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Equifinality at the Gates of Process Innovation: Mapping the Paths for Reducing Cycle Time Variance in the Service Context

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ABSTRACT

This study investigates the predominant approaches for reducing cycle time variance in service settings. A review of the available case examples shows that most studies in the service context address mean cycle time length rather than cycle time variance, although the latter is the correct object of process innovation under the Taguchi principle. Accordingly, using a systematic-review method, this study collects best practices in services that either directly or indirectly target cycle time variance. Synthesizing the cases, the analysis finds three main paths to dominate practical efforts to decrease cycle time variance: simulation, statistical quality control, and value stream mapping.

KEYWORDS: process change, process improvement, quality management, service quality, statistical quality control

INTRODUCTION

Service enterprises today often scrutinize their labor-based processes in terms of cycle time, or the periodicity of activity, to determine how to shorten it and thereby achieve greater use of available labor. To do so, they define an activity, such as a standard service encounter, and measure its starting and stopping times over several iterations. They then rationalize the activity to determine its constituent steps and brainstorm how to reconfigure those steps to shorten the expected mean length of each service encounter of that type (Summers, 2009). The innovation in cycle time reduction therefore amounts to the creative solutions contrived by decision makers to achieve this objective.

This form of process innovation typically produces cost savings by directly targeting the sheer expenditure of labor (Puich, 2001). However, while efforts to increase the operating tempo of services may succeed in fitting more service iterations into an hour's time, it may sometimes undermine the quality of the service encounter. By comparison, reducing cycle time variance can improve predictability and service consistency for the customer, while simultaneously producing a concomitant decrease in cycle time in most cases. More importantly, process variance, hence cycle time variance in the context of services, is the correct object of process innovation in the quality literature (Closs, Mollenkopf, & Keller, 2005).

Efforts to reduce cycle time variance in either service or manufacturing contexts conform to the Taguchi principle, which states that variance in any process translates into a loss of quality because the likelihood of exceeding defined boundaries of quality increases and thereby causes greater error (Arizono, Kanagawa, Ohta, Watakabe, & Tateishi, 1997; Gien, Jacqmart, Seklouli, & Barad, 2003; Meyer & Purser, 1993; Walia, Shan, & Kumar, 2006). The focal issue in process innovation is thus reliability, rather than speed. Greater reliability in cycle times tends to benefit the quest for speed as a mathematical fact insofar as cycle time lengths have a positive statistical skew, but the pursuit of speed for its own sake requires a reasonable limit to maintain quality. Such a limit is imperceptible if the objective is to reduce speed, but it is apparent if the objective is to reduce variance. Insofar as the goal in services is to improve service quality, targeting cycle time variance is therefore the correct objective.

With this perspective in mind, the aim of this study is to capture the state of the art in the application of innovations to reduce cycle time variance. After introducing a problem statement and research question, this study clarifies the methodological approach of systematic review for synthesizing case material. It then reviews the key literature in quality management, presents a guiding theory, describes the method, and undertakes the main analysis. The study then presents a tabulation of best practices in summary form and then illustrates the same to map the dominant innovation paths evidenced by the case material. The study concludes by discussing implications for practice, scholarship, and future research.

PROBLEM STATEMENT

The problem addressed in this study is the lack of systematic research that specifically addresses the reduction of cycle time variance, as opposed to cycle time length, in the service context. A need exists to identify the pattern of innovations adopted by service enterprises to reduce cycle time variance and thereby clarify the optimal range of approaches available to the service sector in the 21st century.

RESEARCH QUESTION

The research question in this study has the aim of discovering the predominant paths of those service process innovations that seek to reduce cycle time variance. It therefore remains open to cases of innovation efforts whose stated objectives are to reduce cycle time length as long as the outcome is also a reduction in cycle time variance. The research question is therefore as follows:

> RQ. What process innovation paths are optimal for reducing cycle time variance in service delivery?

THE METHOD OF SYSTEMATIC REVIEW

This study uses a qualitative systematic-review method to draw common patterns of process innovation from published cases that present institutional efforts to reduce cycle time variance. Systematic review is the process of aggregating findings from past research (Briner & Walshe, 2014). It is the formal methodological approach for converting published research findings into practice, hence the basis of evidence-based management (Briner, Denyer, & Rousseau, 2009). A familiar subset of this methodology is meta-analysis, which involves aggregating purely quantitative results (Gough, Oliver, & Thomas, 2012). Nevertheless, systematic review is also applicable to qualitative research, such as in those research areas in which insufficient evidence is available from which to draw quantitative conclusions (Thomas, Harden, & Newman, 2012). In its qualitative applications, systematic review resembles standard literature review to some extent, but it begins with a rigorous procedure for selecting prior research articles and reducing the article set to an analyzable core array (Gough et al., 2012). That aspect of the systematic review that resembles a standard literature review only begins at the point of interpretation (Stewart & Oliver, 2012). As applied in the present study, qualitative systematic review is useful for assembling a disparate body of case material and translating it into testable theory.

A qualitative systematic review is a methodical approach to synthesizing descriptive or case literature that adheres to a transparent, replicable pattern (Bethel & Bernard, 2010). It begins with a plan for collecting articles that contain evidence involving the variables and linkages of interest through a narrowly defined literature search method, using an explicit selection of scholarly databases and a clear set of keyword search terms specified in advance (Briner & Walshe, 2014). Given the number of irrelevant articles that one inevitably finds through a keyword search, the method applies inclusionary criteria to the database results to permit the rapid identification of articles that are likely to be relevant (*e.g.*, titles and abstracts that appear to address the issue under investigation), followed by exclusionary criteria to apply to the smaller set of articles resulting from the prior step (Stewart & Oliver, 2012). The latter step thus serves to remove articles that, upon closer inspection, overlook the key variables or linkages of interest to the research question (Briner & Walshe, 2014). A quality-oriented appraisal of the surviving articles follows as the next step, wherein the researcher defines quality criteria (*e.g.*, objectivity, replicability, form, and transparency) (Streubert, 2011). The scoring or categorization of articles based on the quality appraisal helps the researcher interpret the articles with a more refined sense of judgment than is possible if the researcher must instead treat the entire array of articles as equivalent on the matter of research quality (Thomas et al., 2012). In the present study, the quality appraisal step uses the weight-of-evidence (WoE) method, which assigns point values to the criteria and thus produces a composite quality score for each article (Griesinger, Desprez, Coecke, Casey, & Zuang, 2016). Researchers usually apply their own judgment on the matter of the quality appraisal (Petticrew & Roberts, 2006), but they may also use a panel of scholars to increase objectivity in this process, as in the approach adopted in the present study. After taking all of these steps to manage the distillation of a range of sources of data or observations relevant to the research question, the researcher may then begin the analysis by tabulating the surviving articles to reveal their contrasts and points of emphasis (Briner & Walshe, 2014), after which the researcher applies standard scholarly reasoning to interpret the display.

REVIEW OF THE LITERATURE ON IMPROVING SERVICE PROCESSES

This literature review briefly surveys process improvement generally, followed by the application of improvement efforts to services. While most applications of process innovation to reduce cycle time variance are in the manufacturing and software sectors, where this science originated (Pang & Whitt, 2009), some have more recently appeared in the service context. Most service-related examples have focused on cycle time length rather than cycle time variance, but the latter is a byproduct of the former whenever the calculation of cycle time lengths shows a positive statistical skew (Furlow, 2003).

Quality as a Function of Consistency

The Taguchi theory asserts a mathematical relationship between variance and efficiency in a process (Taguchi, 1986; Walia et al., 2006). The principle is effectively a statistical law if one interprets efficiency in terms of economic cost. Although the principle is mainly important to process innovation, it is the same statistical principle by which variance in product or service quality causes customers to abandon a business (Tsikriktsis & Heineke, 2004) or suppliers to abandon a business (Bolton, Lemon, & Bramlett, 2006). The theoretical nature of the Taguchi principle notwithstanding, process engineers consider it a mathematical law rather than a theory requiring a search for evidence (*e.g.*, Gien et al., 2003). Nevertheless, the relationship between process variance and quality is indeed a theoretical one. Some sources have therefore explicitly referred to the principle as the Taguchi theory *per se* (*e.g.*, Arizono et al., 1997; Demetrescu, Paris, & Târcolea, 2009; Taguchi, Chowdhury, & Wu, 2005; Târcolea, Paris, & Sylvan, 2013).

Process Innovation Generally

The quality movement has promoted an intense focus on process rules and the interplay between process steps and technological support (Shiba & Walden, 2001). In this application, the Taguchi principle guides practitioners to remove unnecessary steps, gaps, time, production, effort, and rules in the manufacturing context under the rubric of the Toyota Production System (Al-Tahat & Jalham, 2015). The result is inevitably a streamlining of each process in the process sequence that leads to the final product. Mapping this sequence is also therefore a central feature of process innovation (Song, Song, & Di Benedetto, 2009). Called value stream mapping (VSM), it involves illustrating detailed process steps to reveal to decision makers opportunities to merge, simplify, or remove steps (Joosten & Purao, 2002). The VSM approach thus captures all core principles of the kaizen philosophy (Teoh & Cai, 2015).

A Focus on Services

The concept of cycle time also applies to services, in precisely the same form as it does to manufacturing (Schneider & White, 2004). Compared to manufacturing, however, rationalizing services in terms of steps, gaps, time, production, effort, and rules is more difficult, as the most obvious feature of a service cycle time is its length (Debetaz, 1999). Case examples have therefore pursued cycle time reduction rather than variance reduction as their primary focus (McConnell, Nunnally, & McGarvey, 2010). A question that remains in most of these cases is consequently whether targeting cycle time variance would have produced the same result (Summers, 2009). Whether a limit exists beyond which further cycle time reduction in a given kind of service encounter would be counterproductive is thus an important question in this context (Gilbert, 1996; Schneider & White, 2004).

Theory

As applied to service encounters, the Taguchi principle observes that variance in cycle time for a given type of service reflects inconsistencies of some kind, such as irregular inclusion of all necessary service steps, varying practices in the delivery of information to the customer, or uneven levels of care in delivering the service (Summers, 2009). Such inconsistencies imply a lack of certainty and automaticity in the servicer's approach, hence increased error in at least two observable ways. In turn, as error increases, the proportion of actual service encounters with long cycle times increases due to the need to solve problems on the spot or the frequency of customer revisits to correct errors.

Variance takes more than one form in cycle time analysis. Most references to variance naturally denote the variability in the service process as a function of the time of cycle closure minus the time of cycle initiation. However, another aspect of variance in service cycle times is that of the difference between estimates and outcomes, especially in terms of the level of effort necessary to fulfill a service of a given dimensionality, the cost as a function of the actual time taken, and the ability of service providers to adhere to the initial schedule (McGarry & Decker, 2002). An additional type of variance has to do with the "distribution of effort across the life-cycle phases" (McGarry & Decker, 2002, p. 95).

In Chronéer and Bergquist (2012), by comparison, one sees the effects of variance in cycle time inputs as the core issue, at least in terms of implications for supplier relations and product-related concerns. The analogy of this observation for service cycle times is that of variance in prior service fulfillment in a company's internal service chain, such as a hospital, wherein the service to the patient is a function of a chain of tributary services from other people or departments. Any delay in a critical tributary service causes a delay in the service cycle time at issue. From this perspective, the importance of cycle time variance as opposed to cycle time *per se* is apparent: If tributary cycle times have low variance, the agents of focal cycle times can more easily predict pacing, hence make more accurate estimates of scheduling parameters.

In Choo (2014), variance in the design phase of computer project services significantly increased the subsequent service cycle time. In this case, the effect of the variance was thus disproportional to the source, in that service cycle time behaved differently from merely moving up or down as design phase time moved up and down. This study therefore showed that variance in a tributary phase of a service cycle can simply increase the service cycle phase itself, hence represent as significant source of inefficiency in the affected cycle.

PROPOSITIONS

The theoretical literature on service process innovation thus suggests that the goal to reduce cycle time variation is consistent with the Taguchi principle for improving quality by reducing process variation. However, the literature leaves open the question of how best to pursue the goal of reducing variance. From this basis, it is reasonable to expect that the case literature presented in the systematic-review portion of this study will reveal more than one strategy to reducing cycle time variance, hence the first proposition given below. In addition, the lack any indication in the literature that any type of strategy for this purpose is necessarily superior to any other type suggests advancing the second (null) proposition given below.

P1. In line with the principle of equifinality, the case literature will demonstrate the utility of more than one approach to reducing cycle time variance.

P2. No approach to reducing cycle time variance will emerge as clearly superior to the others.

METHOD

This systematic review used the keyword constructions of “service cycle time” + “case study,” “cycle time” + services + “case study,” and “cycle time” + services + variance + “case study.” The search used the EBSCOhost, ProQuest, and Science Direct for its databases. Inclusionary criteria consisted of scholarly, peer-reviewed articles that were downloadable as full-text documents with references and over one page in length. Exclusionary criteria consisted of book reviews, editorials, and studies without actual cases. This section presents the central observations from the most relevant sources identified in this way.

Expert Panel

This systematic review used an expert panel consisting of advanced doctoral students in management to judge the quality criteria of the case selected from the scholarly databases and to categorize the strategies represented in the respective articles to support the analytical phase of the study. For the quality appraisal, the panel members judged each article based on the quality criteria described below and applied a Likert scale value (range 1-5) to it. The researcher then averaged the quality ratings across the panel members and then rounded them to the nearest whole number for inclusion in the table. For the categorization step, the panel members first interpreted the theme (*i.e.*, strategy, methodology, or perspective) adopted in each of the cases to reduce cycle time variance and then deliberated over their selected categories to adopt common phraseology and reconcile conflicts. The result was a concise set of themes, as discussed below, under *Results*.

Quality Appraisal

The four criteria adopted for evaluating the case material selected from the scholarly databases were consistent with standard practice in the systematic review of qualitative material (Streubert, 2011). The first criterion is the source's objectivity, wherein empirical or quantitative sources have an advantage. The next criterion is replicability, which depends on the available guidance in the study. Form reflects the correctness of the order of analysis and the layout of results. Transparency reflects the study's ability to answer the reader's questions.

Table 1 lists the 20 cases selected from the databases of scholarly research using the systematic-review process, after applying all inclusionary and exclusionary criteria, as described previously. The table also presents the quality appraisal scoring by each case, to calculate the weight-of-evidence coefficient (WoE). The WoE is therefore the simple average of the individual quality scores provided by the expert panel.

Table 1: Quality Appraisal Scoring by Source (Weight of Evidence)

Source	WoE	Obj	Rep	Form	Transp
Anda et al. (2009)	3.50	4	2	3	5
Buzby et al. (2002)	3.50	4	5	2	3
Carugati & Hadilias (2007)	3.00	3	3	2	4
Choo (2014)	5.00	5	5	5	5
Chowdhury & Rahman (2010)	3.75	4	4	2	5
Clark (2007)	3.50	3	3	4	4
Deckard et al. (2003)	4.50	5	4	4	5
Gijo et al. (2013)	5.00	5	5	5	5
Gliatis et al. (2013)	4.25	5	4	4	4
Harrison & Fichtinger (2013)	4.25	5	3	4	5
Jiang & Giachetti (2008)	4.50	5	4	4	5
Kim & Kim (2015)	4.50	5	5	3	5
Leyer & Hollmann (2014)	4.00	4	5	3	4
Ng et al. (2000)	3.50	4	3	3	4
Olivero & Kopelman (1998)	3.75	5	3	3	4
Ray & Boby (2011)	4.75	4	5	5	5
Rommelspacher & Fourie (2015)	4.25	5	4	3	5
Sarkar et al. (2013)	5.00	5	5	5	5
Scacchi (2001)	3.50	4	3	3	4
Shu et al. (2013)	4.75	5	5	4	5

Note: Obj[ectivity]; Rep[licability]; Form; Transp[arency]. WoE = mean of these criteria.

RESULTS OF THE ANALYSIS

As explained above, the expert panel identified a concise set of themes reflected in the cases selected in this systematic review. The themes represented strategies, methodologies, or perspectives on the question of service process improvement with a focus on cycle times. The results of this process produced key findings in five main themes for reducing cycle time variance: (a) simulation; (b) VSM; (c) statistical quality control; (d) managing multiple service types; and (e) addressing tributary variance. Of these themes, three of them are interpretable as strategies *per se* and include simulations, statistical quality control, and VSM. These three strategies therefore constitute the main paths of process innovation evident in the best practices reflected in the case literature. The sections that follow explain and exemplify each of the five themes identified by the expert panel.

Simulation

Jiang and Giachetti (2008) used a simulation methodology to model changes in a patient care system that would produce a decrease in cycle time by service type. By organizing processes maximally in parallel structures, they used a VSM methodology by definition. While the sheer variety of combinations of patient triage and patient care creates substantial complexity in this effort, it is nevertheless feasible to use multiple regression analysis to enable treating all data in combination with appropriate weights assigned to different service categories.

Harrison and Fichtinger (2013) studied the impact of variance in global ocean transport networks (GOTNs, p. 7) on inventory management effectiveness among shippers. They used a computer simulation to model optimal logistical configurations, while simultaneously collecting interview data to supplement their insights into innovative process improvement ideas. The authors addressed each source of variance separately. They found a positive effect from reducing cycle time variance on inventory management efficiency (*cf*. Salam & Khan, 2016).

Lastly, Gliatis, Minis, and Lavasa (2013) used a simulation methodology to model how to reduce error rates in the context of financial services. They found that high error rates increase cycle time exponentially, even though the effect on customer satisfaction seems to follow a linear slope. However, the effect of offline rework on both cycle time and customer satisfaction is far steeper than that for official rework. The magnified effect of off-line rework appears to undermine standard processes by over-encumbering personnel.

VSM

Ng, Kent, and Egbert (2000) introduced a total-cycle-time model to reduce cycle times, improve responsiveness, and reduce error in the context of child protective services. They explained the specific case of an identified agency in which case cycle times had been increasing. They explained in detail the technique of cycle time measurement and improvement in the manufacturing sector and then drew parallels with child protective services. They applied VSM by first exhibiting the process sequence as already laid out in agency documents, then scrutinizing each step of the sequence, and finally elucidating its governing assumptions.

Scacchi (2001) investigated the service cycle time for procurement via Internet-based systems in a military supply setting. He observed that the initial condition featured considerable variance in terms of computing infrastructures, hence various norms by which to procure the needed supplies. Data integrity was also a concern in this case. Scacchi (2001) first mapped the logical process by which to compare against current process in the various procurement entities. The solution to cycle time variance involved adapting a software-based function to each of the entities involved. The solution simply followed the ideal sequencing of decision tasks and thus would walk the user through the tasks in an orderly way. The result was a significant decrease in cycle time variance. Scacchi (2001) noted that no task steps in the final solution were unusual to procurement.

Leyer and Hollmann (2014) studied the conversion to a paperless work environment at a German bank using a business process simulation. They first mapped the current process by conducting interviews with staff members. They then mapped a prescriptive procedure for using electronic documents instead of paper ones and ran several simulations to test the differences in cycle time outcomes. The result was a reduction in both cycle times and cycle time variances.

Chowdhury and Rahman (2010) investigated service line balancing to reduce cycle time variance in the teller function in banking services. In the case, the authors specifically sought to reduce cycle time rather than reducing cycle time variance. Nevertheless, the former evidently depended on the latter within the queuing structure under consideration, because the shortest cycle times would naturally rise while the longest ones fell through the line-balancing process. Line balancing had to consider different service types, hence difference service cycle times.

In a comparative analysis of four cases of software engineering services, Anda, Sjøberg, and Mockus (2009) demonstrated a significant association between cycle time variance and process reproducibility. That is, when a software engineering company creates a service process to guide the creation and elaboration of software products for clients, the resulting protocol is more or less reproducible by other software engineering firms. However, different companies have differing degrees of success at creating a truly reproducible protocol. Anda et al.'s (2009) study accordingly sought to identify the main drivers of reproducibility, using variance as the criterion.

Finally, Carugati and Hadilias (2007) compared three cases involving the creation of e-government website interfaces, to identify key sources of variance in the time consumed by service suppliers in this form of website creation. The authors used the case studies to produce an ideal model to guide e-government website creation, analogous to the software engineering models investigated later by Anda et al. (2009) and therefore optimally reproducible, with considerably less variance across service cycles than under the current unguided conditions.

Statistical Quality Control

Deckard, Newbold, and Vidrine (2003) examined cycle times in terms of lumber delivery processing. Their study presented several cases in combination. The authors met the task of accounting for different conditions simply by only considering the shortest quartile of delivery times, thus providing a model for similar applications of cycle time assessment in other contexts. Deckard et al. (2003) then addressed the delivery data for shipments falling outside the best quartile and used the best quartile as the goal to attain for those other shipments. They identified and logged specific categories of causal factors affecting shipping time, and then entered the data into a multiple regression model to reduce those factors to a list of only the statistically significant ones.

Shu, Kung, Nguyen, and Hsu (2013) undertook a case study comparison between technical services in a consulting firm and teller services in a bank, using standard methods of statistical quality control. In the first case, the central issue involving cycle time variance had to do with variability in the number of hours necessary to complete service tasks of different specifications, since technical services in the company at issue have a considerable range of cycle times. Shu et al. (2013) therefore addressed cycle time variance as a function of the difference between estimated and actual time. In the second case, the central issue involving cycle time variance had to do with natural variations in service demand throughout the day and week.

Sarkar, Mukhopadhyay, & Ghosh (2013) applied VSM and Pareto optimality (Islam & Ahmed, 2012), following a Six Sigma approach to measuring process improvement in terms of conformance to requirements, to claims processing in the context of insurance services. The process was straightforward, starting with measuring current subprocesses, identifying and charting sources of error, and creatively addressing possible ways to reduce that error. Sarkar et al. (2013) were able to demonstrate a decrease in service cycle time via a decrease in cycle time variance.

Ray and Boby (2011) applied standard tools of quality management to reducing cycle time variance in the context of business process outsourcing. Their first step was to measure current cycle time means and variances, create visual depictions to convey an accurate understanding of the current state, and then conduct a root-cause analysis to list all distinct sources of time consumption. In this operation, root-cause analysis refers to a logical process of deliberation and inferencing with process participants to determine the main causes of cycle time variance. This analytical step permitted decision makers to brainstorm possible solutions, decide on what to implement and how to implement them, and then set the new process structure in motion. The result was a drop in cycle time variance from 1.569 to 0.204 hours, and in mean cycle time from 3.007 to 1.841 hours.

Gijo, Antony, Hernandez, and Scaria (2013) applied Six Sigma methodology to reduce cycle time variance in the pathology unit of a medical center. Their study included the use of an Ishikawa cause-effect diagram (Islam & Ahmed, 2012), Pareto optimality (*viz*., organizing error causes from most to least frequent), and calculations of cycle time variances to improve service quality. These processes enabled Gijo et al. (2013) to reduce cycle time variance from 17.55 minutes to 10.04 minutes and cycle time lengths from 23.96 minutes to 11.00 minutes.

Buzby, Gerstenfeld, Voss, and Zeng (2002) analyzed the quotation process in the supplier-buyer relationship and applied lean quality management principles to decrease the cycle time associated with it. The quotation process begins with the customer's request for a quote from the supplier, followed by the supplier's offer of a bid to the customer. The significant contributor to cycle time in this process is the supplier's follow-on requests for cost estimates from its own suppliers. The latter processes are tributary to the one under consideration. Greater variance in tributary processes increases the focal cycle time (Chronéer & Bergquist, 2012), hence the essential challenge addressed by Buzby et al. (2002). Buzby et al. (2002) chose the principle of takt time to solve the problem. Takt time refers to calculating the total number of productive units requested by a customer and allocating that number evenly across the available employee-hours (Summers, 2009). The outcome is a work pace that optimally matches the needs of the project, greatly minimizing process variance, and thereby also minimizing errors and lateness. To apply takt time to the quotation cycle, Buzby et al. (2002) first identified the separate task steps associated with the process, calculated mean cycle times for each one, and then calculated a takt time allocation for each task by multiplying the total project time available for the contract task (based on the customer's deadline) by the percentage of task time to total processing time. The result would be a carefully calculated deadline for each task step, hence minimal variance in cycle times from project to project and minimal variance in overall cycle time. Importantly, Buzby et al. (2002) showed how to apply takt time, a concept from manufacturing (Singh & Sharma, 2009), to service cycles.

Finally, Rommelspacher and Fourie (2015) studied turnaround time in rail maintenance in the context of South African rail transport on analogy of turnaround times in delivery truck maintenance, as applied in Florida. In this case, the cycle began with the initiation of rail maintenance and ended with its completion. The authors emphasized the difference between maintenance time and manufacturing cycles, in that the latter presumably benefit from objectives measures, while the former are subject to the fluidity and caprice of labor. Adding specific steps to enable objective measurements of maintenance processes is therefore key to successfully implementing process improvement in the maintenance context, the point of emphasis being that the *status quo* in maintenance usually overlooks the matter of measuring start and stop times. Labor-based cycle times also require consideration for allowances, such as for taking standard breaks and keeping fatigue at bay among operators who must attend to transportation tasks of long duration.

Managing Multiple Service Types

Olivero and Kopelman (1998) applied the VSM technique to the patient flow cycle in an inner-city emergency room. The VSM process took five years to produce the necessary measures and observations, after which a cross-functional team convened to study the data and brainstorm process changes. Cycle time began at 18.1 hours. It dropped to 9.4 hours after the implementation of the process changes. Time-consuming steps identified in the VSM review included having patients complete their forms rather than provide a way to retrieve computerized records from patients' prior visits. Patient movement personnel lacked discretionary access to elevators, having to rely instead on slow elevator operators while transporting patients for emergency care.

In addition, Kim and Kim (2015) addressed the challenge of managing service cycle times under conditions of very different kinds of services, in the context of emergency medical care. An addition element of complexity in their analysis was the fact of seasonal effects through the day, which caused three observable bottleneck points over a 12-hour period. The authors' solution was to categorize service subprocesses (*e.g.*, triage, exam, registration, and X-ray), then construct a service transition matrix to track process flow in this complex process architecture. By separating calculating expected wait times for the respective service subprocesses and the expected number of patients who would need to undergo each subprocess, Kim and Kim (2015) were able to use optimizing algorithms to even out the wait times across patient types. The result was both a decrease in cycle time variance and a decrease in mean cycle time.

Addressing Tributary Variance

Choo (2014) investigated the effects of design phase variance on total project phase in the context of computer manufacturing as a service to institutional customers. He found that increased design phase variance, as opposed to longer or shorter design phases *per se*, had the effect of increasing overall project time. By attuning design phase time toward the mean, the result would be to shorten project time. Thus, in this example, variance in a tributary process directly affects cycle time length in the main service process.

Lastly, Clark (2007) compared the norms of service interaction in two different call centers, one in the Philippines and the other in the United Kingdom, including cycle times and quality criteria. The Philippine call centers used self-paced customer service interaction, with no standard scripts. The service encountered tended to last over 30 minutes. The UK operation had a process of training employees to follow a prescribed sequence while targeting a 4-minute limit on opening and closing the conversation, respectively, but without a time constraint in the middle portion of the service encounter. The service encounters tended to last about 10 minutes.

Summary of Findings by Theme

Table 2 assembles the studies by theme, as judged by the expert panel, and displays the mean WoE rating for the studies associated with each theme. In the latter table, the ratings range from 3.54 for VSM methodology to 4.54 for statistical quality control.

Table 2: Summary of Findings by Theme

Theme	Sources	WoE
Simulation	Gliatis et al. (2013); Harrison & Fichtinger (2013); Jiang & Giachetti (2008)	4.33
VSM	Anda et al. (2009); Carugati & Hadilias (2007); Chowdhury & Rahman (2010); Leyer & Hollmann (2014); Ng et al. (2000); Scacchi (2001)	3.54
Statistical Quality Control	Buzby et al. (2002); Deckard et al. (2003); Gijo et al. (2013); Ray & Boby (2011); Rommelspacher & Fourie (2015); Sarkar et al. (2013); Shu et al. (2013)	4.54
Multiple Service Types	Kim & Kim (2015); Olivero & Kopelman (1998)	4.13
Tributary Variance	Choo (2014); Clark (2007)	4.25

Note: Weight-of-evidence (WoE) = mean quality appraisal scores for the listed studies.

According to Table 2, the cases of the highest mean quality are in the theme of statistical process control. Simulation, tributary variance, and multiple service types follow in turn. The VSM theme shows the lowest mean quality rating. All category means are above the midpoint in the Likert scale range, however. No theme in the case literature on reducing cycle time variance therefore demonstrates any notable concern in interpretation.

Three Strategies

Table 3 next presents a synthesis of the three main strategies for reducing cycle time variance, as extracted from the foregoing list of five themes represented in the case literature. One path (VSM) occurs in isolation, without obvious opportunities for decision makers to transition to another path between phases. To be sure, one may indeed work out how to inject statistical procedures or activity rationalization into a VSM methodology (Adetunji, Yadavalli, & Malada, 2013), but no such transition is evident in the sampled cases. What remain are the other two paths, which contrarily provide self-evident transitioning opportunities. However, the logical direction of this transitioning only occurs from the use of quantitative or computerized methods to the use of qualitative or non-computerized methods (Croson & Donohue, 2003). For example, the intervention may begin with statistical data collection and then use the collected data merely to guide reasoning throughout the remainder of the intervention phases. Alternatively, decision makers may organize data into charts before transitioning to the qualitative decision-making phase (Edward, 2001). Lastly, the data may continue through the computerized mode in the form of simulations or gaming strategies to optimize activity sequencing (Doll & Deng, 2011).

Table 3: Best Practices for Reducing Cycle Time Variance in Service Contexts

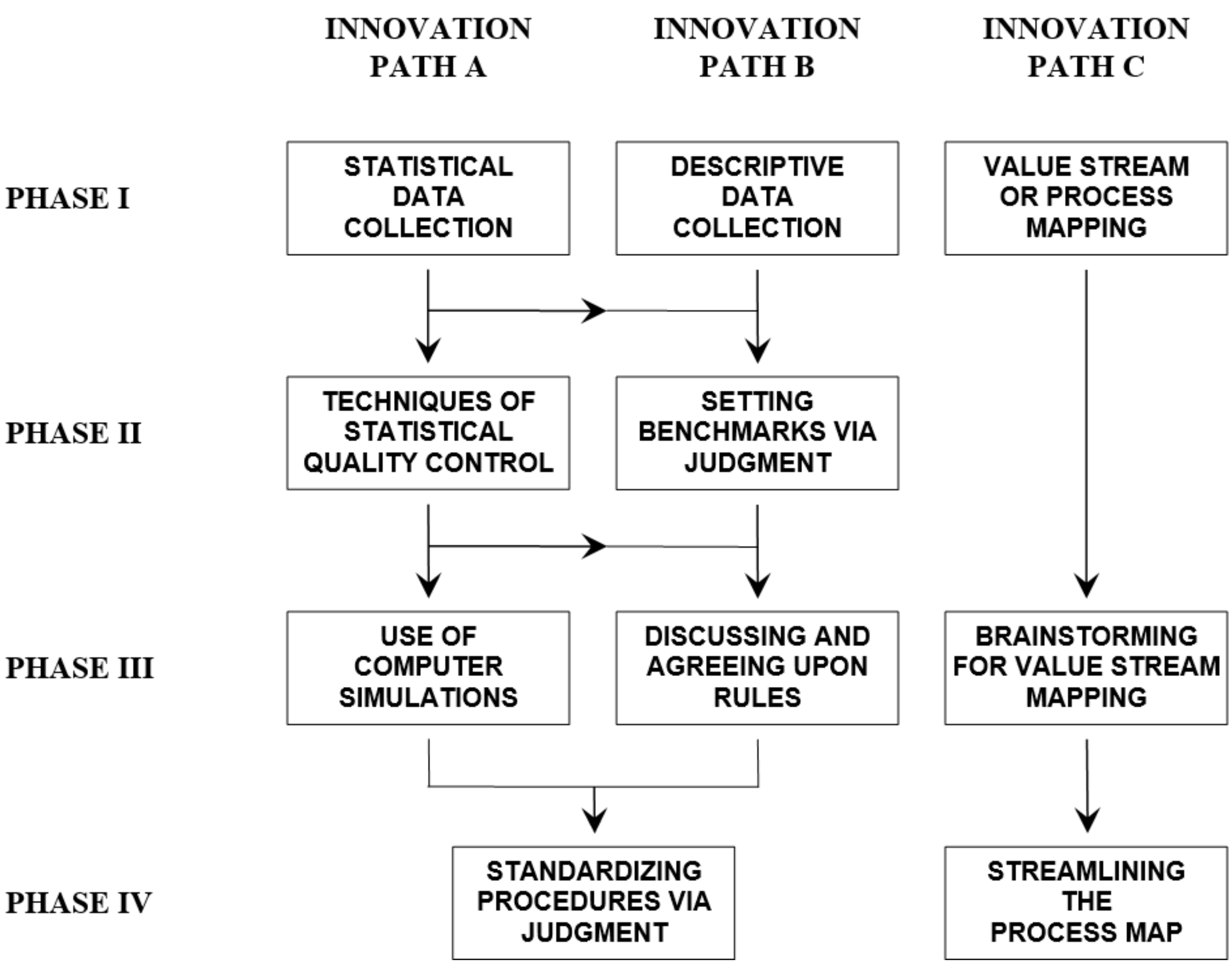
Phase	Path	Approach	Objective
I	1	Statistical data collection	Gather measurable activity data
I	2	Descriptive data collection	Gather descriptive activity information
I	3	Value stream or process mapping	Identify linkages among activities
II	1	Techniques of statistical quality control	Weight or prioritize causes of error
II	2	Setting benchmarks *via* judgment	Clarify desired operating objectives
III	1	Use of computer simulations	Experiment with new configurations
III	2	Discussing and agreeing upon rules	Compare various possible procedures
III	3	Brainstorming for VSM	Compare various possible paths
IV	1, 2	Standardizing procedures *via* judgment	Routinize and integrate human factors
IV	3	Streamlining the process map	Reconfigure for efficiency (kaizen)

Note: The review revealed three core paths for reducing variance in service cycle time.

The Path Diagram to Map the Data

Figure 1 organizes the strategies from Table 3, with three paths and four innovation phases. Path A presents a statistical approach, which may lead to simulation, while Path B presents a logic-based (qualitative) approach. The transitions to Phases II and III in Path A provide an avenue for proceeding without further computer assistance, in which case the remaining phases eventually lead to the same outcome, namely, procedure standardization and margin-setting (*i.e.*, adding a percentage increment of time to compensate for the adoption of strict best-practice benchmarks in human activity). Specifically, based on statistical data, decision makers in Path A may simply use those data to set activity-based benchmarks, and then continue by deliberating or negotiating over procedure to standardize and thereby reduce the incidence of differences across actors regarding how to carry out each activity. Alternatively, they may first employ statistical and graphical aids (Phase II) and then transition to Path B for the same sequence of procedure deliberation and negotiation, prior to standardizing procedures and setting margins.

Figure 1: Innovation paths for decreasing cycle time variance evidenced in the case literature.



Reconsideration of the Propositions

Proposition 1 stated that, in line with the principle of equifinality, the case literature would demonstrate the utility of more than one approach to reducing cycle time variance. The case literature has upheld this proposition by demonstrating three distinct paths, each of which leads to the successful reduction in cycle time variance. Although the VSM strategy showed the lowest mean quality score according to the WoE assessment, all thematic categories identified in the case material demonstrated WoE means above the scale midpoint. No linkage between the quality of the cases studies representing each strategy and the WoE assessment is therefore inferable from this study. All three strategic paths for reducing cycle time variance are therefore arguably equivalent in terms of their practical effectiveness, barring further research on this question.

Proposition 2 stated that no approach to reducing cycle time variance would emerge as clearly superior to the others. The case literature has upheld this proposition as well, by showing that different approaches to variance reduction lead to similar outcomes. The choice of approach is largely a function of the nature and availability of the data, however. The VSM strategy thus appeared most often in cases in which quantitative measures were unavailable. This fact seems to explain the lower mean WoE rating that the analysis revealed for that category.

DISCUSSION

This discussion addresses implications for practice and scholarship, respectively, followed by limitations and general conclusions. It presents ideas for future research pertaining to reducing cycle time variance in services, while emphasizing the need for the literature to begin focusing more squarely on cycle time variance rather than cycle time length.

Implications for Practice

The availability of more than one process innovation path suggests that decision makers need to judge the optimal approach for any process improvement initiative based on scrutiny of data needs and process complexity rather than simply pursue the path that is most apparent. In addition, an important element is lacking in the available case examples, namely, the relationship between the goal to reduce cycle time variances and that to reduce cycle times *per se* (Boon & Adan, 2009). The Taguchi principle advocates the former to improve quality, but practitioners seem to have a fixation on delivering services quickly rather than consistently (Meyer & Purser, 1993). Fast service may often fail to translate into good service (Schneider & White, 2004). Faster service cycle times may invite increased error, if service providers exceed a limit beyond which speed no longer translates into quality from the customer's perspective.

Implications for Scholarship

One may legitimately argue that the quest to reduce cycle times *per se* may inadvertently increase error, increase the need for real-time corrections, and thereby effectively increase cycle time variances. At present, the relationship between cycle time variance and mean cycle time is open to potential debate. Reducing cycle time means may simply cause reductions in cycle time variances due to the mathematical pressure that accompanies the fact of approaching zero (Puich, 2001). Whether this trajectory constitutes long-term quality improvement is an open question, which merits further research.

Limitations

This study's limitations are a product of the use of library databases alone, as the limited number of studies that most clearly and directly address cycle time variance in services suggests that a more thorough search, including books and dissertations, is in order. A systematic review with a much broader base may therefore reveal more cases of service process innovation that address the matter of reducing cycle time variance. Nevertheless, given the interplay between reducing cycle time and reducing cycle time variance, the best practices uncovered in an extended systematic review of this kind may indeed be the same as those uncovered herein.

Conclusions

In conclusion, the propositions that more than one viable process innovation path would emerge among best practices and that the different paths would be similar in their impact has proved valid in this study. Moreover, the foregoing review has resulted in a procedural map of potential practical utility in guiding decision makers. The procedural map answers the research question by illustrating the major process innovation paths for reducing cycle time variance in service delivery. The map shows that the use of statistical procedures is up to the discretion of decision makers. Depending on the nature of the change, statistics may only play a minor role in the intervention. Nevertheless, insofar as the objective is indeed to reduce cycle time variance, objective measures of variance are necessary at least at the very start and at the very end of the intervention. Moreover, one may argue that continuing to measure variance in cycle times through implementation phases is superior to waiting until the end. However, the nature of the case examples reviewed in this study has suggested that interventions often occur as discrete operations. That is, they consist of singular changes, often in conjunction with singular measures.

Future Research

Given that the case illustrations sought primarily to reduce cycle times in every case, while thereby reducing cycle time variation incidentally, future research should include service-oriented case studies that directly entail efforts to reduce cycle time variance instead, as specified by the Taguchi principle (Meyer & Purser, 1993; Summers, 2009). Perhaps the outcome will be effectively identical to those presented in the foregoing cases, namely, a simultaneous reduction of both cycle time and cycle time variance. Nevertheless, it remains important to test whether the Taguchi principle, strictly defined as addressing variance, reliably increases process efficiency by itself, as the principle predicts.

REFERENCES

Adetunji, O., Yadavalli, V. S. S., & Malada, A. (2013). Assessment of the quality of service provided by a national regulatory institution. *South African Journal of Industrial Engineering*, *24*(1), 24-49. doi:10.7166/24-1-647

Al-Tahat, M. D., & Jalham, I. S. (2015). A structural equation model and a statistical investigation of lean-based quality and productivity improvement. *Journal of Intelligent Manufacturing*, *26*, 571-583. doi:10.1007/s10845-013-0816-0

Anda, B. C. D., Sjøberg, D. I. K., & Mockus, A. (2009). Variability and reproducibility in software engineering: A study of four companies that developed the same system. *IEEE Transactions on Software Engineering*, *35*, 407-429. doi:10.1109/TSE.2008.89

Arizono, I., Kanagawa, A., Ohta, H., Watakabe, K., & Tateishi, K. (1997). Variable sampling plans for normal distribution indexed by Taguchi's loss function. *Naval Research Logistics*, *44*, 591-603. doi:10.1002/(SICI)1520-6750(199709)44:6<591::AID-NAV5>3.0.CO;2-Z

Bethel, E. C., & Bernard, R. M. (2010). Developments and trends in synthesizing diverse forms of evidence: Beyond comparisons between distance education and classroom instruction. *Distance Education*, *31*, 231-256. doi:10.1080/01587919.2010.513950

Bolton, R. N., Lemon, K. N., & Bramlett, M. D. (2006). The effect of service experiences over time on a supplier's retention of business customers. *Management Science*, *52*, 1811-1823. doi:10.1287/mnsc.1060.0594

Boon, M. A. A., & Adan, I. J. B. F. (2009). Mixed gated/exhaustive service in a polling model with priorities. *Queueing Systems*, *63*, 383-399. doi:10.1007/s11134-009-9115-z

Briner, R. B., Denyer, D., & Rousseau, D. M. (2009). Evidence-based management: Concept cleanup time? *Academy of Management Perspectives*, *23*(4), doi:10.5465/ AMP.2009.45590138

Briner, R. B., & Walshe, N. D. (2014). From passively received wisdom to actively constructed knowledge: Teaching systematic review skills as a foundation of evidence-based management. *Academy of Management Learning and Education*, 13, 415-432. doi:10.5465/amle.2013.0222

Buzby, C. M., Gerstenfeld, A., Voss, L. E., & Zeng, A. Z. (2002). Using lean principles to streamline the quotation process: A case study. *Industrial Management and Data Systems*, *102*, 513-520. doi:10.1108/02635570210450190

Carugati, A., & Hadzilias, E. (2007). Development of e-government services for cultural heritage: Examining the key dimensions. *International Journal of Technology and Human Interaction*, *3*(2), 45-70.

Choo, A. S. (2014). Defining problems fast and slow: The U-shaped effect of problem definition time on project duration. *Production and Operations Management*, *23*, 1462-1479. doi:10.1111/poms.12219

Chowdhury, A. H., & Rahman, M. Z. (2010). Application of line balancing method for service process improvement: The case of a bank in Bangladesh. *South Asian Journal of Management*, *17*, 137-159.

Chronéer, D., & Bergquist, B. (2012). Managerial complexity in process industrial R&D projects: A Swedish study. *Project Management Journal*, *43*(2), 21-36. doi:10.1002/pmj.21257

Clark, E. E. (2007). Characteristics of work organization in UK and Philippine call centres. *Team Performance Management*, *13*, 227-243. doi:10.1108/13527590710842547

Closs, D. J., Mollenkopf, D. A., & Keller, S. B. (2005). Improving chemical industry performance through enhanced railcar utilization. *Supply Chain Management*, *10*, 206-213. doi:10.1108/13598540510606269

Croson, R., & Donohue, K. (2003). Impact of POS data shazing on supply chain management: An experimental study. *Production and Operations Management*, *12*, 1-11. doi:10.1111/ j.1937-5956.2003.tb00194.x

Debetaz, P. (1999). Rapid cycle-time redesign: Productive at any speed. *Journal for Quality and Participation*, *22*(3), 24-28.

Deckard, D. L., Newbold, R. A., & Vidrine, C. G. (2003). Benchmark roundwood delivery cycle-times and potential efficiency gains in the southern United States. *Forest Products Journal*, *53*(7), 61-69.

Demetrescu, M., Paris, A., & Târcolea, C. (2009). Uni- and multivariate loss functions and the Taguchi theory. *Proceedings of the Balkan Society of Geometers*, 79-83.

Doll, W. J., & Deng, X. D. (2011). Antecedents of improvisation in IT-enabled engineering work. *Journal of Organizational and End User Computer*, *23*(3), 26-47. doi/10.4018/ joeuc.2011070102

Edward, K. A. (2001). Achieving cycle-time excellence in the global economy: The impact of speed. *AACE International Transactions*, *2001*, art. PM.12.

Furlow, L. (2003). Cut the clutter with cycle time reduction. *Nursing Management*, *34*(3), 42-44.

Getz, K. A. (2012). Rethinking the adage time is money. *Applied Clinical Trials*, *21*(3), 28-30.

Gien, D., Jacqmart, S., Seklouli, A., & Barad, M. (2003). An approach based on fuzzy sets for manufacturing system design. *International Journal of Production Research*, *41*, 315-335. doi:10.1080/0020754021000024166

Gijo, E. V., Antony, J., Hernandez, J., & Scaria, J. (2013). Reducing patient waiting time in a pathology department using the Six Sigma methodology. *Leadership in Health Services*, *26*, 253-267. doi: 10.1108/LHS-02-2012-0004

Gilbert, J. T. (1996). Reducing the risks from innovation. *Journal of Systems Management*, *47*(1), 12-15.

Gliatis, V., Minis, I., & Lavasa, K. M. (2013). Assessing the impact of failures in service operations using experimental design with simulation. *International Journal of Quality and Reliability Management*, *30*, 23-46. doi:10.1108/02656711311288405

Gough, D., Oliver, S., & Thomas, J. (2012). *An introduction to systematic reviews*. Thousand Oaks, CA: Sage.

Griesinger, C., Desprez, B., Coecke, S., Casey, W., & Zuang, V. (2016). Validation of alternative *in vitro* methods to animal testing: Concepts, challenges, processes, and tools. In C. Eskes & M. Whelan (Eds.), *Validation of alternative methods for toxicity testing* (pp. 65-132). New York, NY: Springer.

Harrison, A., & Fichtinger, J. (2013). Managing variability in ocean shipping. *International Journal of Logistics Management*, *24*, 7-21. doi:10.1108/IJLM-05-2013-0052

Islam, S., & Ahmed, M. D. (2012). Business process improvement of credit card department: Case study of a multinational bank. *Business Process Management Journal*, *18*, 284-303. doi: 10.1108/14637151211225207

Jiang, L. X., & Giachetti, R. E. (2008). A queueing network model to analyze the impact of parallelization of care on patient cycle time. *Health Care Management Science*, *11*, 248-261. doi:10.1007/s10729-007-9040-9

Joosten, S., & Purao, S. (2002). A rigorous approach for mapping workflows to object-oriented IS models. *Journal of Database Management*, *13*(4), 1-19. doi:10.4018/jdm.2002100101

Kim, S., & Kim, S. M. (2015). Differentiated waiting time management according to patient class in an emergency room care center using an open Jackson network integrated with pooling and prioritizing. *Annals of Operations Research*, *230*, 35-55. doi:10.1007/s10479-013-1477-2

Leyer, M., & Hollmann, M. (2014). Introduction of electronic documents: How business process simulation can help. *Business Process Management Journal*, *20*, 950-970. doi:10.1108/BPMJ-05-2013-0062

McConnell, J., Nunnally, B. K., & McGarvey, B. (2010). Having it all. *Journal of Validation Technology*, *16*(2), 10-14.

McGarry, F., & Decker, W. (2002). Attaining level 5 in CMM process maturity. *IEEE Software*, *19*(6), 87-96. doi:10.1109/MS.2002.1049397

Meyer, C., & Purser, R. E. (1993). Six steps to becoming a fast-cycle-time competitor. *Research Technology Management*, *36*(5), 41-48. doi:10.1080/08956308.1993.11670928

Ng, B., Kent. J. D., & Egbert, M. A. (2000). A "total cycle time" approach to re-engineering social services. *Administration in Social Work*, *24*(3), 35-51. doi:10.1300/J147v24n03_03

Olivero, G., & Kopelman, R. E. (1998). Reducing patient-flow cycle time in the emergency room of an inner-city hospital. *National Productivity Review*, *17*(4), 5-12. doi:10.1002/npr.4040170403

Pang, G. D., & Whitt, W. (2009). Heavy-traffic limits for many-server queues with service interruptions. *Queueing Systems*, *61*, 167-202. doi:10.1007/s11134-009-9104-2

Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences: A practical guide*. Malden, MA: Blackwell.

Puich, M. (2001). Are you up to the cycle-time challenge? *IIE Solutions*, *33*(4), 24-29.

Ray, S., & Boby, J. (2011). Lean Six-Sigma application in business process outsourced organization. *International Journal of Lean Six Sigma*, *2*, 371-380. doi:10.1108/20401461111189443

Rommelspacher, K. O., & Fourie, C. J. (2015). The applicability of the Centeno, Chaudhary, and Lopez repair time standard methodology in a rail maintenance environment. *South African Journal of Industrial Engineering*, *26*(3), 183-193. doi:10.7166/26-3-1225

Salam, M. A., & Khan, S. A. (2016). Simulation based decision support system for optimization: A case of Thai logistics service provider. *Industrial Management and Data Systems*, *116*, 236-254. doi: 10.1108/IMDS-05-2015-0192

Sarkar, S. A., Mukhopadhyay, A. R., & Ghosh, S. K. (2013). Improvement of claim processing cycle time through lean Six Sigma methodology. *International Journal of Lean Six Sigma*, *4*, 171-183. doi:10.1108/20401461311319347

Scacchi, W. (2001). Redesigning contracted service procurement for Internet-based electronic commerce: A case study. *Information Technology and Management*, *2*, 313-334.

Schneider, B., & White, S. S. (2004). *Service quality: Research perspectives*. Thousand Oaks, CA: Sage.

Shiba, S., & Walden, D. (2001). *Four practical revolutions in management: Systems for creating unique organizational capability*. Portland, OR: Productivity Press.

Shu, M. H., Kung, J. Y., Nguyen, T. L., & Hsu, B. M. (2013). Dynamically monitoring the service efficiency with tracking signals. *Industrial Management and Data Systems*, *113*, 1334-1350. doi:10.1108/IMDS-02-2013-0094

Singh, B., & Sharma, S. K. (2009). Value stream mapping as a versatile tool for lean implementation: An Indian case study of a manufacturing firm. *Measuring Business Excellence*, *13*(3), 58-68. doi:10.1108/13683040910984338

Song, L. Z., Song, M., & Di Benedetto, C. A. (2009). A staged service innovation model. *Decision Sciences*, *40*, 571-599. doi:10.1111/j.1540-5915.2009.00240.x

Stewart, R., & Oliver, S. (2012). Making a difference with systematic reviews. In D. Gough, S. Oliver, & J. Thomas (Eds.), *An introduction to systematic reviews* (pp. 227-244). Thousand Oaks, CA: Sage.

Summers, D. C. S. (2009). *Quality management: Creating and sustaining organizational effectiveness* (2nd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Taguchi, G. (1986). *Introduction to quality engineering: Designing quality into products and processes*. Tokyo, Japan: Asian Productivity Organization.

Taguchi, G., Chowdhury, S., & Wu, Y. I. (2005). *Taguchi's quality engineering handbook*. Hoboken, NJ: Wiley.

Târcolea, C., Paris, A. S., & Sylvan, D. (2013). Loss functions and Taguchi theory. *Proceedings of the Balkan Society of Geometers*, 175-180.

Teoh, S. Y., & Cai, S. (2015). The process of strategic, agile innovation development: A healthcare systems implementation case study. *Journal of Global Information Management*, *23*(3), 1-22. doi:10.4018/JGIM.2015070101

Thomas, J., Harden, A., & Newman, M. (2012). Synthesis: Combining results systematically and appropriately. In D. Gough, S. Oliver, & J. Thomas (Eds.), *An introduction to systematic reviews* (pp. 179-226). Thousand Oaks, CA: Sage.

Tsikriktsis, N., & Heineke, J. (2004). The impact of process variation on customer dissatisfaction: Evidence from the US domestic airline industry. *Decision Sciences*, *35*, 129-142. doi:10.1111/j.1540-5414.2004.02483.x

Walia, R. S., Shan, H. S., & Kumar, P. (2006). Multi-response optimization of CFAAFM process through Taguchi method and utility concept. *Materials and Manufacturing Processes*, *21*, 907-914. doi:10.1080/10426910600837814