AN EMPIRICAL INVESTIGATION OF RFID DRIVERS, BARRIERS, IMPLEMENTATION AND BENEFITS

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ABSTRACT

This research conceptualizes and develops four dimensions of RFID implementation (Drivers, Implementation Level, Barriers and Benefits) and tests the relationships between Drivers, Management Leadership, Implementation Level, Barriers and Benefits. Data for the study were collected from 175 organizations and a separate structural equation model was developed for the current RFID implementers and future RFID implementers. Differences among those two groups were discussed. For both current RFID implementers and future RFID implementers, it is found that a higher level of internal drivers (such as improve customer service, reduce operating costs, better visibility into supply chain processes, etc.) will lead to a higher level of top management leadership in RFID implementation. Increased top management leadership leads to increased level of RFID implementation which in turn leads to increased benefits including customer services, productivity, asset management and internal/external communication.
Key Words: RFID, Supply Chain, Structural Model, Survey Research

INTRODUCTION

In late 2003, both Wal-mart and the U.S. Department of Defense (DOD) sparked massive interest in RFID (radio frequency identification) technology when they announced plans to issue mandates to their suppliers to use RFID in order to improve customer service and help automate inventory replenishment systems. We refer to these announcements as the *big band of RFID* because many firms around the world followed their lead. These announcements ignited hype and predictions of a possible RFID revolution that would significantly improve supply chain operations by reducing costs and increasing sales.

Not long after the *big bang of RFID*, reports of Wal-Mart easing back on its mandate (due to a number of reasons including supplier resistance) suggested RFID as a failing technology. While Wal-mart may have scaled back on its initiative, it did not infer that the 600 Wal-mart suppliers already tagging shipments were going to stop (McWilliams, 2007). And, rival retailer Metro of Germany has continued their pilot testing with RFID applications, recently at apparel subsidiary Galeria Kaufhof (Thiesse et al., 2009).

Since the *big bang of RFID,* a number of empirical studies have been conducted to investigate the adoption, benefits and challenges of RFID implementation. However, because of the early stage of RFID implementation, those studies suffered a few problems such as limited sample

size, low percentage of respondents who had actually implemented or were pilot testing RFID (Visich et al., 2009), and a lack of valid constructs in studying RFID implementation. For example, only 14.2% (30 out of 211) of the respondents to a survey by Vijayaraman & Osyk (2006) on RFID implementation by members of the Warehousing Education and Research Council had any hands-on experience with RFID. Similarly, the Reyes et al. (2007) survey of Institute of Supply Management members had 10.1% (67 out of 663) with experience, while 12.2% (6 out of 49) of the respondents to the Li et al. (2010) survey of APICS members had experience. Whitaker et al. (2007) utilized two *Information Week* surveys and data from financial databases to address both RFID adoption and business value. However, the use of cross-sectional data does not imply causality in their results.

Most studies in RFID are focused on respondents' perception on RFID Implementation, not actual RFID implementers. For example, Angeles (2007) identified critical success factors for RFID implementation through a survey distributed to members of the Council of Supply Chain Management Professionals. But, this paper reports findings from respondents who have not yet implemented RFID and a significant majority of the respondents (68.9%) are from the service sector. Bendoly et al. (2007) investigated the effect of infrastructural capabilities on perceptions of RFID benefits and commitment to actually adopt by matching three levels of management at the same firm. The target firms were limited to only those firms that had implemented an ERP system and hence excluded smaller firms that might have been under external pressure to adopt RFID. A survey of Logistics Council of Taiwan members was conducted by Lin (2008) to identify factors affecting the adoption of RFID, however the relationships between these factors is not tested and most of the respondents were small and medium size business. Angeles (2009) conducted a survey of members of the Council of Supply Chain Management Professionals on their perceptions of the importance of absorptive capacity attributes in RFID implementation in the supply chain in order to create operational efficiency and capture market knowledge. This study was limited in that it focused only on those firms intending to adopt RFID and the data was drawn from a convenience sample instead of from a representative sample.

Extended from previous research, the purpose of this study is to develop a valid instrument in studying RFID implementation and develop/test a causal model in understanding drivers, top management support, barriers, implementation level and benefits in the implementation of RFID. In this research we close several gaps in the RFID supply chain literature. First, we conceptualize and develop four dimensions of RFID implementation (Drivers, Implementation Level, Barriers and Benefits). Second, we used a bigger sample size (175 respondents) covering various industries and had a higher percentage of organizations (about 32%) that are pilot-testing/implementing RFID and about 27% are considering it within next two years. Third, we build a separate structural equation model for the current and future RFID implementers so that differences between those two groups can be compared.

The reminder of this paper is organized as follows. We first review previous literature for developing our constructs and framework. Next, we describe our methodology and data collection followed by our validation of constructs using structural equation modeling. We then present our data analysis. Finally, we offer implications and our conclusion to the study, followed by limitations of this study and future research.

RESEARCH FRAMEWORK

The RFID framework developed in this research is shown in Figure 1. The framework illustrates the direct and indirect relationships of the RFID implementation constructs. Bendoly et al. (2007) noted "*the relatively underinvestiagted nature of RFID adoption*" (p. 430) and looked to the practitioner research for cues on the development of their scale items. In the development of our research framework and scale items we utilized more recent empirical survey research and academic survey articles based on practitioner research. In this section we first discuss our research model which is comprised of the constructs implementation drivers, management leadership, barriers, implementation level and benefits. In Table 1 we list these dimensions, their definitions and supporting literature. Then we discuss the relationships between the dimensions and present out research hypothesis.

Implementation Drivers

The well known RFID mandates that led to the big bang of RFID created external pressure on suppliers to tag cases and pallets sent to Wal-Mart distribution centers and DOD supply depots. However, research by Visich et al. (2009) identified many RFID implementers who were not under a mandate. From this we can conclude that these organizations deployed RFID for internal reasons and therefore we separated implementation drivers into external drivers and internal drivers. We define implementation drivers as the level of pressure externally and internally to adopt RFID in order to improve a wide range of organizational and supply chain process outcomes.

Respondents to the Vijayaraman and Osyk (2006) survey indicated the top reason for deploying RFID was meeting the Wal-Mart compliance. Wal-Mart's RFID objectives were to increase supply chain speed, efficiency and security (Weil, 2004) and to reduce inventory, stockouts and labor costs (Seideman, 2003). Other external drivers they identified were other retailer compliance and DOD compliance. A survey by Li et al. (2010) identified DOD and retailer compliance, and pressure from customers as external drivers.

Vijayaraman and Osyk (2006) found that for companies either considering or implementing RFID, internal reasons for deploying RFID included better inventory and supply chain visibility, efficiency gains, labor efficiency, asset tracking and out of stock reduction. Li et al. (2010) asked considering or implementing respondents to rate the importance of 30 factors that might motivate an organization to implement RFID, with the top three categories being inventory management, competitive decision, and cost reduction in processes. Customer service/collaboration was the lowest scoring category, however the factors improved customer service, improved response time to customer inquires, improved supply chain information sharing, and increased collaboration and planning were all rated as high motivations. These internal reasons and motivations were used to develop measurement items for internal drivers.

Management Leadership

Management leadership is a concept been operationalized in the existing literature with an initial focus on total quality management practices in the manufacturing environment (Saraph et al., 1989; Flynn et al., 1995; Ahire et al., 1996; Black and Porter, 1996; and Kaynak, 2003), in the supply chain (Kaynak and Hartley, 2008; Ou et al., 2010) and in health care (Li, 1997; Meyer

and Collier, 2001; and Marley et al., 2004). The importance of management leadership is also recognized in the Malcolm Baldrige National Quality Award framework, where leadership has the 2nd highest point value category (NIST, 2010).

Because the deployment of RFID requires a significant investment in time and money, top management leadership is a critical enabler of RFID. Attaran (2007) identified top management involvement as a critical success factor that might influence RFID adoption, while Reyes et al. (2007) consider the implementation of RFID a risky proposition unless it is supported by senior management. While top management will initiate and fund RFID projects, it is often the responsibility of mid-level management to implement the technology. Therefore, we define management leadership as the role of top management and mid-level management in RFID implementation. We adapted the top-management and organization cooperation survey items from Li (1997) for our top management leadership and mid-level management leadership constructs.

Barriers

A large number of barriers to the successful implementation of RFID have been identified in the RFID/supply chain survey and overview literature. Vijayaraman and Osyk (2006) found that the top five reasons for not implementing RFID were: lack of a foreseeable benefit; cost; lack of funding; lack of standards; and lack of integration. Reyes *et al*. (2007) identified the top five reasons for not planning to implement RFID as: not applicable in our business; initial costs are too high; expected benefits are not enough; our system works fine; and technology too new or standards not set. The survey results of Li *et al*. (2010) were similar to Reyes et al. (2007), where return on investment was rated highest, followed by not applicable in our business, expected benefits are not enough, lack of understanding of the benefits, and other projects have a higher priority. All three of these empirical surveys only asked those respondents who were not considering RFID implementation why they were not implementing RFID.

In the RFID/supply chain overview literature Srivastava (2004) lists impediments to RFID adoption in supply chains to include a lack of universal standards, cost issues associated with tags and readers, a lack of software applications, technology problems and privacy issues. Major barriers identified by Li & Visich (2006) included: cost, a lack of standards, system integration issues, security and privacy risks, and environmental issues associated with the tags. Obstacles to adoption identified by Reyes & Frazier (2007) were costs, standards, accuracy, and security/privacy concerns.

Based on this review we developed the following four new subconstructs for the construct barriers: cost issues; lack of understanding; technical issues; and privacy concerns. Barriers to the implementation of RFID is defined as the extent to which possible obstacles reject or delay the implementation of RFID including cost issues, a lack of understanding, technical issues, and privacy concerns. We provide a brief discussion of each subconstruct in the following paragraphs.

Cost Issues

The implementation of an RFID system has a number of costs associated with it. First, there is the purchase cost of tags and readers (Srivastava, 2004; Li & Visich, 2006; Reyes & Frazier,

2007) and the software to run the system (Li & Visich, 2006). Once the tags and readers have been purchased there is the installation cost and the cost to maintain the system (Li & Visich, 2006). Based on these projected costs, the return on investment in a RFID project can become a barrier to deployment (Li & Visich, 2006; Reyes & Frazier, 2007: Li et al., 2010). Finally, a lack of funding might impede an investment in RFID (Vijayaraman, 2006; Li et al., 2010).

Lack of Understanding

Commercial use of RFID began in the railroad and trucking industries in the 1980s (Landt, 2001) and then migrated to manufacturing as a way to control the production line and parts bins that fed the line (Stall, 1993). These early RFID deployments used battery-powered active tags and were based on proprietary systems (Dinning & Schuster, 2003). Recent interest in RFID has been on passive tags and open systems for supply chains, hence there is a general lack of understanding around various aspects of RFID (Li & Visich, 2006). The survey results of Li et al. (2010) identified numerous issues around a lack of understanding including: 1) how to develop a feasible business case with accurate costs and how to measure the benefits from an RFID system; 2) how to integrate an RFID system with existing technology; and 3) a lack of knowledge and buy-in by top management.

Technical Issues

While issues of technology standards has been largely resolved by EPCglobal (Reyes & Frazier, 2007), there are still technical issues associated with RFID. The installation of hardware and the placement of tags need to be precise since various factors such as metal, moisture, reader range and antenna orientation can affect read rates (Li & Visich, 2006). Other technical issues include the magnitude of collected data, the filtering of data before it reaches the database, and how to analyze and use that data (Delen et al., 2007).

Privacy Concerns

The subconstruct privacy concerns is comprised of three linked items: privacy, education, and security. Each item includes concerns of customers, employees and external entities that will be or may be impacted by RFID technologies. Reyes and Frazier (2007) identified four consumer concerns around privacy and discussed a pilot study that violated the privacy of customers in a retail establishment. Customer privacy has also been mentioned as an impediment to RFID adoption by Srivastava (2004) and Li & Visich (2006). In order to allay privacy concerns, RFID implementers should educate stakeholders on the purpose of the RFID system. And, before an RFID system is installed, the integrity of the tags must be ensured in order to prevent eavesdropping, tampering, unauthorized tracking, and fraudulent tags need to be addressed (Li & Visich, 2006).

Implementation Level

Implementation level is a new construct we develop to identify how RFID is used for processes within organizations and along the supply chain. Tracking inventory at the item, case and pallet levels were mentioned as among the most frequent processes for implementation in the surveys by Vijayaraman and Osyk (2006), Reyes et al. (2007), and Li et al. (2010). The tracking of containers had a high likelihood of implementation in the Vijayaraman and Osyk (2006) survey, while the automation of inventory replenishment, monitoring inventory usage, and counting inventory in storage were all ranked highly among the respondents to the Reyes et al. (2007)

survey. The order put-away and shipping processes were other top responses found by Li et al. (2010). All respondents to these three empirical surveys were from the considering and implementing groups, and the implementation levels were either planned for the future or already in use. We define implementation level as the level of RFID implementation to support specific business processes within the organization and along the supply chain.

Benefits

For companies planning to implement, piloting or implementing RFID, Vijayaraman and Osyk (2006) found that the top three sources of RFID cost savings (Benefits) were reduced out-of-stocks, minimized inventory losses, and reduced labor cost due to less material handling. Reyes *et al*. (2007) asked respondents who had already implemented RFID to score 8 areas where improvements were realized. Top areas were the improved accuracy and availability of information, increased process automation, improved customer service, and enhanced operations capabilities. Other benefits identified in the supply chain overview literature included increased sales due to a reduction in stockouts, increased safety and security, better supply chain planning and collaboration (Li and Visich, 2006), asset tracking, automatic inventory replenishment, inventory identification, and real-time tracking (Reyes and Frazier, 2007). In addition, a wide range of empirical benefits from the implementation of RFID are summarized in Visich et al. (2009).

For the construct Benefits we developed four new subconstructs: Customer Service; Productivity; Asset Management; and Communication. Benefits is defined as the level of benefits the organization and their supply chains can receive from RFID implementation including customer service, productivity, asset management, and communication. In the following paragraphs we provide a brief discussion of each sub-construct.

Customer Services

In the Li at al. (2010) survey, respondents who had actual hands-on experience with RFID rated improved customer service as the highest perceived benefit to implement RFID.

Productivity

Asset Management

Communication

RESEARCH HYPOTHESIS

The RFID framework developed in this research is an exploratory model that seeks to validate the above discussed dimensions on the implementation of RFID in the supply chain. These dimensions have direct and indirect relationships, ultimately leading to benefits from the implementation of RFID technology. From our model we derive seven hypotheses regarding these relationships as shown in Figure 1.

The decision to implement RFID technology is one that requires the support and direction of top management leadership, who react to outside pressure from customers to implement RFID (Vijayaraman & Osyk, 2006) as well as to internal pressures to improve processes and communication (Li et al. 2010). Both internal and external drivers have a direct impact on the

involvement of top management leadership in the RFID implementation. Therefore it is hypothesized that:

H1: Organizations facing high levels of external pressure to adopt RFID will have a high level of support from top management leadership for the implementation of RFID.
H2: Organizations that have a strong desire to improve internally will have a high level of support from top management leadership for the implementation of RFID.

The importance of top management leadership in initiatives has been well-documented in the literature. Since RFID is a relatively new supply chain technology top management should be involved in the development of the RFID implementation plan. They also need to provide direction to and ensure communication among the different mid-level managers whose departments are affected by the RFID implementation. Top management leadership also provides funding for pilot testing and then, based on the results, full implementation. Mid-level managers are responsible for executing the RFID plan, making sure the project stays on budget, and to use the newly implemented system effectively. And, both levels of management have an interest in determining which processes RFID will be implemented in. This leads to the following three hypotheses:

H3: The higher the level of top management leadership, the higher the level of mid-level management leadership for the implementation of RFID
H4: The higher the level of top management leadership, the more positive the impact on the RFID implementation level.
H5: The higher the level of mid-level management leadership, the more positive the impact on the RFID implementation level.

The level of RFID implementation is not only impacted by management leadership, but also by barriers that impede or terminate a successful RFID implementation. Therefore, barriers are expected to be negatively related to implementation level and we hypothesize:

H6: The higher the levels of barriers (including cost issues, lack of understanding, technical issues and privacy concerns) to the implementation of RFID, the more negative the impact on the RFID implementation level.

If the barriers to RFID implementation can be overcome, then the organization should derive benefits from a successful RFID implementation. The Bain 2005 and 2007 Management Tool surveys found that in cases where a tool had been implemented as part of a major organizational effort, RFID ranked first in satisfaction out of the 25 tools (Rigby and Bilodeau; 2005, 2007). Therefore, a positive relationship between implementation level and benefits can be hypothesized as:

H7: Organizations with a higher level of RFID implementation will reap a higher level of benefits (including customer services, productivity, asset management and communication) from the implementation of RFID.

INSTRUMENT DEVELOPMENT AND VALIDATION

Instrument development methods for Drivers, Implementation Level, Barriers and Benefits of RFID implementation include three phases: (1) item generation, (2) pilot study, and (3) large-scale data analysis. Instruments that measure Management Leadership (top Management Leadership and Mid-level Management Leadership) were adopted from previous literature (Li, 1997). The items for these five instruments are listed in Appendix A. In phase three, rigorous statistical analysis was used to determine the validity and reliability of all constructs. All survey items were measured using a 7-point Likert scale. The research framework in Figure 1and the associated hypotheses were then tested using structural equation modeling.

Item generation and pilot study

The basic requirement for a good measurement is content validity, which means that the measurement items in an instrument cover the major content of a construct (Churchill, 1979). Content validity is usually achieved through a comprehensive literature review and interviews with practitioners and academicians. The items for Drivers, Implementation Level, Barriers and Benefits of RFID implementation were generated based on previous RFID literature.

In the pilot study stage, the Q-sort method was used to pre-assess the convergent and discriminant validity of the scales. Managers were requested to act as judges and sort the items into appropriate dimensions for Drivers, Implementation Level, Drivers and Benefits of RFID based on similarities and differences among items. To assess the reliability of the sorting conducted by the judges, three different measures were used: the inter-judge raw agreement scores, Cohen's Kappa, and item placement ratios. Raw agreement scores were calculated by counting the number of items both judges placed in the same category. Cohen's Kappa (Cohen, 1960) was used to evaluate the true agreement score between two judges by eliminating chance agreements. Item placement ratios were calculated by counting all the items that were correctly sorted into the target category by each of the judges and dividing them by twice the total number of items.

In the first round, the inter-judge raw agreement scores averaged 0.73, the initial overall placement ratio of items within the target constructs was 0.75, and the Cohen's Kappa score averaged 0.70. Following the guidelines of Landis and Koch (1977) for interpreting the Kappa coefficient, the value of 0.73 was considered a good level of agreement (beyond chance) for the judges in the first round. In order to improve the Cohen's Kappa measure of agreement, an examination of the off-diagonal entries in the placement matrix was conducted. Items classified in a construct different from their target construct were identified and dropped or reworded. Also, feedback from both judges was obtained on each item and incorporated into the modification of the items.

The reworded items were then entered into a second sorting round. In the second round, the inter-judge raw agreement scores averaged 0.84, the initial overall placement ratio of items within the target constructs was 0.92, and the Cohen's Kappa score averaged 0.82. Since the second round achieved an excellent overall placement ratio of items within the target constructs (0.92), it was decided to keep all the items for the large scale data collection. Appendix A provides a list of the final items measuring each construct.

Data Collection
The research methodology used in this research is based on empirical data collection through the use of a web-based questionnaire survey of supply chain professionals. Our focused study of RFID in logistics is a continuation of prior studies specific to the RFID technology impacts on supply chain performance. Our invitation to participate was administered by DC Velocity to their membership via emails. The invitation stated that this survey was supported by DC Velocity and hence branded as the "DC Velocity and the Principle Investigators' Study of RFID in Logistics."

The initial invitation and two follow up emails were sent during a six month period, which we received 183 responses to the survey, of which 8 were dropped because of missing values leaving 175 for our analysis. The majority of the respondents work in the Warehouse/Distribution (33%), Manufacturing (32%) or Full Service Logistics Provider (14%) business environment and the key areas of responsibility are Warehouse Operations Management (39%), Logistics Management (33%), and Material Handling (10%). The Position Title of the respondents, with 41% at the Manager level and 27% at the Director level. Of the 31 respondents in the Other category, 18 (10%) indicated a position at the Vice President or higher level. From our analysis of the respondent demographics we believe the survey sample is an accurate representation of the people who are responsible for the implementation decisions surrounding RFID in the warehousing and distribution environment.

In terms of number of employees in the survey, about 25% (44 organizations) have over 500 employees, about 35% (62 organizations) have between 100 and 500 employees and the rest (39%, 69 organizations) have below 100 employees.

Among all the respondents, almost one-third of the respondents (32.0%, 56 respondents) are either pilot testing, implementing or have implemented RFID technology in their business operations. We consider these 3 groups as current RFID implementers. Another 27% (47 respondents) are considering the RFID implementation in next two years and are titled future RFID implementers in this study. The rest (41%, 72 respondents) are not considering it within the next two years. Compared to similar surveys that have conducted over the past four years (Vijayaraman & Osyk, 2006; Reyes et al., 2007; Li et al., 2010), this is a significant increase in actual hands-on experience with RFID. Perhaps the most notable finding of this research was the indisputable evidence that the reports on the death of RFID have been greatly exaggerated. Nearly one in three of our survey respondents are either using, piloting, or in the midst of implementing RFID technologies into their logistics operations - and another 27 percent are considering an RFID implementation in the next two years.

Assess Validity
Following the methodology suggested by Flynn et al. (1999) and Bendoly et al. (1997), a factor analysis was conducted to assess the convergent validity and discriminant validity of each construct (Drivers, Management Leadership, Implementation Level, Barriers and Benefits).

RFID Drivers were initially represented by 2 dimensions and 17 items. After removing ID10 (reduction of theft), the remaining items were factor analyzed using varimax rotation and the results are shown in Table 3a. It can be seen that all items loaded on their respective factors, with most of loadings greater than .80. The cumulative variance explained by 2 factors is 66.92%.

Management leadership includes 2 dimensions and 10 items. Table 3b shows the results of the factor analysis. It can be seen that all items loaded on their respective factors, with all loadings greater than .80. The cumulative variance explained by the two factors is 80.5%.
RFID implementation level was represented by one single factor and 9 items. Table 3c shows that the loadings for all items are over 0.80, and the cumulative variance explained by this factor is 74.4%.

For RFID barriers, a factor analysis was conducted using the 27 items that measure the four dimensions. After removing Bar_Cost5 (lack of funds for the RFID implementation), all items dominantly loaded on their respective factors with most loadings above .70 as shown in Table 3d. The cumulative variance explained by the four factors is 70.4%.

The RFID benefits construct was initially represented by 4 dimensions and 18 items. After removing Ben_P1(improve efficiency of customer order delivery fulfillment), the remaining items were factor analyzed and the results are shown in Table 3e. It can be seen that all items dominantly loaded on their respective factors, with most of loadings greater than .70. The cumulative variance explained by the five factors is 87.9%.

Assessing reliability
The reliabilities of RFID drivers, management leadership, implementation level, barriers and benefits were assessed with Cronbach's Alpha. Table 4a, Table 4b, Table 4c, Table 4d, and Table 4e report means, standard deviations, correlations, and reliability values for each of constructs. It can be seen that external drivers and cost issues have reliability above .80 and all other constructs have a reliability value greater than .90. , which are considered good (Nunnally, 1978).

ANALYSIS AND RESULTS

The theoretical framework illustrated in Figure1 has seven hypothesized relationships among the variables External Drivers, Internal Drivers, Top Management Leadership, Mid-level Management Leadership, RFID Barriers and Benefits. To understand the differences in RFID implementation between the current and future implementers, a separate structural equation model was run for each group and the results were shown in Figure 2a, Figure 2b and Table5a.

Results for the Current RFID implementer
Figure 2a shows the structural model for the current RFID implementers. The model fit measures for this model are: GFI= .91, NFI= .81, CFI= .88, and RMSR=.049. These results indicate good fit of the proposed model to the data. Out of seven hypothesized relationships, five hypotheses are supported, including H2 (internal drivers to top management leadership), H3 (top management leadership to mid-level management leadership), H4 (top management leadership to implementation level), H5 (mid-level management leadership to implementation level) and H7 (implementation level to benefits). Those results show that internal drivers are important in getting management support in RFID which in turn leads to increased level of RFID implementation, leading to improved benefits. The results also show that top management support in RFID will lead to increased mid-level management leadership in RFID leading to an

increased level of RFID implementation. It can be seen that top management leadership not only has a direct impact on RFID implementation but also has an indirect one through mid-level management leadership.

Figure 2a also shows that H1 (external drivers→ top management leadership) and H6 (RFID barriers→ RFID implementation level) are not significant at a significant level of 0.05. Those results indicate that for the current RFID implementers, external drivers are not critical in getting the support for top management leadership. Instead, internal drives (such as an organization's desire to improve customer service, productivity, visibility into supply chain processes, and etc.) will increase top management support in RFID implementation. In addition, barriers such as cost, lack of understanding, technical issues and privacy and security concerns do not have an impact on the level of RFID implementation for the implementers. One possible explanation may be they have overcome those barriers before the implementation.

Figure 2b and Table 5a shows that the top three standardized coefficient for the current implementers are .50 (H3: top management leadership to mid-level management leadership), .44 (H4: top management leadership to implementation level) and .34 (H7: implementation level to benefits), indicating that top management leadership is the most important factor in driving the RFID implementation and RFID implementation will lead to increased benefits.

Results for the Future RFID implementer

Figure 2b shows the structural model for the future RFID implementers. The model fit measures for this model are: GFI= .88, NFI= .85, CFI= .91, and RMSR=.050, showing good fit of the proposed model to the data. Figure 2b shows that except H5 (mid-level management leadership to implementation level), all the other hypothesized relationships are significant. For the future implementer, the results show that internal and external drivers are all important in getting the top management support for the implementation. In addition, top management support, not mid-level management support is critical in the RFID implementation and the higher level of RFID implementation will lead to increased benefits.

The results also show that a higher level of RFID barriers is positively related to a higher level of RFID implementation, which is in contrast to our original hypothesis. This may indicate that barriers may not necessarily prevent organizations from implementing RFID if their perceived benefits from the RFID implementation exceed the barriers. This can be verified by the results in this study. As shown in Table 5b, the means for the perceived benefits for the future implementers is 5.20, which is far greater than 3.25, the means for the perceived barriers.

Figure 2b and Table 5a shows that the top three standardized coefficient for the future implementers are .54 (H3: top management leadership to mid-level management leadership), .53 (H4: top management leadership to implementation level) and .42 (H7: external drives to top management leadership). Similar to the current implementers, the results show that top management leadership has a very strong impact on both mid-level management leadership and implementation level. In addition, external drivers (such as meeting customer mandates) have an important role in getting top management leadership in RFID implementation for the future implementers.

Comparison between Current and Future Implementers

Figure 2a and 2b show that for both current and future implementers, four hypotheses are significant, including H2 (internal drivers to top management leadership), H4 (top management leadership to implementation level), H7 (implementation level to benefits) and H3 (top management leadership to mid-level management leadership). The results indicate for both current and future implementers, a higher level of internal drivers (such as improve customer service, reduce operating costs, better visibility into supply chain processes, etc.) will lead to a higher level of top management leadership in RFID implementation. Increased top management leadership leads to increased level of RFID implementation which in turn leads to increased benefits including customer services, productivity, asset management and internal/external communication.

However, significant differences are also found between those two groups. The results show that external drivers are important for future implementers, but not for current implementers. Barriers have a significant impact on the level of RFID implementation for future implementers, but not for current implementers. In addition, mid-level management leadership have no significant impact on level of RFID implementation for future RFID implementers, but have a significant impact on the RFID implementation level for current implementers. The implication of those results will be discussed in next section.

Table 5b also shows that compared to current implementers, the future implementers have a lower means on barriers and higher means on all other constructs. This may reflect a gap between perception and reality. Before the implementation, organizations usually have a higher expectation. As represented by the future implementer group, they have anticipated a higher level of external and internal drivers, a higher level of management leadership, a higher level of implementation, a higher level of benefits and a lower level of barriers. However, when these future implementers begin to deploy RFID, they may scale back their expectations as exhibited by the current implementers group.

DISCUSSION AND IMPLICATIONS

First, this study represents one of early attempts to develop major constructs of RFID implementation (drivers, implementation level, barriers and benefits) using a bigger sample size (175 respondents) covering various industries. Drivers includes two sub-dimensions (internal and external drivers), implementation level is a single construct measured by various items (such as track parts at individual unit level, at case/pallet/container level, track equipment, help automate inventory replenishment, etc). RFID barriers are measured by cost, lack of understanding, technical issues, and privacy concerns. RFID benefits can be divided into four dimensions including customer service, productivity, asset management, and communication. The results are helpful in understanding barriers and benefits in RFID implementation. In addition, the development of major constructs provides a springboard for future empirical studies. Further studies can test various causal relationships in RFID implementation using the constructs developed in this study.

Second, the results provide the strong support for the benefits of RFID implementation. For the current and future implementers, a higher level of RFID implementation will lead to a higher

level of benefits. This is an encouraging finding as there are doubts in the literature regarding the benefits of RFID in the supply chain. The findings show that RFID is not dying and the implementation of RFID will improve performance of an organization.

Third, the results show the importance of top management leadership in RFID implementation. Top management leadership has a direct impact on RFID implementation and also an indirect one through mid-level management leadership. The links from top management leadership to RFID implementation level and from top management leadership to mid-level leadership are found to be one of the strongest relationships for both current and future implementers. Therefore, it can be concluded that top management leadership is critical for a successful implementation of RFID.

Fourth, the findings also show that internal drivers such as an company's desire to improve customer services, productivity, supply chain visibility, and etc. lead to top management support in both RFID implementation for current and future implementers. This is an interesting finding. It is known that early RFID implementations are mostly driven externally by Wal-Mart or DOD mandates. The results indicate that the motivation for the implementation of RFID may be driven by internal factors as time goes.

Fifth, it was found that there exist differences between current and future RFID implementers. For example, the results show that external drivers are important for future implementers, but not for current implementers. Barriers have a significant impact on the level of RFID implementation for future implementers, but not for current implementers. In addition, mid-level management leadership have no significant impact on level of RFID implementation for future RFID implementers, but have a significant impact on the RFID implementation level for current implementers. The above differences can be explained if we divide RFID implementation into two stages (adoption stage and usage stage) and use future implementers to represent adoption stage and current implementers to represent usage stage. Adoption stage refers to the RFID planning period in which an organization decides on whether to adopt RFID; while usage stage refers to the RFID implementation period in which an organization is pilot-testing/implementing RFID. The results show that in the adoption stage, external drivers (such as mandates) and top management leadership are most important; and mid-level management leadership are not important. This finding verifies the assertion in the literature that companies implement RFID to meet customers' mandates. In addition, mid-level management are usually not involved in a strategic decision such as RFID adoption, therefore, it has no impact in the adoption stage. In the usage stage, internal drivers (not external drivers) and mid-level management leadership are important. This result indicates that an organization's motivation to implement RFID may change from external forces to internal ones in the usage stage. The leadership of mid-management is important in the implementation stage as they are responsible for day-to-day RFID implementation.

In the adoption stage, perceived barriers have a significant positive impact on perceived implementation level; while barriers have no significant impact on the implementation level in the usage stage. This finding is surprising. One possible explanation may be that barriers do not necessarily prevent a company from adopting RFID if perceived benefits exceed perceived barriers as indicated in previous session. Meanwhile, barriers may not have a significant impact

on actual implementation level as companies have overcome such barriers when implementing RFID. Another reason for the positive/no-significant relationships may be that companies face difference barriers during the adoption stage and usage stage, therefore, difference dimensions are needed for each stage. This can be a direction for future research.

LIMITATIONS AND FUTURE RESEARCH

This study has a few limitations that may be addressed by future research. First, even though this study has an overall larger sample size (175 respondents) compared to previous studies, the sample size for current implementers (56 respondents) and future implementers (47 respondents) is still small because of the early stage of the RFID development. Future studies can use a bigger sample size for each of these two groups.

Second, this study only focuses on drivers, management leadership, barriers and benefits of RFID to keep the parsimony of the paper. However, it is possible that other factors (such as firm size, industry type, IT infrastructure, etc.) may impact the implementation of RFID. Future research can explore the impact of these and other factors as well. As discussed in the previous section, a better measurement for barriers may be needed for studying RFID implementation.

Tables, figures, references and the appendix are available from the first author.