsilon} + y + \frac{2(p+c_P+a_P^{CER})}{\lambda} < m < 1 + \bar{\epsilon} + y - \frac{2(p+c_P+a_P^{CER})}{\lambda}$. The expected rebate is $S^{CER} = \int_{-\bar{\epsilon}}^{\epsilon^{CER}} \left(\left(p + c_P + a_P^{CER}\right)q - \lambda b\right) g(\epsilon)\, d\epsilon = \frac{\left(2\left(p+c_P+a_P^{CER}\right)-(1-m-\bar{\epsilon}+y)\lambda\right)^2\left((2+m+\bar{\epsilon}-y)\lambda-\left(p+c_P+a_P^{CER}\right)\right)}{12\bar{\epsilon}\lambda^2}$. The optimal values are solved with the same manner and shown in Table A2.

1 - b - iii. $\epsilon^{CER} > \bar{\epsilon}$

The condition for this case is $m > 1 + \bar{\epsilon} + y - \frac{2(p+c_P+a_P^{CER})}{\lambda}$. The rebate is $S^{CER} = \int_{-\bar{\epsilon}}^{\bar{\epsilon}} \left(\left(p + c_P + a_P^{CER}\right)q - \lambda b\right) g(\epsilon)\, d\epsilon = (p + c_P + a_P^{CER})(1 + m - y) - \frac{1}{6}(3 - \bar{\epsilon}^2 - 3(y - m)^2)\lambda$.
The optimal values are solved with the same manner and shown in Table A2.

Case 2 ($y - m - \bar{\epsilon} \leq 0$, i.e., $m \geq y - \bar{\epsilon}$):

The expected totals sales and the expected total health benefit are given by $Q = 1 - \frac{(y+\bar{\epsilon}-m)^2}{4\bar{\epsilon}}$ and $B = \frac{1}{2} - \frac{(y+\bar{\epsilon}-m)^3}{12\bar{\epsilon}}$ when $y - m + \epsilon > 0$, $Q = 1$ and $B = \frac{1}{2}$ when $y - m + \epsilon \leq 0$.

2 - a. PVA:
The expected rebate is $\frac{p(m+\bar{\epsilon}-y)(y-m+\bar{\epsilon})^2}{8\bar{\epsilon}^2}$ when $y - m + \epsilon \leq 0$, and $\frac{p(y+\bar{\epsilon}-m)^4}{64\,\bar{\epsilon}^3}$ when $y - m + \epsilon > 0$, and the total expected rebate is the sum of the two quantities. The optimal values are solved with the same manner and shown in Table A1.

2 - b. CER:
With similar procedure in other cases, we solve the optimal values and conditions for this case which are shown in Table A2.

Table A1. Optimal solutions for a PVA

	Optimal solutions
m^{PVA1*} [a]	$\min\left\{y - \bar{\epsilon}, \frac{1}{2k}(p - c_M)\right\}$
m^{PVA2*}	$\min\{y + \bar{\epsilon},$ $\max\{0, y - \bar{\epsilon}, (-4\,3^{2/3}c_M p\bar{\epsilon}^2 + 2\,3^{2/3}p^2\bar{\epsilon}^2 + 163^{2/3}kp\bar{\epsilon}^3 - 3p\bar{\epsilon}(\phi^{PVA})^{1/3} + 3py(\phi^{PVA})^{1/3} - 2\,3^{1/3}(\phi^{PVA})^{2/3})/(3p(\phi^{PVA})^{1/3})\}\}$
π_P^{PVA1*}	$\frac{1}{6}(3 - \bar{\epsilon}^2 - 3\,(y - m^{PVA*})^2)\lambda - (p + a_P{}^{PVA} + c_P)(1 - y + m^{PVA*}) + \frac{p\bar{\epsilon}}{4}$
π_P^{PVA2*}	$(\frac{1}{2} - \frac{(y - m^{PVA*} + \bar{\epsilon})^3}{12\bar{\epsilon}})\lambda - (p + a_P{}^{PVA} + c_P)(1 - \frac{(y - m^{PVA*} + \bar{\epsilon})^2}{4\bar{\epsilon}}) + \frac{p(y - m^{PVA*} - 3\bar{\epsilon})^2(y - m^{PVA*} + \bar{\epsilon})^2}{64\bar{\epsilon}^3}$
π_M^{PVA1*}	$(p - c_M)(1 - y + m^{PVA*}) - k(m^{PVA*})^2 - \frac{p\bar{\epsilon}}{4}$
π_M^{PVA2*}	$(p - c_M)(1 - \frac{(y - m^{PVA*} + \bar{\epsilon})^2}{4\bar{\epsilon}}) - k(m^{PVA*})^2 - \frac{p(y - m^{PVA*} - 3\bar{\epsilon})^2(y - m^{PVA*} + \bar{\epsilon})^2}{64\bar{\epsilon}^3}$

[a] The optimal values with a superscript 1 is for case 1 (when $m \leq y - \bar{\epsilon}$); the optimal values with a superscript 2 is for case 2 (when $m > y - \bar{\epsilon}$).
[b] $\phi^{PVA} = 9c_M p^2\bar{\epsilon}^3 - 9p^3\bar{\epsilon}^3 - 18kp^2\bar{\epsilon}^4 + 18kp^2\bar{\epsilon}^3 y + \frac{1}{48}\sqrt{4(-24c_M p\bar{\epsilon}^2 + 12p^2\bar{\epsilon}^2 + 96kp\bar{\epsilon}^3)^3 + (432c_M p^2\bar{\epsilon}^3 - 432p^3\bar{\epsilon}^3 - 864kp^2\bar{\epsilon}^4 + 864kp^2\bar{\epsilon}^3 y)^2}$

Table A2. Optimal solutions for a CER

	When p is small [a]	When p is intermediate [b]	When p is large [c]
m^{CER1*} [d]	$\min\left\{y-\bar{\epsilon}, \max\left\{0, \frac{1}{2k}(p-c_M)\right\}\right\}$	$\min\left\{y-\bar{\epsilon}, \max\left\{0, \frac{1}{\lambda}(-a_P{}^{CER}-c_P-p-4k\bar{\epsilon}-\bar{\epsilon}\lambda+y\lambda+\phi^{CER})\right\}\right\}$ [d]	$\min\left\{y-\bar{\epsilon}, \max\left\{0, \frac{y\lambda-c_M-c_P-a_P{}^{CER}}{2k+\lambda}\right\}\right\}$
m^{CER2*}	$\min\left\{y-\bar{\epsilon}, \max\left\{0, y-\bar{\epsilon}, \frac{(p-c_M)(\bar{\epsilon}+y)}{p-c_M+4k\bar{\epsilon}}\right\}\right\}$	$\min\left\{y-\bar{\epsilon}, \max\left\{0, y-\bar{\epsilon}, \frac{2a_P{}^{CER}+2c_P+2p+2c_M\bar{\epsilon}-2p\bar{\epsilon}+2c_My-2py-\lambda}{2(c_M-p-4k\bar{\epsilon})}\right\}\right\}$	$\min\left\{\frac{-2a_P{}^{CER}-2c_P-2p+\lambda+\bar{\epsilon}\lambda+y\lambda}{\lambda}, \max\left\{0, y-\bar{\epsilon}, \frac{2a_P{}^{CER}+2c_P+2p+2c_M\bar{\epsilon}-2p\bar{\epsilon}+2c_My-2py-\lambda}{2(c_M-p-4k\bar{\epsilon})}\right\}\right\}$
π_P^{CER1*}	$\frac{1}{6}(3-\bar{\epsilon}^2-3(y-m^{CER*})^2)\lambda-(p+a_P{}^{CER}+c_P)(1-y+m^{CER*})$	$\frac{1}{6}(3-\bar{\epsilon}^2-3(y-m^{CER*})^2)\lambda-(p+a_P{}^{CER}+c_P)(1-y+m^{CER*})+\frac{(2(a_P{}^{CER}+c_P+p)+(1+y-m^{CER*}-\bar{\epsilon})\lambda)^2(-a_P{}^{CER}-c_P-p+(2+m^{CER*}+\bar{\epsilon}}{12\bar{\epsilon}\lambda^2}$	0
π_P^{CER2*}	$(\frac{1}{2}-\frac{(y-m^{CER*}+\bar{\epsilon})^3}{12\bar{\epsilon}})\lambda-(p+a_P{}^{CER}+c_P)(1-\frac{(y-m^{CER*}+\bar{\epsilon})^2}{4\bar{\epsilon}})$	$(\frac{1}{2}-\frac{(y-m^{CER*}+\bar{\epsilon})^3}{12\bar{\epsilon}})\lambda-(p+a_P{}^{CER}+c_P)(1-\frac{(y-m^{CER*}+\bar{\epsilon})^2}{4\bar{\epsilon}})+\frac{(m^{CER*}+\bar{\epsilon}-y)(a_P{}^{CER}+c_P+p-\frac{\lambda}{2})}{2\bar{\epsilon}}-\frac{(a_P{}^{CER}+c_P+p-2\lambda)(-2(a_P{}^{CER}+c_P+p)+\lambda)^2}{12\bar{\epsilon}\lambda^2}$	$(\frac{1}{2}-\frac{(y-m^{CER*}+\bar{\epsilon})^3}{12\bar{\epsilon}})\lambda-(p+a_P{}^{CER}+c_P)(1-\frac{(y-m^{CER*}+\bar{\epsilon})^2}{4\bar{\epsilon}})+\frac{(m^{CER*}+\bar{\epsilon}-y)(a_P{}^{CER}+c_P+p-\frac{\lambda}{2})}{2\bar{\epsilon}}-\frac{(a_P{}^{CER}+c_P+p-2\lambda)(-2(a_P{}^{CER}+c_P+p)+\lambda)^2}{12\bar{\epsilon}\lambda^2}$
π_M^{CER1*}	$(p-c_M)(1-y+m^{CER*})-k(m^{CER*})^2$	$(p-c_M)(1-y+m^{CER*})-k(m^{CER*})^2-\frac{(2(a_P{}^{CER}+c_P+p)+(1+y-m^{CER*}-\bar{\epsilon})\lambda)^2(-a_P{}^{CER}-c_P-p+(2+m^{CER*}+\bar{\epsilon}}{12\bar{\epsilon}\lambda^2}$	$(p-c_M)(1-y+m^{CER*})-k(m^{CER*})^2-(a_P{}^{CER}+c_P+p)(1+m^{CER*}-y)-\frac{1}{6}(3(m^{CER*}-y)^2-3+\bar{\epsilon}^2)\lambda$
π_M^{CER2*}	$(p-c_M)(1-\frac{(y-m^{CER*}+\bar{\epsilon})^2}{4\bar{\epsilon}})-k(m^{CER*})^2$	$(p-c_M)(1-\frac{(y-m^{CER*}+\bar{\epsilon})^2}{4\bar{\epsilon}})-k(m^{H*})^2-\frac{(m^{CER*}+\bar{\epsilon}-y)(a_P{}^{CER}+c_P+p-\frac{\lambda}{2})}{2\bar{\epsilon}}+\frac{(a_P{}^{CER}+c_P+p-2\lambda)(-2(a_P{}^{CER}+c_P+p)+\lambda)^2}{12\bar{\epsilon}\lambda^2}$	$(p-c_M)(1-\frac{(y-m^{CER*}+\bar{\epsilon})^2}{4\bar{\epsilon}})-k(m^{CER*})^2-\frac{(m^{CER*}+\bar{\epsilon}-y)(a_P{}^{CER}+c_P+p-\frac{\lambda}{2})}{2\bar{\epsilon}}+\frac{(a_P{}^{CER}+c_P+p-2\lambda)(-2(a_P{}^{CER}+c_P+p)+\lambda)^2}{12\bar{\epsilon}\lambda^2}$

[a] When $p < p^{CER1I}$ for case 1 and $p < p^{CER2I}$ for case 2, where $p^{CER1I} = \max\{0, \frac{\lambda}{2}-a_P{}^{CER}-c_P, \frac{-4a_P{}^{CER}k-4c_Pk+c_M\lambda+2k\lambda-2k\bar{\epsilon}\lambda+2ky\lambda}{4k+\lambda}\}$ and $p^{CER1II} = \frac{\lambda}{2}-a_P{}^{CER}-c_P$.

[b] When $p^{CER1I} < p < p^{CER1II}$ for case 1 and $p^{CER2I} < p < p^{CER2II}$, where $p^{CER1II} = \max\{0, (\frac{1}{2}+\bar{\epsilon})\lambda-a_P{}^{CER}-c_P, \frac{-4c_P-4a_P{}^{CER}+\lambda(2+2y+\lambda+w(2+\lambda)+c_M-c_P-a_P{}^{CER})}{2(2+\lambda)}\}$ and $p^{CER2II} = \lambda-a_P{}^{CER}-c_P$.

[c] When $p > p^{CER1II}$ for case 1 and $p > p^{CER2II}$ for case 2.

[d] The optimal values with a superscript 1 is for case 1 (when $m \le y-\bar{\epsilon}$); the optimal values with a superscript 2 is for case 2 (when $m > y-\bar{\epsilon}$).

[e] $\phi^{CER} = \sqrt{a_P{}^{CER2}+2a_P{}^{CER}c_P+c_P{}^2+2a_P{}^{CER}p+2c_Pp+p^2+8a_P{}^{CER}k\bar{\epsilon}+8c_Pk\bar{\epsilon}+8kp\bar{\epsilon}+16k^2\bar{\epsilon}^2-2a_P{}^{CER}\lambda-2c_P\lambda-2p\lambda-4c_M\bar{\epsilon}\lambda+4p\bar{\epsilon}\lambda+8k\bar{\epsilon}^2\lambda-8k\bar{\epsilon}y\lambda+\lambda^2}$

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Volunteer Management in Charity Storehouses: Volunteer Experience, Congestion and Operational Performance

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ABSTRACT

We study volunteer management at a large faith-based organization that operates a charity storehouse. The whole supply chain works exclusively with volunteers from supply to delivery. We model the preparation of beneficiaries' orders by volunteers in the storehouse as a function of volunteer experience and congestion. We explore how operational decisions, such as the type of volunteers' pairing in teams and whether to allow or impede congestion, affect two performance measures: on-time order preparation rate and additional time to prepare the orders. Using empirical data, we build a simulation model to study these relations.

KEYWORDS: Supply chain management, Volunteer management, Agent-based modeling, Humanitarian logistics

DECISION SCIENCES INSTITUTE

Who should be served first and who would not be admitted when customers require different service durations?

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ABSTRACT

The inverse newsvendor model determines the number of customers that could be served in the time available, measured in units of time. For identically distributed service durations, decision variable of interest is the number of assigned (or admitted) customers. For non-identically distributed service durations, we have to determine who to be assigned first and who would not be admitted. We take into accounts both identical and nonidentical normal service durations. We propose three heuristics to decide who to be served when all customers require different service durations, based upon the optimal assigned number of customers when all customers require an identical service duration. We conduct extensive numerical studies to show the efficacy of the heuristics.

KEYWORDS: Inverse Newsvendor, Stochastic Demand, Fixed Capacity, Demand Setting, Customer Admission

INTRODUCTION

The traditional newsvendor problem harkens back to the age-old problem of choosing the number of newspapers to stock in a vending machine in order to achieve a service level under a known stochastic demand distribution that will maximize profit in a single period (Edgeworth 1888, Arrow and Harris 1951). The inverse newsvendor problem is a variant of the traditional approach where the problem is characterized by choosing a demand distribution that could be fit in the available capacity. Industrial applications would be service-oriented firms such as hospital and law-firm. Capacity cannot typically be stored for service organizations. The stochastic element in this paper is the time required to provide service that we refer to as the service duration. In our study, by selecting customers to be served, we implicitly choose the total service duration. That is, the total time to serve all customers is simply the sum of the individual service durations. Since the total service duration represents demand, the decision is tantamount to choosing the demand distribution and this gives rise to the phrase inverse newsvendor model that was first coined by Carr and Lovejoy (2000). Our problem is similar to Carr and Lovejoy (2000), but our focus is on choosing customers to be served rather than explicitly choosing a demand distribution.

There are a few other studies that also address the inverse newsvendor models. Taaffe et al. (2008a) allow a supplier to shape the best demand distribution for a single product by selecting from different potential markets, naming the selective newsvendor problem. Taaffe et al. (2008b) allow for demand flexibility by modeling a random demand as consisting of a set of potential demands. Bakal et al. (2008) address a planning problem to construct a demand portfolio (e.g., market, price, purchase quantity) from a set of potential markets having price-sensitive demands. Taaffe et al. (2008a), Taaffe et al. (2008b), and Bakal et al. (2008) take into

account a set of various parameter values of potential demand distributions. Merzifonluoglu et al. (2012), which is similar to our problem, model a stochastic knapsack assignment, show a Karush-Kuhn-Tucker (KKT) condition for the optimality, and suggest a branch-and-bound approach to select a subset of items with random sizes, which allows nonidentical distributions. All prior studies except Merzifonluoglu et al. (2012) try to select demand distribution itself. Our main approach is to determine the demand size (i.e., discrete opportunity set) assuming that each demand follows independently distributed service duration.
Carr and Lovejoy (2000), Taaffe et al. (2008a), Merzifonluoglu et al. (2012), and Choi and Wilhelm (2014b) assume that demands are independent and normally distributed, while Taaffe et al. (2008b) assumes the Bernoulli distribution, a discrete one. Choi and Wilhelm (2014b) take into account identical service durations in each operating room and allow different normal service durations for multiple operating rooms. We take into account both identically and nonidentically normally distributed service durations, the latter of which can be applied to the static stochastic knapsack problem (Merzifonluoglu et al. 2012).
The remainder of this paper is organized as follows. Section 2 defines the inverse newsvendor model with parameters and decision variables and provides analysis for identically and normally distributed service durations. We prescribe a closed-form solution to the inverse newsvendor model. We prescribe three heuristics based upon the fundamental results. Section 3 provides numerical studies to show various effects of penalty costs. Section 4 concludes our study with future research directions.

MATHEMATICAL MODEL

The decision of interest is to choose $\boldsymbol{x}$ customers to be served in a period with the objective of minimizing the costs associated with a mismatch between the total service duration and available capacity that are both measured in units of time when all customers require the same service durations. Two penalty cost factors are considered. We have 1) penalty cost $\boldsymbol{\ell}$ for under-usage that results in lost sales and 2) penalty cost h for over-usage that corresponds to overtime. Capacity $\boldsymbol{c}$ is fixed, measured in time units, and without loss of generality, we assume that time units are in minutes. For nonidentical service durations, our interest lies in who will be served and who will not be admitted to minimize the sum of expected under- and over-usage. First, consider the identically distributed service durations. Let $\boldsymbol{\Pi}$ denote the random variable representing the service duration in minute for an individual customer. We assume that $\boldsymbol{\Pi}$ has a mean of $\boldsymbol{\mu}$ and variance of $\boldsymbol{\sigma^2}$. Service durations are independent and identical random variables across customers. Hence there is no correlation between two pair-wise individual customer service durations, although this is an important avenue for future research in this area. The total service duration is a random variable defined as $\boldsymbol{\Pi^x}$ with mean $\boldsymbol{x\mu}$ and variance $\boldsymbol{x\sigma^2}$ such that $\boldsymbol{\Pi^{x+y} = \Pi^x + \Pi^y}$. Choi and Ketzenberg (2018) establish how to find the optimal value of $\boldsymbol{x}$, i.e., $\boldsymbol{x^*}$. Consider the $\boldsymbol{x}$-fold sum of the individual normal service duration $\boldsymbol{\Pi}$ with mean $\boldsymbol{\mu}$ and variance $\boldsymbol{\sigma^2}$. The optimal value $\boldsymbol{x^*}$ is expressed explicitly as follow:

$$x^* = \lfloor \hat{x} \rfloor \text{ or } \lceil \hat{x} \rceil \tag{1}$$

$$\text{where } \hat{x} = \left(\frac{-z\sigma + \sqrt{z^2\sigma^2 + 4\mu c}}{2\mu} \right)^2 \tag{2}$$

Now, consider non-identically distributed service durations. Suppose that there are N customers, of which index is $\boldsymbol{i = 1, 2, \ldots, N \in I}$, respectively and that individual service duration $\boldsymbol{\Pi_i}$ of customer $\boldsymbol{i}$ has mean of $\boldsymbol{\mu_i}$ and standard deviation of $\boldsymbol{\sigma_i}$. New decision variable $\boldsymbol{x_i}$ is a binary variable, 1 if customer $\boldsymbol{i}$ is served, 0 otherwise. The number of customers to be served is

$\sum \boldsymbol{x_i}$, which is equivalent to $\boldsymbol{x}^*$for the case of identical normal distributed service durations, i.e., (1) and (2). The total service duration is defined as $\sum \boldsymbol{x_i \Pi_i}$. The inverse newsvendor problem with non-identical service durations can be represented as follows:

$$\min_{x_i} \ell E[(c - \sum x_i \Pi_x)^+] + hE[(\sum x_i \Pi_i - c)^+] \quad (3)$$

We have to evaluate $\boldsymbol{2^N - 1}$ possible combinations to find the optimal number of customers to be served, because we are able to analytically evaluate $\boldsymbol{E}[(\boldsymbol{c} - \sum \boldsymbol{x_i \Pi_x})^+]$ and $\boldsymbol{E}[(\sum \boldsymbol{x_i \Pi_i} - \boldsymbol{c})^+]$ (Choi and Wilhelm 2014a). To find the optimal solution based on numerical evaluation of (3), we reformulate the inverse newsvendor model using Stochastic Programming (SP) with scenarios $\boldsymbol{\omega} \in \boldsymbol{\Omega}$. We adopt the sample average approximation (SAA) approach (Birge and Louveaux 1997) to get a close approximation. Let $\boldsymbol{\Pi_i^\omega}$ be the service duration for customer $\boldsymbol{i}$ under scenario $\boldsymbol{\omega}$; $\boldsymbol{u^\omega}$ under-usage under scenario $\boldsymbol{\omega}$; $\boldsymbol{o^\omega}$ over-usage under scenario $\boldsymbol{\omega}$; $\boldsymbol{p^\omega}$ probability of scenario $\boldsymbol{\omega}$, respectively. SP formulation is given as follows:

$$\min \ell \sum u^\omega p^\omega + h \sum o^\omega p^\omega \quad (4)$$

$$\text{s.t. } \sum x_i \Pi_i^w + u^w \geq c, \omega \in \Omega \quad (5)$$

$$\sum x_i \Pi_i^w - o^w \leq c, \omega \in \Omega \quad (6)$$

Equation (4) defines the objective function; (5) under-usage under scenario ω; (6) over-usage under scenario $\boldsymbol{\omega}$, respectively. We can get the optimal solution based on the SAA approach. However, it is hard to derive a certain (intuitive) rule for the optimal allocation of customers. We suggest three heuristics to get a near-optimal solution in a reasonable time limit: smallest-variance (SV) first, smallest-coefficient-of-variation (SCV) first, and smallest-mean (SM) first selection rules. Such heuristics are based on the discussion that partial expected values are associated with variability rather than central location measure (e.g., mean or median) (Choi and Wilhelm 2012). All three heuristics are the same except the sequencing rule. We conjecture that it is optimal or near-optimal if the number of the assigned customers is equal to the solution to the (1) and (2). In other words, we take advantage of the result from i.i.d. normal service durations, i.e., (1) and (2).

Suppose that $\boldsymbol{n}$ customers are about to be served. Let $\boldsymbol{\bar{\mu}}$ be the sample average service duration for $\boldsymbol{n}$ customers; $\boldsymbol{\bar{\sigma}}$, the standard deviation of sample average service durations for $\boldsymbol{n}$ customers, respectively. If $\boldsymbol{n}$ is equal to the solution of (1) and (2) with $\boldsymbol{\bar{\mu}}$ and $\boldsymbol{\bar{\sigma}}$, we stop adding customers to be served. As $\sum \boldsymbol{x_i}$ increases, the objective function (3) is decreasing-then-increasing. When the current solution $\boldsymbol{x}^*$ is greater than the optimal number of assigned customers, the objective function (3) increases as we assign additional customers. Hence, the stopping rule is valid. We show the detail procedure of the heuristic with the SV selection rule, for example, as follows:

Algorithm for the Heuristic with the SV selection rule

Initialization. Let $\boldsymbol{A} = \boldsymbol{A}^* = \{\}$, $\mathbb{N} = \{\boldsymbol{1, 2, \dots, N}\}$, and $\boldsymbol{Z_{opt}} = \infty$, respectively.

Step 1. Select $\boldsymbol{i}$ with the smallest variance, i.e., $\boldsymbol{i} = \mathbf{arg\,min}\{\boldsymbol{\sigma_k}, \boldsymbol{k} \in \mathbb{N}\}$. Remove $\boldsymbol{i}$ from $\mathbb{N}$ and add $\boldsymbol{i}$ to $\boldsymbol{A}$.

Step 2. Compute sample mean, $\boldsymbol{\bar{\mu}}$ and sample standard deviation, $\boldsymbol{\bar{\sigma}}$ of the set A as follows:

$$\bar{\mu} = \frac{\sum_{k\in\mathbb{N}} \mu_k}{|\mathbb{N}|}$$

$$\bar{\sigma} = \sqrt{\frac{\sum_{k\in\mathbb{N}} \sigma_k^2}{|\mathbb{N}|}}$$

Step 3. Plug $\bar{\boldsymbol{\mu}}$ and $\bar{\boldsymbol{\sigma}}$ into (1) and (2) to compute $\boldsymbol{x}^*$.
Step 4. Compute the objective function value $\boldsymbol{Z_{curr}} = \boldsymbol{\ell E}[(\boldsymbol{c} - \sum \boldsymbol{x_i \Pi_x})^+] + \boldsymbol{hE}[(\sum \boldsymbol{x_i \Pi_i} - \boldsymbol{c})^+]$ (Choi and Wilhelm 2014a). If $\boldsymbol{Z_{curr}} < \boldsymbol{Z_{opt}}$, let $\boldsymbol{A}^* \leftarrow$ A and $\boldsymbol{Z_{opt}} \leftarrow \boldsymbol{Z_{curr}}$.
Step 5.If $\boldsymbol{x}^* \leq |\boldsymbol{A}^*|$ and $\mathbb{N} \neq \{\}$, go to Step1. Otherwise, go to Step 6.
Step 6. Let $\boldsymbol{A}^*$ be the set of optimally assigned customers and $\boldsymbol{Z_{opt}}$ be the heuristic result.

For the SM and SCV heuristics, we modify the Step 1 with an appropriate sequencing rule. The SM heuristic selects $\boldsymbol{i} = \mathbf{arg\,min}\{\boldsymbol{\mu_k}, \boldsymbol{k} \in \mathbb{N}\}$; the SCV $\boldsymbol{i} = \mathbf{arg\,min}\{\boldsymbol{CV_k}, \boldsymbol{k} \in \mathbb{N}\}$, respectively. We show how the SV heuristic works for next simple example. We use the cost ratio of 0.5:0.5; 120 minutes blocks without loss of generality. Table 1 shows all parameter values of twelve customers: μ, σ, and CV, respectively. Note that the expected required service duration for all twelve customers (i.e., 263.8 minutes) is much larger than the given capacity, 120 minutes.

Table 1: Parameter values for $\boldsymbol{\mu, \sigma,}$ and CV of twelve customers. Parameter values have been generated randomly.

Index(i)	1	2	3	4	5	6	7	8	9	10	11	12
$\boldsymbol{\mu_i}$	18.5	24.0	27.9	24.9	28.5	26.8	27.5	16.7	27.3	19.8	11.6	10.3
$\boldsymbol{\sigma_i}$	6.5	11.6	21.7	17.3	7.5	18.8	5.7	10.4	3.9	6.4	5.6	1.8
$\boldsymbol{CV_i}$	0.35	0.48	0.78	0.69	0.26	0.70	0.21	0.62	0.14	0.32	0.48	0.17

The SV heuristic will select customers as the following order: 12 → 9 → 11 → 7 → 10 → 1 → · · · → 3; the SCV heuristic, 9 → 12 → 7 → 5 → 10 → 1 → · · · → 3; the SM heuristic, 12 → 11 → 8 → 1 → 10 → 2 → ⋯ → 5, respectively. The followings are detail steps resulted from the SV selection rule.

Initial step
$\boldsymbol{A} = \boldsymbol{A}^* = \{\}$; $\mathbb{N} = \{\boldsymbol{1, 2, \dots, 12}\}$; $\boldsymbol{Z_{opt}} = \infty$,.
Iteration 1
$\boldsymbol{A}$ ={12}; $\bar{\boldsymbol{\mu}}$=10.3; $\bar{\boldsymbol{\sigma}}$=1.80; $\boldsymbol{x}^*$ =12>$|\boldsymbol{A}^*|$=1; $\boldsymbol{Z_{curr}}$ =54.87; $\boldsymbol{Z_{opt}}$ =54.87; $\boldsymbol{A}^*$ ={12}.
Iteration 2
$\boldsymbol{A}$ ={12,9};$\bar{\boldsymbol{\mu}}$=18.79; $\bar{\boldsymbol{\sigma}}$=3.07; $\boldsymbol{x}^*$=6>$|\boldsymbol{A}^*|$=2; $\boldsymbol{Z_{curr}}$ =41.21; $\boldsymbol{Z_{opt}}$ =41.21; $\boldsymbol{A}^*$ = {12, 9}.
Iteration 3
$\boldsymbol{A}$ ={12,9,11};$\bar{\boldsymbol{\mu}}$=16.38; $\bar{\boldsymbol{\sigma}}$=4.09; $\boldsymbol{x}^*$=7>$|\boldsymbol{A}^*|$=3; $\boldsymbol{Z_{curr}}$ =35.43; $\boldsymbol{Z_{opt}}$ =35.43; $\boldsymbol{A}^*$ ={12,9,11}.
Iteration 4
$\boldsymbol{A}$ = {12,9,11,7}; $\bar{\boldsymbol{\mu}}$ = 19.16; $\bar{\boldsymbol{\sigma}}$ = 4.55; $\boldsymbol{x}^*$= 6 > $|\boldsymbol{A}^*|$ = 4; $\boldsymbol{Z_{curr}}$= 21.67; $\boldsymbol{Z_{opt}}$ = 21.67; $\boldsymbol{A}^*$ = {12, 9, 11, 7}.
Iteration 5
$\boldsymbol{A}$ = {12,9,11,7,10}; $\bar{\boldsymbol{\mu}}$= 19.3; $\bar{\boldsymbol{\sigma}}$= 4.97; $\boldsymbol{x}^*$= 6 > $|\boldsymbol{A}^*|$ = 5; $\boldsymbol{Z_{curr}}$ = 11.82; $\boldsymbol{Z_{opt}}$ = 11.82; $\boldsymbol{A}^*$ ={12,9,11,7,10}.
Iteration 6

$\boldsymbol{A}$ = {12,9,11,7,10,1}; $\bar{\boldsymbol{\mu}}$= 19.16; $\bar{\boldsymbol{\sigma}}$= 5.27; $\boldsymbol{x}^*$= 6 = $|\boldsymbol{A}^*|$; $\boldsymbol{Z_{curr}}$ = 5.53; $\boldsymbol{Z_{opt}}$ = 5.53; $\boldsymbol{A}^*$ ={12,9,11,7,10,1}.

Iteration 7

$\boldsymbol{A}$ = {12,9,11,7,10,1,5}; $\bar{\boldsymbol{\mu}}$= 20.51; $\bar{\boldsymbol{\sigma}}$= 5.64; $\boldsymbol{x}^*$= 6 < $|\boldsymbol{A}^*|$ = 7; $\boldsymbol{Z_{curr}}$ = 12.15; $\boldsymbol{Z_{opt}}$= 5.53; $\boldsymbol{A}^*$ ={12,9,11,7,10,1}.Stop.

NUMERICAL STUDY

We conduct extensive numerical studies to evaluate the efficacy of three heuristics by comparing them with the optimal allocation resulted from the SAA approach. We take into account cost ratio, $\boldsymbol{\mu_i}$, and $\boldsymbol{\sigma_i}$ (equivalently $\boldsymbol{CV_i}$). Capacity, c is 240 or 480 minutes without loss of generality. μi and c are scaleable. We find little difference between the case of c = 240 and the case of c = 480. Hence, we show the case of c = 480 minutes in Table 2. We generate N = 25 customers with mean times $\boldsymbol{\mu_i}$, generated from U[10, 25]; $\boldsymbol{CV_i}$ from U[0.1, 0.7], respectively. We exclude the case of $\boldsymbol{CV_i}$ ≥ 0.7, because it is less likely for them to be selected owing to the effectiveness of the SV or SCV rule. We use five cost ratios, h:l = 0.1:0.9, 0.3:0.7, 0.5:0.5, 0.7:0.3, and 0.9:0.1 to see how cost ratios affect the allocation decision. For each cost ratio combination, we run ten simulations. We assign simulation index to each scenario, from 1 to 50. Preliminary tests show that we have little variance when we generate around 1,000 scenarios. For the sake of robustness, we test 10,000 scenarios in order to reduce an optimality gap to a minimum.

Table 2: A comparison of optimal allocation and three heuristics: SM, SCV, and SM. For each cost ratio combination, the first five results are shown.

Simulation Index	$\boldsymbol{c^w}$: $\boldsymbol{c^i}$	GAP			SCV			
		SV	SCV	SM	Opt	SV	SCV	SM
1	0.1:0.9	9	7	18	16	17	14	18
2		3	0	14	16	16	16	17
3		5	6	56	15	16	14	18
4		3	7	56	14	15	13	17
5		5	16	33	15	15	14	16
11	0.3:0.7	1	12	30	13	14	13	16
12		0	12	58	13	13	13	14
13		0	8	24	14	14	13	15
14		3	2	29	13	14	12	15
15		0	8	15	14	15	13	16
21	0.5:0.5	8	14	42	13	14	12	14
22		6	10	37	13	14	11	15
23		12	17	77	12	12	11	14
24		9	1	38	13	14	13	14
25		3	0	28	13	14	13	15
31	0.7:0.3	4	8	49	11	12	9	13
32		0	9	44	12	12	10	12
33		1	0	41	12	12	12	15
34		4	1	33	13	14	12	15
35		3	3	18	13	14	12	14
41	0.9:0.1	4	5	51	11	12	10	13
42		12	3	41	11	12	10	13
43		12	12	11	13	0	6	55
44		0	2	49	12	12	11	13

45		1	6	60	10	10	10	12

Table 2 describes a comparison of three heuristics and the optimal allocation and Table 3 shows a summarized result of the pairwise matched t-test. The first column from the left of Table 2 is simulation index; the second one, cost ratio; the third through the fifth one, gap values between optimal and each heuristic; the sixth through ninth one, the number of customers to be served resulted from the optimal and three heuristics, respectively. We do not show all 50 simulation results, but the first five results of each cost ratio combination. Hence, simulation indices shown in Table 2 are 1 through 5; 11 through 15; 21 through 25; 31 through 35; 41 through 45, respectively. In addition, we conduct the matched t-test to verify our findings, as shown in Table 3, which provides p-value for each matched two-tailed t-test when $\boldsymbol{c}$ = 240 minutes. We compare the objective values as well as the number of assigned customers. The first column of Table 3 is the cost ratio combination; the second mean value; the others p-value for each pairwise t-test. The first row of each cost combination is about the comparison of the objective values; the second row the comparison of the assigned customers, respectively. The null hypothesis is as follows:

$$H0 : Opt \equiv SV \equiv SCV \equiv SM.$$

Cost ratio affects without respect to the selection rules. When $\boldsymbol{c^i} > \boldsymbol{c^w}$, it tends to assign more customers in order to avoid under-usage penalties more than over-usage penalties. On the contrary, it tends to assign fewer customers to avoid over-usage penalties more than under-usage penalties when $\boldsymbol{c^i} < \boldsymbol{c^w}$.

Table 3: p-value for matched two-tailed t-test. We use **bold** face for the p-value of 0.01 or greater in order for readers to easily contrast it with $\boldsymbol{\alpha}$. Vey small p-vlaue's (e.g., 0.00001) are expressed as <0.0001.

$\boldsymbol{c^w}$: $\boldsymbol{c^i}$	Mean value	Opt vs. SV	Opt vs. SCV	Opt vs. SM	SV vs. SCV	SV vs. SM	SCV vs. SM
0.1:0.9	Obj value	**0.0301**	0.0013	<0.0001	**0.2635**	<0.0001	0.0002
	Customers	**0.0150**	0.0031	<0.0001	0.0002	0.0002	<0.0001
0.3:0.7	Obj value	**0.0116**	0.0017	<0.0001	**0.6786**	<0.0001	<0.0001
	Customers	**0.0522**	0.0007	0.0007	0.0001	0.0002	<0.0001
0.5:0.5	Obj value	**0.0523**	0.0059	<0.0001	**0.2789**	0.0001	<0.0001
	Customers	**0.0248**	**0.0239**	<0.0001	0.0007	0.0003	<0.0001
0.7:0.3	Obj value	0.0032	0.0029	<0.0001	**0.9213**	<0.0001	<0.0001
	Customers	**0.0107**	0.0002	0.0005	0.0002	**0.0107**	<0.0001
0.9:0.1	Obj value	**0.0160**	**0.0103**	<0.0001	**0.2789**	<0.0001	<0.0001
	Customers	0.0007	**0.0368**	<0.0001	0.0002	0.0007	<0.0001

Most p-value's (the first row) for the matched t-test against the null hypothesis of Opt ≡ SV are boundary at the significance level of α = 0.5 or 0.1. Technically, we fail to reject the null hypothesis, depending upon the significance level α. The SV heuristic provides a close objective function value to the optimal, and the gap between the optimal allocation and the SV heuristic can be regarded as marginal, i.e., 4% on average. We obviously fail to reject the null hypothesis of SV ≡ SCV because of high p-value, e.g., greater than 0.25. The SV heuristic and the SCV heuristic give close but slightly different objective values. The objective function value gap between the SV heuristic and the SCV heuristic is 3% because the gap between the optimal allocation and the SCV is 7%. However, the SV heuristic slightly outperforms the SCV heuristic,

32 times out of 50 simulations. Both the SV and the SCV heuristics outperform the SM heuristic and p-value's are so small to reject the null hypotheses of SV ≡ SM and SCV ≡ SM, respectively. The gap between the optimal allocation and the SM heuristic is 39%. Note that both $\boldsymbol{E}[(\boldsymbol{c}-\boldsymbol{\Pi}^{\boldsymbol{x}})^{+}]$ and $\boldsymbol{E}[(\boldsymbol{\Pi}^{\boldsymbol{x}}-\boldsymbol{c})^{+}]$ are related to the deviation from the given capacity $\boldsymbol{c}$ (Choi and Wilhelm 2012), or variability measure rather than location measure (e.g., mean or median). p-value's (the second row) greater than α for the null hypothesis of Opt ≡ SV show that the assigned numbers between them are little different. p-value's smaller than α for the null hypothesis of SV ≡ SCV show that the assigned numbers between them are significantly different. p-value's with respect to the objective function value and the assigned number conclude that the SV and SCV heuristics assign a different number of customers but their objective function values are close. The SM heuristic assigns one more customer and has the worst gap among three rules, because the SM rule has nothing to do with variability measure (e.g., $\boldsymbol{E}[(\boldsymbol{c}-\boldsymbol{\Pi}^{\boldsymbol{x}})^{+}]$, $\boldsymbol{E}[(\boldsymbol{\Pi}^{\boldsymbol{x}}-\boldsymbol{c})^{+}]$) directly.
Hence, the SM heuristic is the worst among three heuristics. The SV and the SCV heuristics are closely related in terms of variability. Variance is a direct measure of variability and the SCV heuristic takes into account the only variability, whereas CV is a relative measure of variability, i.e., $\boldsymbol{c}$. Smaller CV means either smaller variance, or larger mean, or both. Hence, the SCV heuristic $\boldsymbol{\mu}$ tends to assign fewer customers than other heuristics for some combinations.
We recommend that one use the SV heuristic first and compare it to the SCV heuristic later, because the SV heuristic outperforms the SCV heuristic slightly, gap between optimal and the SV heuristic is smaller than gap between the optimal and the SCV heuristic, and the SV heuristic provides optimal result 15 times out of 50 simulations; the SCV, 8 times of 50, respectively.

CONCLUSION

We investigate the inverse newsvendor model with normal distributed service durations. We prescribe three heuristics for nonidentically normally distributed service durations, based upon the results from identical normal service durations. With these heuristics, one may decide how many will be served, who will be served first, and who would not be admitted in a capacitated environment.
There might be several avenues for future research. A notable example is extending the problem to multi-period problems. This would correspond to situations in which the current period decisions affect the future period decisions, as might occur when certain specialized labor is restricted to the case when they cannot work more than a certain number of hours in a month. Choi and Banerjee (2015) studied a multi-period inverse newsvendor model with identical normal service durations. One can combine our approach and Choi and Banerjee (2015) for multi-period newsvendor model with non-identical normal service durations Other research could address some of our limiting assumptions. For example, we assume that penalties are the same across customers, but this need not be the case. Each customer may have different weight of importance. In this case, the order of customers served may become an important decision particularly if the penalties for earliness or lateness vary by customer. Lastly, different service durations can be taken into account. Note that Choi and Wilhelm (2012) studied normal, gamma, and lognormal service durations with one patient in one block.

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WIGA – A Web-based Interactive Graph Analytics Application for Managing, Visualising and Analysing Big Movement Data

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ABSTRACT

Visualizing and analyzing large spatial-temporal movement data can be tedious and time-consuming. We have designed and developed WIGA, a web-based application for managing, visualizing and analyzing movement data by integrating an open source graph database and visual analytics methodology. In this paper, we share our experience of developing the application as well as the various capability such as transforming large volumes of movement data into well-structured graph database, enabling data analyst to explore and detect the spatio-temporal patterns of these massive movement data with easy to understand visualization.

KEYWORDS: Big movement data, Visual analytics, Graph database, Graph analytics, Visualization, Analyzing, Spatial-temporal data

INTRODUCTION

Movement data provide information about the number of people in a location at a particular point in time. The data also provides insights into movements between two locations. Traditionally, these data were collected through traffic survey which were very time consuming and laborious, not to mention the sample size were relatively small due to financial constraint. The advances in location-based data collection technologies such as GPS, RFID and Internet of Things (IoT) and the rapid reduction of their costs provide us with a huge and continuously increasing amount of data about movement of vehicles, people and goods in and around an area. This huge amount of data not only records the historical activities but also provides valuable information for planners and decision-makers. These massive movement data collected by various devices today contain structure and patterns such as peak times, lull periods that provide useful information to various stakeholders such as street traffic planners, building space planners etc. The identification, analysis and comparison of such patterns captured through vehicle movements will provide further insights into human movement and behaviors within a city or a region. These understandings will potentially contribute to a better transport management and useful information to both private and public transport services providers to formulate informed decision to gain competitive advantage on providing timely and quality service. Second use case is social media where users operate in

small sub-networks to large networks and data is generated at a tremendous speed every second. Using similar techniques as demonstrated in this paper social media scientists can analyze the use networks for influencers, interaction patterns, information flows, bottlenecks, user clusters and profiling. Third use case, which we see, is in banks, investment firms and startups where individuals and startups are constantly looking out for venture capitalists (or VCs). Venture capitalists invest in different projects via certain agencies facilitating the investments. A network analysis of this sort can highlight the cluster of these VCs who invest in similar projects and how to connect to a particular VC in a network.

There are myriad applications that emerge out of network and sensor based datasets but the true values of these data will not be fully appreciated until they are processed, analyzed and the analysis results are communicated to decision makers in a user-friendly manner.

The aim of this work is to create a framework that can help to visualize any sensor tracked movement dataset easier. The whole data to visualization pipeline is broken down into smaller chunks that need attention and this paper is an attempt to make it easier for the readers to understand the whole process.

This paper reports on our research and development effort to design and implement a web-enabled visual analytics application for supporting the management, visualization and analysis needs of urban and transport planning professional. It consists of five sections. Section 1 provides a general introduction of the paper. Followed by literature review, an overview of the motivation and objectives of our research effort. Section 3 provides a high-level view of the overall design of WIGA. This is followed by a detailed discussion of the data preparation process. In this section, the graph database design and implementation will be discussed too. In section 5, the data visualization techniques used to design and implement the graphical user- interface (GUI_ of WIGA will be presented. In the next section, the practical use of the WIGA is demonstrated using a set of movement data. Lastly, the paper concludes by highlighting the future direction of the research.

LITERATURE REVIEW

In recent years, big movement data has been one of the major research focus in the academic research community especially in the field of computer science and the software vendors who provide big data services. Dynamic graphs are capturing interests of researchers and industry alike as with growing populations these graphs are emerging everywhere such as computer networks, traffic, social circles etc. These graphs in real life scenarios are quite large and need to be represented and analyzed carefully [10] as they are directed in nature with a considerable number of nodes and their interactions. These works either focus on techniques for massive graph visualization [4] [5] [6], or different ways of looking at the information embedded in graphs [7] [8]. Largely, the current academic research and practice development efforts, however, tend to focus on the technological aspect of big data. To address this need research work has been done [9] but the focus is still theoretical and not on an end-to-end commercially viable product. Such a gap is evident and this paper aims to explore the possible approach to design and implement a *scalable, flexible* big data analytics application by integrating an open source big data processing framework and an open source data visualization analysis environment.

Our research and development efforts were motivated by the general lack of effective and easy to use web-enabled interactive visual analytics tool for discovering spatio-temporal patterns in massive movement data. It aims to provide transport planners and transport services operator with an analytical tool for visual discovery of human movement in a geographical area and their interaction in time and space. Specifically, it attempts to support the following analysis requirements:

1. To manage and transform a large movement data collected from automatic sensor such as RFID and traffic sensors into intelligence graph database;
2. To create an interactive visual analytics framework to display massive movement data over time;
3. To provide a graph visualization and analysis framework that can display the distribution of movement data over time and space; and
4. To be able to display detailed records on-demand.

WIGA-AN OVERVIEW

The development and implementation of WIGA consists of three major phases as shown in the Figure 1 below. They are: (1) Data Processing, (2) Graph Database Design and Implementation, and (3) Visual Analytics Application Design and Development. In the next three sections, a detailed discussion of each of these processes will be shared.

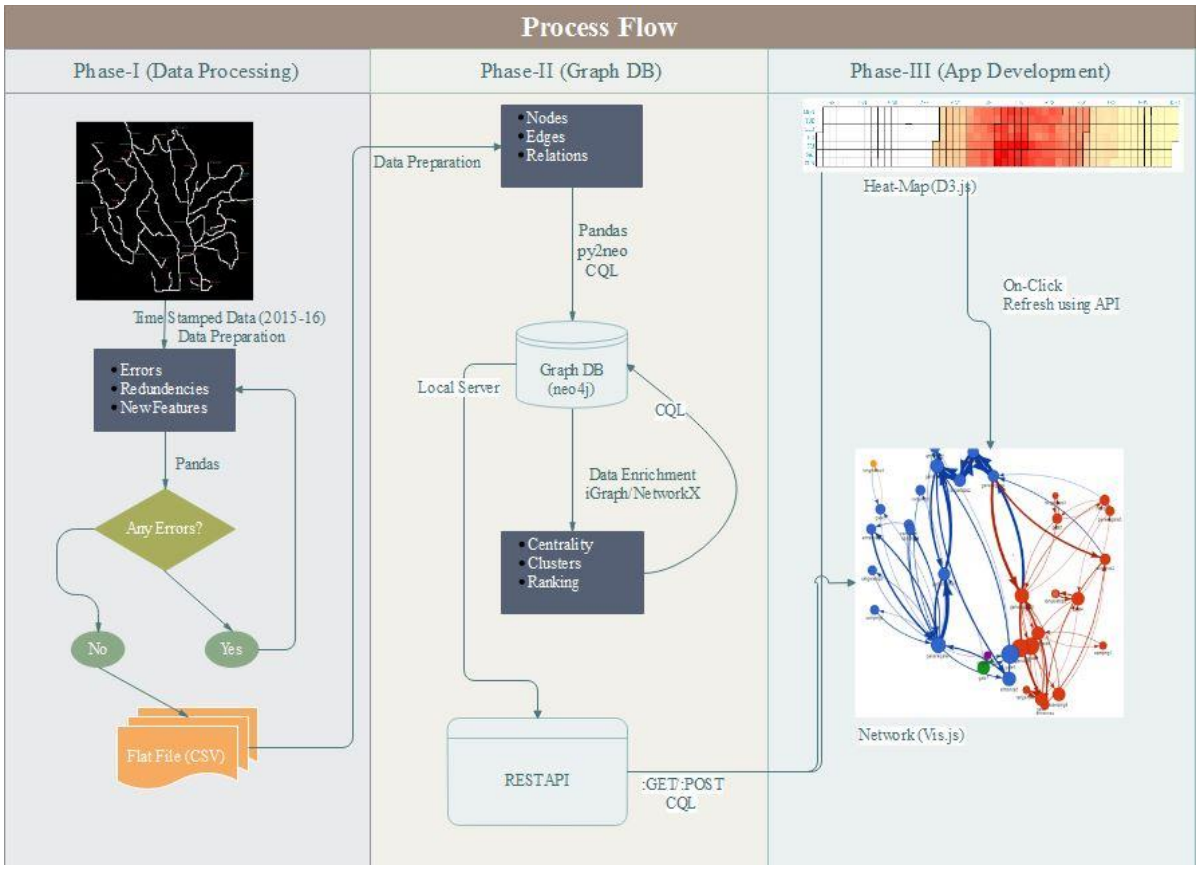

Fig. 1. Design and implementation of WIGA.

PHASE I: DATA PREPARATION AND PROCESSING

The data used for this work comes from VAST 2017 MC-1 [3], which contains a csv file containing data recorded from sensors around the Boonsong Lekagul Nature Preserve. This data set has various merits to for this project:

1. Raw and dirty: many corrections such as duplicate removal, erroneous values corrections were required to make the provided dataset useable for the end-system.
2. Feature Engineering: only four columns were present initially but to unlock the potential patterns we ended up creating 21 columns. A very useful illustration of importance of feature engineering in any data science project.
3. Potential for machine learning: The prepared data can be used for predicting traffic peaks for a given day of week (or year) for a given period. Although it is not the focus of this paper.
   The csv file had 171477 rows and 4 columns as shared below:

TABLE I. THE RAW DATA

Timestamp	car-id	car-type	gate-name
1/5/2015 0:43	20154301124328-262	4	entrance3
1/5/2015 1:03	20154301124328-262	4	general-gate1
1/5/2015 1:06	20154301124328-262	4	ranger-stop2
1/5/2015 1:09	20154301124328-262	4	ranger-stop0
1/5/2015 1:12	20154301124328-262	4	general-gate2
1/5/2015 1:24	20154301124328-262	4	general-gate5
1/5/2015 1:31	20153101013141-937	1	entrance3
1/5/2015 1:33	20154301124328-262	4	entrance4

Initial phase-I of data preparation is focused on identifying data entry errors, deduplication, and creation of new features including digitization of jpg image provided to get location coordinates which can serve as a proxy of latitude and longitude.

For deduplication, a composite key is used which includes all 4 columns ('timestamp', 'car-id', 'car-type', 'gate-name') of the given dataset and duplicate records are first flagged and later excluded from the dataset after careful examination.

As a vehicle moves, from one location (gate) to another (gate) location, using appropriate grouping on car-ids four new columns are created namely EntryGate, EntryTime, ExitGate, and ExitTime. The entry and exit time related columns help further create a set of columns depicting seconds, minutes and days spent between two consecutive time stamps. Similarly, date, day of week, hour of day and year fields were created.

The provided map image of the nature park is used to get the X, Y coordinates of each sensor point. Later, this information is combined with the entry and exit time information between two sensor locations to compute the speed with which a certain vehicle moves between these two locations to observe the violations of speed limits.

All the records where the timestamps between two consecutive locations are the same but the exit gate is different from entry gate, are flagged as erroneous records and are removed consecutively because it is physically impossible for a car to be at different gates at the same time. The final dataset contains 169050 rows and 21 columns. A little redundancy is observed in the dataset to facilitate faster realization of visualizations by avoiding computations on the fly wherever possible.

TABLE II. THE TRANSFORMED DATA

car-id	car-type	Date	Entry Time	Exit Time	Entry Gate	Exit Gate	Second Spent	Minute Spent	Days Spent	Entry X	Entry Y	Exit X	Exit Y	Day Of Week	Hour Of Day	Week Of Year	Year
2015430	4	20150501	1/5/2015 1:03	1/5/2015 0:43	generalgate1	entrance	1200	20	0	316	128	564	818	Friday	1	18	2015
2015430	4	20150501	1/5/2015 1:06	1/5/2015 1:03	rangerstop2	generalga	180	3	0	394	174	316	128	Friday	1	18	2015
2015430	4	20150501	1/5/2015 1:09	1/5/2015 1:06	rangerstop0	rangerstc	180	3	0	440	82	394	174	Friday	1	18	2015
2015430	4	20150501	1/5/2015 1:12	1/5/2015 1:09	generalgate2	rangerstc	180	3	0	510	160	440	82	Friday	1	18	2015
2015430	4	20150501	1/5/2015 1:24	1/5/2015 1:12	generalgate5	generalga	720	12	0	608	548	510	160	Friday	1	18	2015
2015310	1	20150501	1/5/2015 1:31	1/1/1970 0:00	entrance3	entrance	0	0	0	564	818	564	818	Friday	1	18	2015
2015430	4	20150501	1/5/2015 1:33	1/5/2015 1:24	entrance4	generalga	540	9	0	688	902	608	548	Friday	1	18	2015

PHASE II: GRAPH DATABASE DESIGN AND IMPLEMENTATION

The popular avenue to store data these days are, namely, flat files (such as csv), relational databases (such as MySQL) and NoSQL databases (such as MongoDB, Neo4J). For this project, we used a graph database to manage, transform and analysis the movement data. Graph databases fall in the category of NoSQL databases and are suitable for storing, managing and processing large movement data involving large number of connections between entities.

In a graph database, each node (entity or attribute) in the graph database model directly and physically contains a list of relationship-records that represent its relationships to other nodes. These relationship records are organized by type and direction and may hold additional attributes. Whenever you run the equivalent of a JOIN operation, the database just uses this list and has direct access to the connected nodes, eliminating the need for an expensive search/match computation. [11]

For the purpose of our project, Neo4j has been selected to implement the graph database. Neo4J is a JVM application. The reason of using Neo4j to implement our application is because it is known to be a highly scalable native graph database that leverages data relationships and can handle graphs of several billion nodes/relationships/properties on a single machine and also traverse depths of 1000 levels and beyond at millisecond speed.

The dataset after initial phase is still in a csv file and not suitable for graph database hence the phase-II focuses on loading the dataset into a locally run instance of Neo4J database. To load the dataset from initial phase into neo4j, we make use of Cypher Query Language (CQL) of Neo4j and py2neo module of python programming language.

There are two different query languages that can be used to access data in Neo4j, they are: CQL and Gremlin.

In our work, CQL is used to access data stored in Neo4j instance running locally on our computer. Cypher is a declarative, pattern-matching query language that makes graph database management systems understandable and workable for any database user—even the less technical ones.

Using py2neo we incrementally create cypher queries for every car-id with merging similar gate names to keep them unique in the final network. Every time a car moves between two gates, a directed edge with weight one unit is added to the network with few other edge properties such as timestamp, date etc. Peculiar cases happened when a car loops back to same gate, the source and target gates are same with different timestamps, create too many self-loops during the initial data load. Such self-looping inflates the centrality measures and is corrected in subsequent data load refresh. Each car-id will have a node labelled year as a parent to facilitate filtering of data, if needed, on yearly basis while constructing queries.

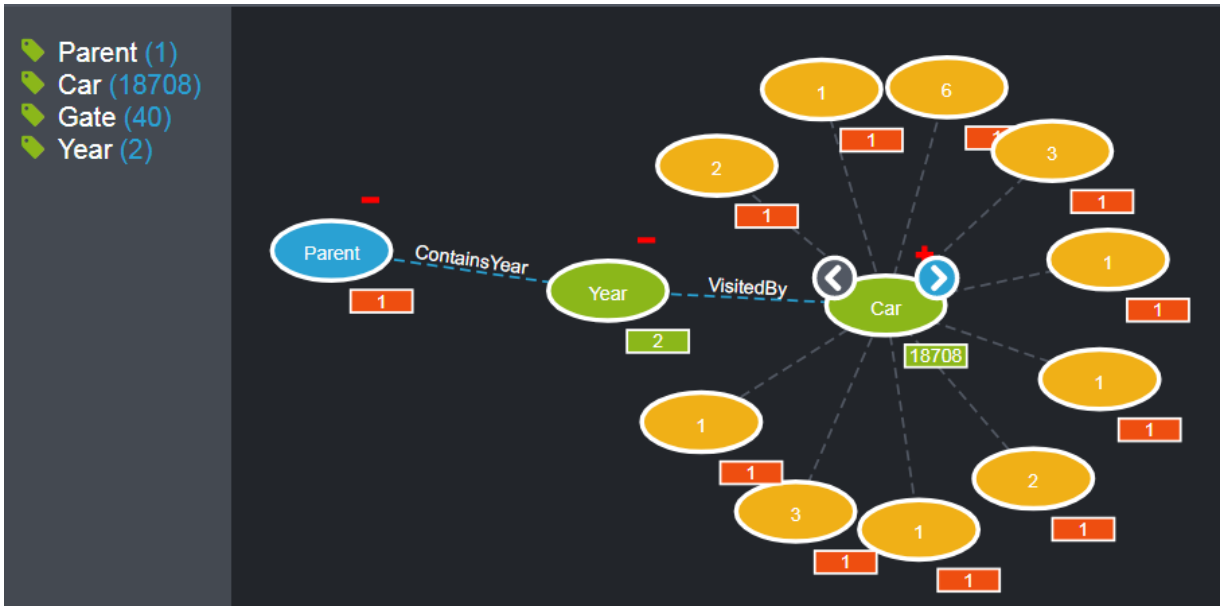

Fig. 2. Hierarchy of Nodes (depicted using popoto.js [12]).

The year node has two distinct values 2015, 2016 and the car node has 18708 distinct cars which further enter a network of 40 gates of the nature preserve. In our work, the focus is on the gate network to study the traffic and usage of these gates at various instance of time. In the network below, one may observe that cars generally start their journeys at one the six gates out of the available 40 gates in the nature preserve.

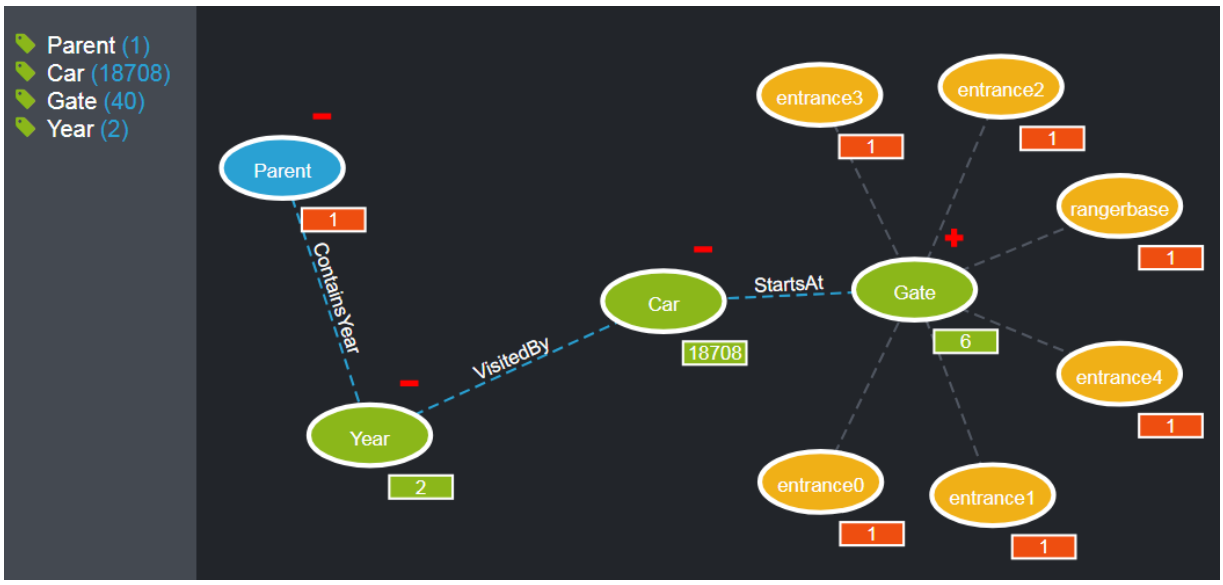

Fig. 3. Car generally starts journey at one of the six gates out of 40 gates. This shows that the park can be visited by only six gates.

Once the dataset gets loaded into the graph database with various pieces of information residing in nodes, edges and their properties, it becomes easy to get various statistics about the network with simple cypher queries.

For example, if we are looking for number of total directed edges in the network:

```
### number of total edges in netwrok
query = """MATCH (c)-[r]->() RETURN count(r)"""
result = graph.cypher.execute(query)
df = pd.DataFrame(result.records, columns=result.columns)
df
```

	count(r)
0	175684

Similarly, it is very easy to compute shortest paths, network diameter, isolated nodes, and in-degrees, out-degrees of all the nodes (gates) for the complete dataset or at any point in time if we wish to analyze the network in between two time periods. All these directly link to some business use cases such as urban planning where commuters can be guided to the locations or priority traffic movements for VIPs. Another example could be connecting isolated locations with a bus route for ensuring accessibility.

The data stored in the graph database is further enriched using python iGraph module to assign values to every node on the centrality measures such as closeness, PageRank, betweenness, cluster (community). We observe that the whole dataset is divided into five clusters using the walktrap algorithm for community detection [13]. PageRank of gates in a park can be used to predict how many vehicles will pass through them. Betweenness can used to find the controlling

gates between two clusters of nodes. The gates can be further monitored to study traffic flow patterns or rate of interaction between two sub-networks identified by clusters.

PHASE III: VISUAL ANALYTICS APPLICATION DESIGN AND DEVELOPMENT

In the final phase, phase-III, we move our focus on providing users with a visual analytics dashboard where they can interact with the graph data stored in Neo4j database and explore the movement data spatio-temporally.

The architecture of WIGA was designed and developed with a purpose to make it an open, flexible and re-usable tool which could be used for analysis and exploration of movement data. As a result of this endeavor, it was decided to make it as a web based tool to enable a wider access by the end users.

The system architecture of WIGA consists of two major views namely: Multi-day Analysis view and Daily Analysis view as shown in the Figure 4. Multi-day is a macro view which serves to explain demand and supply over a period of time for capacity planning. Daily view on the other hand is a micro view, which is more for day to day operations.

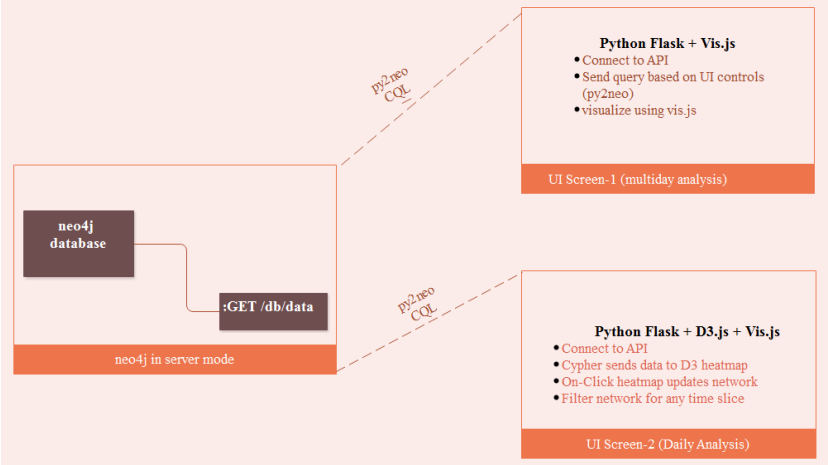

Fig. 4. The Daily Analysis View.

A. The Multi-day Analysis View

The Multi-day view is designed to enable user to analyse the flow patterns of the movement data beyond a single day. As a result, only the graph visualization is provided.

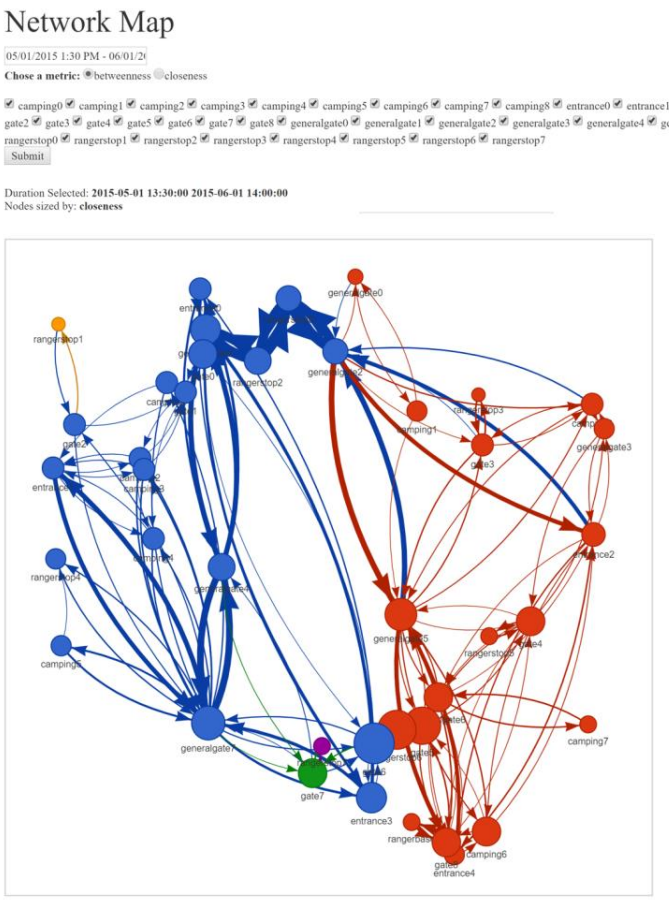

Fig. 5. The Multi-day Analysis View

One of the new interface added in the Multi-day view is the Time Window selector [16]. It is specially used to enable user to select a starting date and time and an end date and time available based on start and end date of dataset.

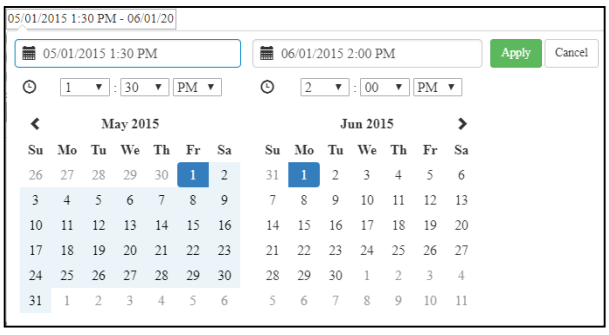

Fig. 6. The time window selector

Besides the Time Window selector, the Multi-day Analysis view also include user-interface to modify the properties of the graph entities such as size of edge, size of node, font of node, just to name a few of them. These user interface provides the user the flexibility to customize their graph visualization.

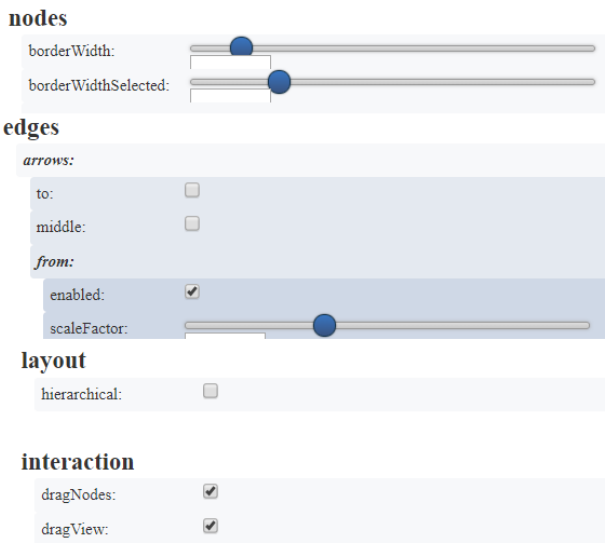

Fig. 7. The graph properties interface.

B. The Daily Analysis View

The Daily Analysis view consists of two data visualization, namely: calendar heatmap [14], a graph visualization and a time selector [8] as shown in the Figure 8 below.

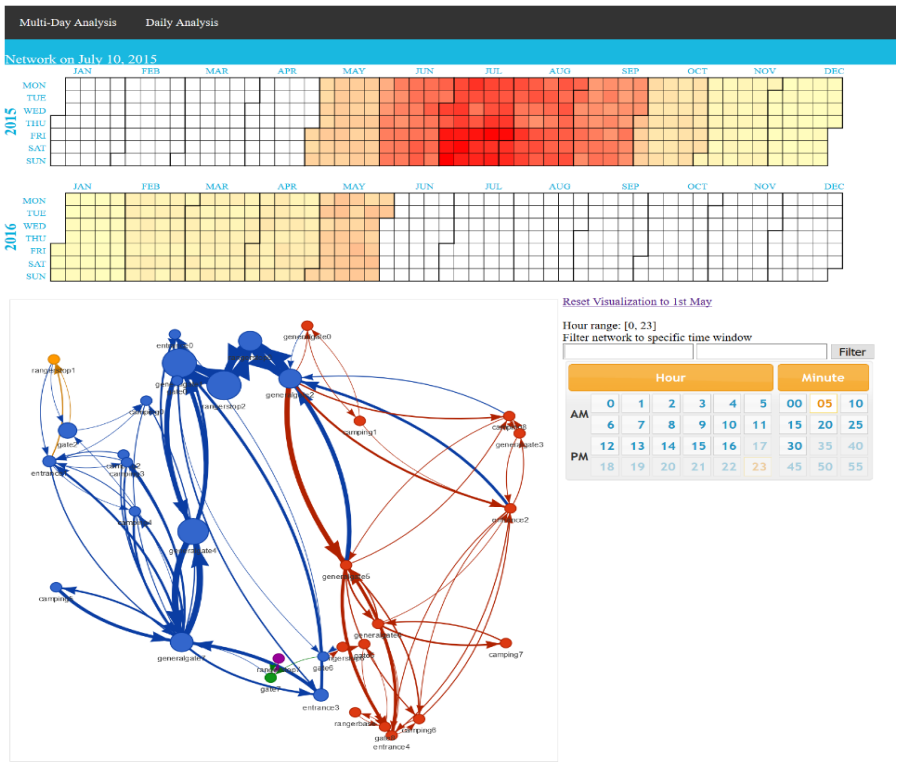

Fig. 8. The Daily Analysis View.

The design of WIGA's visual analytics application follows closely the data visualization general guidelines suggested by Schneiderman's mantra [1]: over, zoom and filter, details on demand. The calendar heatmap is designed to provide an overview of the entire year movement data by day of the week and by month of the year. The network graph visualization reveal detail movement patterns at each entrance, gate and campsite. Lastly, the time selector allows users to select a particular time interval of interest for further detail investigation.

The calendar heatmap is designed using D3.js, a JavaScript library for producing dynamic, interactive data visualizations in web browsers. The calendar heatmap is designed to provide a macro view of the movement data by day of a week, month and year. For example, the calendar heat map above shows using the color intensity (from yellow to red) how the traffic was for every date of month. In the cells dense red color cells represent high number of people on the park.

The graph visualization, on the other hand, is designed using Vis.js, a dynamic, browser based visualization library. It is able to handle large amounts of dynamic data, and to enable manipulation of and interaction with the data.

Although the geo-layout in our work retains the actual locational context and relationships of the entrances, gates and campsites. The edges are used to represent the number of flow from a location to another location. Arrows are used to show the flow direction. The nodes are colored using cluster values. The size of the node are used to represent a centrality measure such as in-degree, out-degree, closeness or betweenness. By default, betweenness values are used to represent the size of the node. We can clearly see separate clusters in the visualization, which are indicative of two sub-networks emerging in the park. Perhaps traffic from different gates stays focused to certain parts of the park.

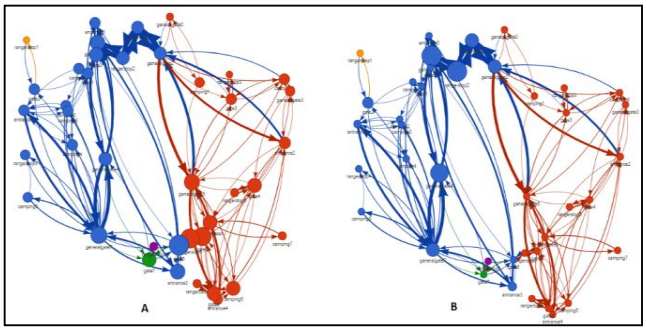

Fig. 9. Nodes sized by closeness (A) and betweenness(B).

To support interactive exploration of the movement data over time and space, coordinated link function has been implemented between the calendar heatmap and graph visualization. This design enables user to click on any grid cell of the calendar heatmap and the graph will reveal the flow patterns occurred on the selected day.

The Time Selector interface, on the other hand, is specially used to support detail investigation of the flow patterns at a selected range of time interval.

CONCLUSION

Although the presented use case is for a sensor-based data monitoring; this work is equally extendible to social media analysis and commercial network analysis for startups. All these uses cases of security, traffic control and optimization, social media analytics and commercial banking and VC networks have similarities of sub-graphs, centrality that generate influencer nodes, bottlenecks. Such analysis also highlights untapped opportunities in a network at large.

The above presentation had provided an indepth discussion of the design and implementation of WIGA. Our initial use of WIGA to analyse movement data provided by Boonsong Lekagul Nature Preserve revealed many interesting patterns.

There are a number of options available for constructing the data pipelines for a visualization but not all are equally flexible. In this context we played by our strengths and picked up technologies such as python flask, d3.js which we were already familiar from past experiences. The graph database Neo4j and the network visualization library Vis.js were new to the team. The team quickly picked up the nuts and bolts of the graph database but mastering the cypher query language took time because the need was not just to fire queries but also to envision and later construct the data model in Neo4j using the cyphers trough python programming language.

The D3.js network visualization is not as configurable as options available with vis.js so we opted for the latter. We used it for both daily and multi-day analysis data pipelines. We linked queries to user inputs to fire them dynamically with ease. Another challenge was to link the heatmaps with the network visualization for daily network chart which was achieved using flask web framework. We further improved this visualization by providing a time slicing option so that a user can go to a particular time period for a selected day.

This whole application can be further improved in terms of usage by providing machine learning based alerts on possible bottlenecks buildups at certain hours and re-routing options thereby helping the authorities to manage the park operations effectively and provide improved user experience to visitors. We plan to bring in this aspect in our future work.

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'Does it pay to be green?' revisited: LGM assessment of the relationship between sustainability performance and financial performance

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ABSTRACT

The question 'does it pay to be green?' has been part of operations management research for decades. As firms face increasing pressure to reduce their social and environmental impacts, managers and researchers alike work to understand the impact of sustainability practices on a firm's bottom line. To add to this on-going dialogue, this paper uses a latent growth modelling approach with longitudinal sustainability performance data to investigate the relationship between changes in sustainability performance and financial performance over time. This paper illuminates areas for future research on the relative financial returns of different types of sustainability investments.

KEYWORDS: sustainability, social performance, environmental performance, financial performance, latent growth modelling

INTRODUCTION

In 1995, Hart asked if the way a firm interacts with the natural world could be a source of competitive advantage? This represented an extension of Barney's Resource-Based View of the firm (RBV) by incorporating the importance of the external environment and sustainability practices in the development of firm capabilities (Hart, 1995). This natural resource-based view (NRBV) proposes that different sustainability measures, like pollution prevention, can lead to sustained competitive advantage in the presence of particular firm capabilities that support their successful implementation. This proposition brought with it a slew of empirical research attempting to understand the relationship between a firm's environmental performance and its financial performance (King and Lenox, 2002; Mitra and Datta, 2014; Sharma and Vredenburg, 1998). More recently, this discussion has expanded to include a firm's social performance (Lu et al., 2013; Barnett and Salomon, 2006), asking 'does it pay to be good?' (Javed et al., 2016) in addition to 'does it pay to be green?'.

All of the above papers suggest that the benefits associated with sustainability policies extend beyond the expected sustainability outcomes like less waste-to-landfill or reduced employee turnover. Yet, these studies provide limited insight into how sustainable this enhanced competitive performance is over the long-term. While it is clear from existing that there is an association between exemplary sustainability performance and strong financial performance, there is limited research on the association between the change trajectories of environmental and/or social performance and financial performance over an extended period of time (King and Lenox, 2002; Liao et al., 2018; Sharma and Vredenburg, 1998; Xiong et al., 2016), leading to calls for more research using longitudinal data (Longoni and Cagliano, 2015; Mitra and Datta, 2014; Russo and Fouts, 1997). To truly understand the impact of sustainability performance improvements, research must examine how long the performance benefits associated with sustainable practices can be maintained. Can a firm improve their sustainability performance

over one period and expect improved financial performance over multiple periods, or is continuous sustainability improvement required for sustained financial gain? Using a latent growth model (LGM), this paper seeks to answer the following question: how do sustained changes in a firm's sustainability performance over time affect the trajectory of its financial performance?

I will begin by summarizing existing work on the resource-based view of the firm and how it has been applied in the context of sustainable operations. Next, I will explain my research methodology and data sources. Finally, I will summarize the results of my analysis, limitations and conclusions.

RESOURCE-BASED VIEW

The resource-based view, as originally theorized by Barney (1991) argued that firm resources that are valuable, inimitable, rare and not easily substitutable can lead to sustained competitive advantage for that firm. Resources in this context refer not only to physical goods, but also intangible resources like skills, knowledge and relationships. This stream of research has been criticized for its frequent failure to differentiate between capabilities and resources (Hitt et al., 2016). Capabilities are defined in the literature as 'the actions through which resources are used and that firms engage in to get something done and accomplish their objectives' (Branco and Rodrigues, 2006, p. 116). Some of these concerns were addressed successfully by Sirmon et al. (2007) in their theory of dynamic capabilities. This theory posits that firms bundle their resources to create particular capabilities, and that it is those capabilities that are leveraged to create sustainable competitive advantage (Sirmon et al., 2007).

In order to successfully implement a particular sustainability practice a firm needs to deploy particular skills. These skills may themselves be a source of competitive advantage for the firm. In his explanation of the 'natural-resource-based view of the firm', Hart (1995) explains the link between different sustainability practices and competitive performance by comparing and contrasting pollution control and pollution prevention. Pollution control, as an 'end-of-pipe' solution', traps and filters emissions immediately prior to their release into the environment, without requiring any changes to the plant's existing processes. Pollution prevention, on the other hand, Hart describes as being 'analogous to total quality management (TQM)' (1995, p. 992) in that it requires higher level capabilities like effective employee engagement and continuous improvement that can have spillover effects like cost reduction. In his work, Hart suggests that pollution prevention practices are associated with process management capabilities that may provide firms with sustained competitive advantage. Pollution control, however, does not involve the development or deployment of these capabilities.

These claims were supported by King and Lenox (2002), which found an association between financial performance and waste prevention, but not waste treatment or transfer. Similarly, Klassen and Vereecke (2012) describe three 'social management capabilities' that have clear implications for competitive performance: monitoring, collaboration and innovation. For example, a firm will need to have strong collaboration capabilities to ensure that sustainability guidelines are implemented successfully across the supply chain, and supply chain collaboration has been demonstrated to have benefits that extend far beyond social sustainability performance (Raskovic and Morec, 2013; Zu and Kaynak, 2012). In this way, the development of social management capabilities may contribute to sustained competitive advantage.

Upon publication, Barney's work had immediate relevance to the issue of corporate sustainability performance through his inclusion of a positive stakeholder reputation in his discussion of potentially beneficial firm resources (Barney, 1991). As stakeholders are increasingly holding firms to account for the environmental and social impacts of their

operations, reputations are becoming a more important source of risk (O'Callaghan, 2007), as well as advantage (Russo and Fouts, 1997). Russo and Fouts (1997) provide several examples of firms like Procter & Gamble who link their reputations for strong environmental performance to their profitability. Strong sustainability performance can also improve the firms' reputation in the eyes of its own employees, increasing employee morale and subsequently performance (Branco and Rodrigues, 2006). Together, this literature suggests that a firm's ability to successfully manage its sustainability performance and image can have important implications for its future competitiveness and profitability.

This paper builds on this existing work by assessing how changes to a firm's social and environmental performance over time may be associated with changes to a firm's financial performance over several years. Based on the literature described, I hypothesize:

> ***Hypothesis 1 (H1)***: The rate of improvement in firm environmental performance is positively associated with the rate of change in firm financial performance.
>
> ***Hypothesis 2 (H2)***: The rate of improvement in firm social performance is positively associated with the rate of change in firm financial performance.

RESEARCH DESIGN

Though there is a substantial set of empirical studies that indicate a link between sustainability performance, especially environmental performance, and financial performance, there are fewer that provide insight to how these relationships hold over time (see Sharma and Vredenburg (1998); Liao et al. (2018); Xiong et al. (2016)). To address calls for more longitudinal research on the link between sustainability performance and financial performance (Longoni and Cagliano, 2015) this paper will use a latent growth model to assess the association between the change trajectories of a firm's sustainability performance and financial performance over a six-year period. The theoretical model being evaluated in this paper is summarized in Figure 1.

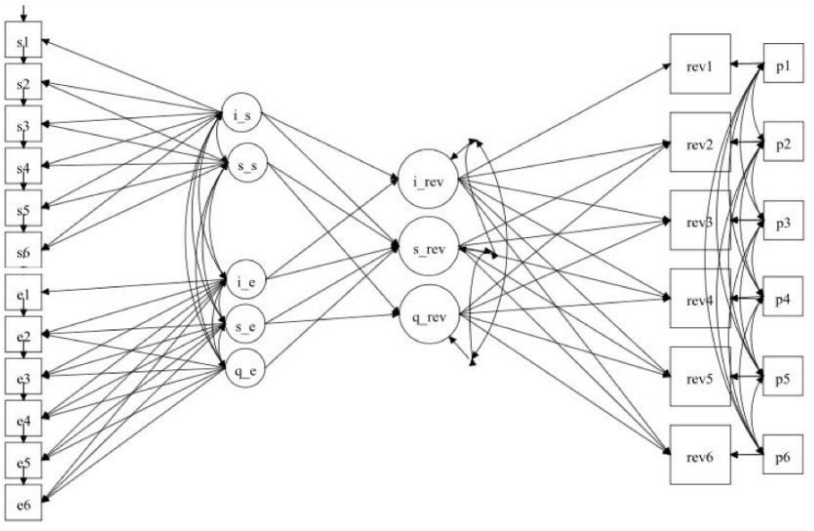

Figure 1: Theoretical model [e = Environmental Score, s = Social Score, rev = Revenue, p = Number of employees, I_x = Intercept of growth curve for variable X, S_x = Slope of growth curve for variable X, Q_x = quadratic term of growth curve for variable X, Numbers 1-6 represent time period 1-6]

One advantage of LGM over methods like fixed-effect regression is that it estimates an independent intercept and growth curve for each observational unit; in the case of this paper, firms. Using these individual growth curves and estimates, two latent factors are estimated, one representing the sample intercept and one representing the sample slope. These latent factors can then be included as predictors of both the initial state and change trajectory of a dependent variable (Lance et al., 2000).

Latent growth models are a well-accepted method for assessing change in particular characteristics over time, both within and between individuals (Lance et al., 2000). As Ketokivi and McIntosh explain, commonly-used methods like fixed-effect regressions can effectively capture variance of a variable within an observational unit over time, but this is not the same as capturing change over multiple periods of time (2017, p. 9). Though this method is most commonly used in human development and other social science literature (Barnes et al., 2000; McArdle and Epstein, 1987), there are no published examples of its use within the OM literature (Ketokivi and McIntosh, 2017). As this paper seeks to understand how the rate of change in sustainability performance relates to the rate of change in financial performance, LGM is an appropriate method of analysis.

DATA SOURCE & SAMPLE

All data used in this study was retrieved from Thomson Reuters ASSET4 database. This dataset, which covers nearly 7,500 public firms, gathers data from firms' annual reports, company websites, news and other sources on over 400 ESG indicators (Thomson Reuters, 2017). These indicators are then collapsed into ten categories, each either classified as environmental, social or governance-related, which are then combined into the total ESG score. Given that this paper aims to investigate the impacts of environmental performance and social performance on financial performance separately, the individual environmental and social scores are used. Each firm's environmental or social score is the weighted sum of all relevant indicator scores in that category, where each indicator score represents the firm's percentile rank compared to other firms in the database (Thomson Reuters, 2017). While the average and standard deviation of the percentile rank scores for the entire dataset are not informative, they provide useful information in this context to frame how the performance of firms in the sample compare to all other firms for which data is available.

The sample for this study is composed of a series firms who appeared on the NASDAQ 100 and/or S&P 500. Initially, data for 521 firms was extracted, though due to data availability issues, the final sample comprises only 471 firms. To represent environmental and social performance, each firm's environmental score and social score was extracted in its final firm from the ASSET4 database. Financial performance is measured using the firm's pre-tax revenue for each period. The number of employees for each firm at each time period was included to control for firm size, which is an accepted practice in the literature (Ambulkar et al., 2015; Wagner and Krause, 2009). Descriptive statistics for the sample can be found in Table 1. Data included in the analysis cover the years 2011 to 2015.

ANALYSIS

An important prerequisite of latent growth modelling is ensuring that the operationalization of the constructs remain valid over time (Lance et al., 2000). Fortunately, given the data used in this paper and the act that all variables included in the model are either directly observed, or compiled in advance at the data source, measurement invariance is not an important concern.

The analysis, which was conducted using Mplus 7 (Muthen & Muthen, 2012) required two stages. First, the appropriate functional form of the growth curve was determined for each variable used in the model. For each variable, the fit of the following types of growth curves were assessed: linear, non-linear, quadratic, exponential and various piecewise models. This was done by constraining the factor loadings of each observational period for each variable to a particular value (e.g., t1=0, t2=1, t3=2 for a linear growth model). By constraining the loading of the first time period for each variable to 0, the intercept of each variable can be interpreted as the initial value of the measured variable (Lance et al., 2000). The relative fit of each potential growth curve was compared using a series of chi-square difference tests for nested models and comparing fit indices when chi-square difference tests were not relevant. As a result of this stage, environmental performance and revenue were modelled using quadratic growth curves, and social performance was modelled using a linear growth curve.

Second, using the appropriate functional firm for each growth curve as established in the first stage, the theoretical model was tested in accordance with Figure 1.

Table 1. Descriptive Statistics

Variable	Period	N	Mean	SD	Min	Max
Environmental Score	1	451	55.6	32.0	9.1	95.0
	2	456	58.6	31.6	8.8	94.7
	3	457	59.7	30.1	8.3	94.2
	4	464	60.2	30.5	8.7	94.5
	5	464	61.3	29.9	8.4	94.7
	6	458	66.9	28.2	9.7	95.1
Social Score	1	451	55.5	29.9	9.1	95.0
	2	456	58.5	28.2	8.8	94.7
	3	457	59.6	32.0	8.3	94.2
	4	464	60.0	31.6	8.7	94.4
	5	464	61.2	30.1	8.4	94.7
	6	458	66.7	30.5	9.7	95.1
Number of Employees	1	455	47727.3	118095.4	79	2100000
	2	462	49077	122161.1	80	2200000
	3	460	50721.4	123487.8	79	2200000
	4	453	51749.5	124240.9	81	2200000
	5	453	52787.4	124471.8	83	2200000
	6	449	55508.9	130718.1	93	2300000
Revenue	1	462	2565136	4659973	-1234728	42541000
	2	464	2820653	5458156	-4842000	58215000
	3	466	2769511	6063005	-29768000	64043000
	4	466	3066235	5808041	-3282000	50291000
	5	467	3081868	5553587	-6618921	53867000
	6	463	2759704	6527230	-27956000	73248000

RESULTS

Before running the analysis, correlations between all variables were calculated. As expected, correlations between repeated measure of each variable over multiple time periods is high. Referring back to the descriptive statistics presented in Table 1, all variables show a general increasing trend over the duration of the measurement period.

To test the hypotheses, a single model was run that connected the slopes and intercepts of each firm's environmental and social performance scores to the slope of its financial performance. Within each firm, the intercept and slope were permitted to covary. To control for the effect of firm size on revenue, each period's revenue was regressed on the number of employees at the firm during that period. The number of employees was a statistically significant predictor of revenue at each period of analysis.

A term was also included that linked the intercept of each firm's environmental and social performance to the intercept of its financial performance to assess if these findings agree with existing work about the association between sustainability performance and financial performance (Esteban-Sanchez et al., 2017; Javed et al., 2016; King and Lenox, 2002; Mitra and Datta, 2014; Sharma and Vredenburg, 1998; Xiong et al., 2016).

The results of the above analysis are presented in Table 2. As shown in the table, the fit indices for the structural model are quite poor. Though the CFI value (0.928) is satisfactory according to some guidelines, some more stringent guidelines suggest a value greater than .95 to claim acceptable fit (Schreiber et al., 2006). The chi-square value and RMSEA both suggest a poor fit. Several alternative specifications were attempted, none of which yielded a significant improvement in the model fit. Despite the poor fit of the model, I chose to move forward with the interpretation of the coefficients.

Table 2 indicates that none of the hypothesized relationships were found to be highly significant, though there was a marginally significant relationship between the quadratic term of the environmental growth curve and the slope of revenue.

Table 2. LGM Results

	Coefficients	**p-value**
I_rev		
I_e	0.595 (.151)	0.000
I_s	-.203 (.173)	0.241
S_rev		
S_e	.504 (.367)	0.170
S_s	-1.535 (1.320)	0.245
I_e	-.045 (.111)	0.688
I_s	0.046 (.110)	0.674
Q_e	2.435 (1.444)	0.092
Q_rev		
S_e	-.022 (.049)	0.656
S_s	0.199 (.241)	0.409
I_e	0.012 (.021)	0.580
I_s	-.017 (.021)	0.429
	Fit Indices	

Chi-square	1290.982
df	233
RMSEA	0.103
CFI	0.928

Hypothesis 1 predicted that there would be a significant and positive association between the slope of a firm's environmental performance over time and its financial performance. This relationship was found to be positive but insignificant (p=.170). However, the quadratic growth term associated with environmental performance was found to have a marginally significant positive effect on the slope of financial performance (p=.092). Together, these findings suggest that there may be a marginally significant, positive, non-linear relationship between a firm's environmental performance change trajectory and their revenue growth trajectory over time such that firms with a greater rate of improvement in their environmental score may also present a greater rate of improvement in their financial performance. A plot of this relationship can be seen in Figure 2.

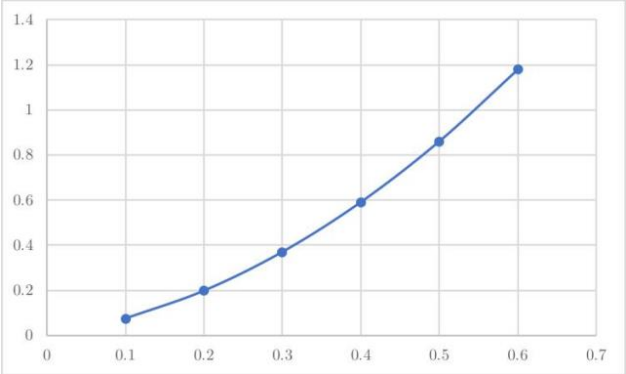

Figure 2. Predicted values of revenue slope by environmental slope

With respect to Hypothesis 2, the results are less ambiguous in their failure to support the hypothesis. The results demonstrate a negative relationship between improvement in social performance and improvement in financial performance, though the relationship is not statistically significant (p=.245).

To assess the presence of a positive association between sustainability performance and financial performance established in existing literature, I regressed the intercept of revenue on the intercept for environmental scores and social scores. This yielded a statistically significant positive relationship between the environmental score intercept and revenue intercept (p<.000). Practically, this means that higher initial environmental performance was associated with higher initial revenue performance. This echoes existing literature that indicates a positive relationship between environmental performance and financial performance (Russo and Fouts, 1997). The relationship between initial social performance and initial revenue, however, was not found to be significant (p=.241), contradicting work that suggests a link between corporate social performance and profitability (Esteban-Sanchez et al., 2017).

To test the robustness of these results and examine the usefulness of this analysis in making causal claims about the relationship between sustainability and financial performance, I conducted an initial analysis using lagged dependent variables. In this model, the change

trajectory from period 1 to period 4 for both environmental and social performance were used to predict the change trajectory from period 3 to period 6 for revenue. These results are presented in Table 3. The fit of the lagged model is significantly better than the fit of the original model, with each measure of fit falling within the acceptable values outlined in Schreiber et al. (2006). Comparing the lagged model to the original model, the quadratic term of the environmental growth curve is no longer marginally significant. This lack of significance in the lagged model casts doubt on any interpretation of the previous results that suggests a causal relationship between environmental performance and financial performance. It supports earlier findings of no relationship between social performance and financial performance.

Table 3. Results, analysis with lagged DV

	Coefficients	**p-value**
I_rev		
I_e	0.267 (.365)	0.464
I_s	0.171 (.461)	0.71
S_rev		
S_e	0.281 (.273)	0.303
S_s	-.383 (.565)	0.497
I_e	0.198 (.207)	0.339
I_s	-.194 (.256)	0.447
Q_e	0.152 (.508)	0.765
Q_rev		
S_e	-.047 (.049)	0.345
S_s	0.059 (.101)	0.559
I_e	-.028 (.031)	0.374
I_s	0.019 (.038)	0.627
	Fit Indices	
Chi-square	208.544	
df	82	
RMSEA	0.059	
CFI	0.985	

LIMITATIONS AND CONCLUSIONS

One important limitation of this analysis is the lack of support for measurement invariance (Vandenberg and Lance, 2000). Although the environmental and social performance scores used in this analysis are themselves latent constructs encompassing many dimensions of sustainability performance, they were extracted from the ASSET 4 dataset in their compiled form, prohibiting the analysis of measurement invariance. However, ASSET4 data is being used more frequently within the literature in recent years (Chopra and Wu, 2016; Dell'Atti et al., 2017; Esteban-Sanchez et al., 2017) and has been shown to converge well with other commonly-used measures of environmental performance (Semenova and Hassel, 2015), supporting the validity of their methodology.

An additional limitation of the analysis is the use of a single indicator as a measure of financial performance. Though revenue performance is often used as a measure of financial performance, it is often included with other indicators in more comprehensive latent construct (Blome et al., 2014; Xiong et al., 2016). For example, some papers use both accounting-based measures and market-based measures to present a more comprehensive picture of firm financial performance (Esteban-Sanchez et al., 2017; Wang and Sarkis, 2017). This analysis would have been strengthened by the inclusion of additional financial performance indicators.

Future studies can use a similar LGM approach to assess how changes in sustainability performance affect operating performance over time. The inclusion of a latent construct representing the change in operating performance could provide more insight into the impacts of improving sustainability performance that may not be easily captured by market-based performance measures, like improvements to operating margins or improved ROA.

Though these results should be interpreted carefully due to model misfit, the results suggest an interesting discrepancy between the returns associated with investments in social performance relative to environmental performance. Contrary to the hypotheses, a quicker rate of improvement in social sustainability was associated with a decrease in the rate of improvement of financial performance. While these negative coefficients may be solely due to model misspecification, they present an interesting research question: what is the difference, if any, in firm returns on investments in environmental performance and social performance? Pullman et al. (2009) examine the impacts of social and environmental practices on cost performance via environmental and quality performance, but only a small subset of sustainability practices is included in their analysis. Future research can expand on their work to examine the subset of a wider set of environmental and social sustainability practices and their change over time as a predictor of the growth trajectory of other dimensions of performance (e.g., operational, financial) to highlight which specific sustainability practices may provide the greatest performance returns over time.

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