An Empirical Test of Three Design Rules in Healthcare Process Improvement

Abstract

Prior work identified four rules-in-use (three rules to design work and one rule for problem solving) as the DNA of the Toyota Production System. This paper presents field research to investigate whether the first three rules-in-use apply in a hospital setting. Using a methodological approach that combines qualitative and quantitative research methods, the study suggests a strong association between proper application of the rules and significant process improvement. The results demonstrate that, with some refinement, the rules-in-use are transportable to healthcare and may provide a partial answer to healthcare's systemic issues.

Key Words: Lean manufacturing, healthcare, process improvement, process design

1. Introduction

If any issue has persistently gained the attention of the United States government, businesses, and citizens for more than a decade, it is healthcare. There are legitimate reasons for such concerns. The current picture of healthcare looks grim: mounting operational costs and diminishing reimbursements from payers, uneven clinical and service quality, overworked staff, high attrition rates, shortages of skilled workers in various service lines, and complex, often uncoordinated processes. Wastes, errors, and duplication of efforts abound across the entire healthcare system.

Today, the growing body of literature suggests that the healthcare industry is in serious crisis and does not have sound systems in place. Hospital errors in ordering, administration, transcription, and diagnosis have recently received considerable attention because of high defect rates (Merry and Brown, 2002). In fact, Kohn et al. (1999) report in their often cited study that nearly 100,000 people die of preventable medical related errors annually in the U.S.

Many scholars attribute the poor performance of healthcare organizations to their inability to manage operations (Tucker, 2004; Tucker and Edmonson, 2003; Thompson, et al., 2003; Mango and Shapiro, 2001). Some maintain that simple everyday functional tasks in the healthcare field are still underdeveloped (Patel, et al., 2002), others that healthcare leaders have favored product innovation over process innovation (Uhlig, 2001). Overall, the lack of focus on work processes and their impact on operational failures appears to have had a deleterious effect on the smooth functioning of the healthcare industry, ultimately exposing patients to significant risks.

This is not to say, however, that healthcare leaders have remained oblivious to their industry's problems. A decade earlier, in an effort to address broken systems, healthcare leaders adopted different process improvement initiatives, such as healthcare's version of Total Quality Management known as Continuous Quality Improvement (CQI), and Six Sigma programs. However, CQI appears to have achieved limited success (Huq and Martin, 2001; Blumenthal and Kilo, 1998; Shortell et al., 1998; Arndt and Bigelow, 1995; Westphal et al., 1997), and Six Sigma has remained confined to very few healthcare organizations (Revere and Black, 2003; Torres and Guo, 2004). Thus it seems the healthcare industry still needs a model to address its broken operational systems.

A third continuous improvement philosophy, lean manufacturing, also called Toyota Production System (TPS) as it originated in Toyota Motor Company, has been gaining popularity in the U.S. over the last decade because of its ability to produce the same output with high quality while using a fraction of the organizational resources. The success of TPS has been attributed to its relentless effort to eliminate all sources of waste (Womack and Jones, 1996; Shingo, 1989; Ohno, 1988). The specific tools used in TPS have been described in great detail (see, for example: Sugimori et al., 1977; Cusumano, 1988; Krafcik, 1988), yet few organizations have been able to achieve a level of performance comparable to Toyota (Liker, 2004). In a recent study, Spear and Bowen (1999) contend that Toyota's success in creating highly efficient production systems is not due to the specific tools, but rather to four so-called rules-in-use that it uses in designing work processes, dubbed the DNA of TPS. The first three rules describe characteristics of high performing work processes, while the fourth rule concerns how to improve them. The implication of this work is that replicating the DNA of TPS may yield better results than copying the tools.

Even though TPS, or lean, is widely accepted in the management literature as the most efficient production system developed to date, its applicability outside manufacturing is little known (Hines, et al., 2004). In fact, to our knowledge, its applicability in healthcare is relatively scarce, and has only very recently been applied. The central aim of the study reported here, then, is to test the applicability of three general principles (or rules) for the design of high performing operations in a healthcare setting.

In the following section, we review some relevant literature and describe the TPS design rules as propounded by Spear and Bowen (1999). Next, we state our research objectives and describe the research approach adopted, including the development of the constructs used in analysis. We then present the analysis results, and discuss the findings in light of the qualitative data gathered. The results suggest that the three TPS design rules with some refinement are transferable outside manufacturing, and may be at least a partial answer to fixing the broken systems found in the U.S. healthcare industry and beyond.

2. Literature review

Barley (1996) and Barley and Kunda (2001) contend that over the last few decades, organizational theorists have paid lesser attention to studies on work. Though they (Barley 1990; Barley and Bechky, 1994; Barley 1996) focus on studies of work, they note a serious dearth in research studies on work by others and attribute this to the fact that organizational theorists since the 1960s have relegated "studies on work" to its sister discipline, the sociology of work and communications. As Barley and Kunda quip, "Organization studies have been less effective at understanding verbs than nouns. We tend to study organizations, not organizing" (2001: p. 88). In a subsequent study, Bailey and Barley (2005) note that Industrial Engineering, the nodal engineering discipline that studies work, has gradually shifted focus from work-studies to more abstract quantitative approaches for financial reasons and to glorify its image in the academic circles. Consequently, it became ill positioned to address issues related to work.

2.1. Research on work processes

A significant number of scholars describe work in organizations in terms of routines. Nelson and Winter (1982) define routines as "repetitive patterns of activity in an entire organization." Since Nelson and Winter proposed the concept of routines more than twenty years ago, researchers have studied and researched its characteristics as: patterns of behavior, recurrence of an activity, collective phenomenon, mindless execution of tasks versus effortful accomplishments, and processes embedded in an organization and situated in practice. They have also studied use of routines to: coordinate and control, develop truces, economize on organizational resources, reduce uncertainty, provide stability, and store knowledge (for an overview, see: Becker, 2004).

Despite extensive studies on routines and its pervasive nature in organizations, it has still been difficult to conceptualize and study, and many ambiguities remain (Feldman and Pentland, 2003; Pentland and Rueter, 1994; Becker, 2004). There is much we do not yet understand about the inner workings of routines, how they are constructed, and how they can be imitated in a different setting to achieve similar levels of performance (O'Dell and Grayson, 1998; Pfeffer and Sutton, 1999; Szulanski and Winter, 2002; Winter and Szulanski, 2001). Nonetheless, with the rapidly changing global marketplace and increasing market demands, change of routines has become mandatory.

A noteworthy contribution of research on routines has been their role in organizational change (Feldman, 2000, 2003; Feldman and Pentland, 2003). Adler et al. (1999) from their empirical work at New United Motor Manufacturing, Inc (NUMMI), a Toyota-General Motors joint venture, observe how production workers use meta-routines to change routines thus remaining creative in work, even while maintaining efficiency through standardized work procedures. Meta-routines are standardized procedures for changing existing routines and creating new ones. Spear and Bowen (1999) corroborate and extend these findings. They observed during their four-year field research that Toyota and TPS driven plants are successful because they design organizational routines using three rules-in-use, and employ a meta-routine (the fourth rule) for improvement and adaptation.

2.2. The TPS Rules-in-Use

Spear and Bowen (1999) imply that production systems (and by extension, all organizational systems) are comprised of three basic building blocks: activities, connections, and pathways. Each can be construed as a different type of routine required for an organization to deliver its goods or services. Spear and Bowen observe that Toyota seems to design each building block according to an unwritten rule for gaining maximum efficiency, i.e., a “rule-in-use.”

The first building block, an activity, is the set of routines that people or machines do to transform materials, information or energy. Spear and Bowen observe that Toyota specifies work tasks much more rigorously and systematically, and in greater detail than do those in non-TPS driven organizations. In fact, to Spear and Bowen, Toyota appears to specify activities according to the following rule:

> ***Rule 1:*** *All work shall be highly specified as to content, sequence, timing, and outcome.*

Content refers to the specific tasks within an activity, sequence to the sequential order in executing the tasks, timing to the time taken by individual tasks, and outcome to the desired results from the activity.

The second building block, a connection, is the collection of routines by which adjacent customers and suppliers transfer material, information, and energy. Spear and Bowen find that Toyota emphasizes clear and direct interactions between adjacent customers and suppliers to communicate requests for goods and services and response to such requests. The clearest communications are binary, as indicated in the second rule-in-use:

> ***Rule 2:*** *Every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses.*

The third building block, a pathway, is defined as a series of connected activities that creates and delivers goods, services, and information. It is the larger set of routines that produce the organization's output. Spear and Bowen observe that the flow of goods and services in Toyota plants follow a designated path from beginning to end, in contrast with non-TPS organizations where flows tend toward the next available resource often resulting in convoluted paths. Thus Spear and Bowen define Rule 3 as:

> ***Rule 3:*** *The pathway for every product and service must be simple and direct.*

These three rules, then, represent a framework to better understand the inner workings of routines. They appear to have sufficient depth in specificity to describe the inner workings of routines, yet appear actionable in real world settings. The rules do not appear to be peculiar to high volume, low variety manufacturing contexts, suggesting that they are transferable to other contexts. Moreover, they imply that an organization can develop its own competency, capability, and independency to create routines for gaining maximum efficiency.

The fourth rule-in-use is a meta-routine for making changes to processes. Spear and Bowen claim that within Toyota process improvements are made "in accordance to the scientific method, under the guidance of a teacher, at the lowest possible level in the organization" (1999: 98). The study reported here, however, focuses on the first three rules-in-use, what we call the TPS design rules.

3. Hypotheses

Spear and Bowen's empirical work was conducted in the manufacturing sector, primarily in high volume production facilities. To our knowledge, the design rules have not been studied much outside of manufacturing. A few recent studies (e.g., Thompson, et al., 2003; Sobek and Jimmerson, 2003; Jimmerson, et al., 2005; and Spear, 2005) present anecdotal accounts of interventions that, while promising, are subject to extraneous factors and therefore require additional work to establish the validity of the findings. Thus, the work presented here is the first research attempt to test the applicability of the TPS design rules in a non-manufacturing workplace.

Our initial work at the research site found that, seemingly without exception, failing processes violated one or more of the design rules resulting in errors, delays, and wasted resources. Further, we found that reconstructing the work processes with the design rules was understandable to all actors participating in the problem solving exercise, which motivated further research work. We became interested in exploring to what extent present work practices conform to the rules, and to what degree the rules can be implemented for making improvements. Based on these initial field investigations, we induced three hypotheses related to the rules-in-use previously described.

> **H1:** *Increased activity specification leads to better process outcomes in a healthcare setting.*

Even though standardized work procedures have long been advocated as foundational to efficiently achieving organizational goals (Shingo, 1989; Ohno, 1988), and some have observed superior outcomes at lower costs with standardized work processes in healthcare (Porter and Tiesberg, 2004), others have challenged this line of reasoning. They argue that the long-term effectiveness of standardization is unclear, and could stifle the creativity of the workers or hinder their flexibility to adjust to new circumstances (Gilson, et al., 2005). Hypothesis H1 is intended to help gain some clarity on this tension.

> **H2:** *Increased connection clarity leads to better process outcomes in a healthcare setting.*

Organizational processes encompass multiple interpersonal connections that enable participants to communicate, share understanding, transfer information, and coordinate activities (Feldman and Rafaeli, 2002). However, the characteristics of effective versus ineffective connections have not been articulated, yet are critical to the success of transferring the right information and ensuring better understanding and coordination. Spear and Bowen argue that Toyota strives to design connections with specific qualities whose suitability in a healthcare context is still untested. Hence, we purposed to investigate the second hypothesis (H2).

> **H3:** *Increased pathway simplification leads to better process outcome in a healthcare setting.*

While Spear and Bowen argue that Toyota strives for designated pathways for goods and services, other authors in operations management contend that variability pooling can be advantageous in reducing overall process variability (Hopp and Spearman, 2000). By combining sources of variability, overall variability decreases as the different sources tend to "average out" if they are independent. However, though variability pooling may be an effective solution for the short term, it may hide inefficiencies in the system. For example, an efficient worker covers the inefficiencies of a poorly trained worker that may never surface to get resolved on a long-term basis. A simplified pathway is likely to surface problems faster, which means they can be addressed faster, leading to process improvement. These conflicting views on the nature of pathways for delivering goods and services lead to the third hypothesis (H3) for further investigation.

4. Research Approach

The research approach adopted is a blend of qualitative and quantitative techniques to understand an intervention (the effect of the TPS design rules) in a particular healthcare setting (Miles and Huberman, 1994). Because little empirical research exists on the application of TPS design rules in healthcare, a qualitative approach was adopted as the primary method of data collection. However, since we had definite constructs in mind, we also developed three hypotheses related to them, which we attempted to test quantitatively.

4.1. Background

The setting of this research was a mid-sized hospital located in the Rocky Mountain region of the U.S. serving a regional community of 90,000 with 1,200 employees. The hospital's activities include obstetrics, pediatrics, rehabilitation, surgery, neonatal intensive care, nuclear medicine, emergency, cardiology, and general medical care. The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) and the Rehabilitation Accreditation Commission (CARF) accredit the facility.

Work at the site started in May 2001 as a collaborative project between a North American University and the hospital with funding from the National Science Foundation. In the first year of the project, the principal investigators introduced the TPS design rules to staff members in a pilot area of the hospital. They adapted and tested two tools to aid in deployment: the value stream map, a graphical tool that focuses on the total system and identifies value added and non-value added activities (Rother and Shook, 1998); and the A3 problem-solving report, a documentation template that fits on an 11" x 17" paper to guide the problem-solver through a systematic problem-solving approach (Sobek and Jimmerson, 2004). Both tools are used internally within Toyota for process improvement, but required adaptation to a hospital setting. The initial work seemed to confirm the application of the design rules to healthcare, and enabled the investigators to learn how to translate the rules into language that healthcare workers would readily understand.

In the second year, the investigators developed a training workshop which was administered to staff members from different functional departments across the hospital. The workshop trained hospital managers and workers in TPS principles, with special emphasis on the design rules, and the aforementioned tools. It was taught by a hospital employee who was also a co-investigator on the grant. Over the next two years, more than two hundred employees received training. Workshops were supplemented by one-on-one coaching in process-related problem solving and application of the design rules.

In parallel, an undergraduate research assistant carried out multiple process improvement exercises in the pharmacy and cardiology departments. These pilot studies indicated that one or more of the TPS design rules were defied in all the poorly performing work processes observed, and that reconstructing the work processes using the TPS rules led to significant improvements across varied process measures such as reduced medication errors, reduced outstanding orders, and shorter order-to-delivery times.

In the third year, the first author resided for six months at the research site to gain first-hand knowledge of the deployment and application of the design rules and problem-solving tools adapted from Toyota. He spent approximately 1000 hours observing work processes across functional specialties, attending problem-solving meetings, coaching participants in applying the tools, and assisting them in problem solving activities. During this time, he kept field notes of his experiences and collected artifacts produced during problem-solving activities.

4.2. Data collection

Six months later, the first author revisited the hospital for the purpose of collecting data on process improvement efforts stemming from the TPS training and coaching. He formally selected (through purposive sampling) and interviewed participants from more than ten functional departments. The informants represented various levels within the organization (directors, managers, senior employees with supervisory responsibility, and junior employees).

Participants selected for this study all completed the aforementioned workshop, then applied the problem-solving tool and design rules to address a "problem" pertaining to their daily work. For ease of investigation, we selected problems that were well-defined, of a repetitive nature, and not dealing with the direct patient-clinician interface due to privacy concerns. In total, eighteen problem-solving events were studied (see Table 1). Many of the problems primarily concerned logistical issues impacting the efficiency hospital operations, but a number of others dealt with support operations that significantly impact patient care (e.g., intravenous medication rate miscalculation or delayed patient transport). All but two of the cases were tackled under the guidance of a TPS coach other than the authors.

Prior to conducting interviews, the first author developed a set of interview questions aimed at understanding the problem addressed, the process used to study the problem and generate redesign ideas, changes in work processes, and changes in performance metrics. The second author and several hospital employees checked the interview questions for validity. Prior to each interview, interviewees were sent a letter describing the objectives of the research project. The semi-structured interviews typically lasted for 90 minutes, although a few ran for as long as 120 minutes. They took place in the informant's office, or in a neutral location such as a conference room or cafeteria. Follow-up interviews were conducted as needed to clarify facts and fill in details. Attempt was made to avoid any leading questions during the interview and to take extensive notes to capture details of the informants' answers.

Table 1. List of Cases Studied

Case No.	Type of problem addressed during problem solving
1	Names mismatch between Medicare and hospital database
2	Lost charges on medical supplies used
3	Low productivity of therapists in Rehab Nursing Unit
4	Bill denials by Medicare on re/certifications
5	Delayed returns of over aged accounts to Patient Financial Services department
6	Incorrect transcribing of stress tests
7	Stock out of probes to Emergency department
8	Incomplete documentation on restraints in the clinical Departments
9	Low productivity of the transcriptionists
10	Wrong IV medication drip rate calculation in ICU
11	Poor productivity of the therapists in Med Surge floor
12	Missing information on specimens from operating room to the laboratory
13	Misdirected specimens from the operating room to the laboratory
14	Operating room specimens sent to lab without orders
15	Preventative maintenance of kitchen equipment
16	Faulty echo cardiogram ordering procedure
17	Long patient transportation time from the floors to the diagnostic departments
18	Delayed submission of X-ray reports to the clinical departments

After each interview, the investigator typed an interview report based on notes and his memory, and gave it to the informant to check factual errors. In all the cases, the informants reviewed and approved the document within 48 hours. As the interviews concerned a specific problem that employees addressed using the A3 report tool, the investigator collected the A3 report from each informant. The A3 report contained, among other things, a diagram of the current work processes, a root cause analysis, and a diagram of the envisioned process change. The reports depicted the extent to which problem-solvers applied the design rules, and supplemented the interview data. To augment data collection even further, other artifacts were also collected, such as: meeting minutes of the quality council, safety council, and Falls and Restraint committee; protocols; performance data sheets; and emails.

The first author made periodic contact with the informants about the extent of process improvement for one year after implementation to assess the sustainability of the outcome. Scholars argue that if the trend in improvement is sustained beyond the normal fluctuations of time-series the success can certainly be attributed to the improvement process (Speroff, et al., 2004). Finally, meticulous records of all documents for each informant and analysis process were organized and filed for future reference.

4.3. Case development

First, eighteen case reports were developed based on all the artifacts that were available: (1) the interview reports, (2) A3 problem solving reports, minutes of meetings of safety council, quality council, and Fall and Restraint committee, (3) policies and procedures, and (4) emails. Each one was used as a check against the others. However, the primary document for building the case report was the interview report that the first author obtained from each informant.

The case report represented a comprehensive account of the problem studied for the research. It also allowed us to become intimately familiar with each case. Creating the case report was an iterative process as all sources of data were revisited multiple times to represent the reality as closely as possible. Finally all the case reports were entered in the Atlas Ti software indexed by case number and informant’s name.

The case reports were then coded for activity, connection, and pathway using a pre-determined coding scheme developed for each construct. We focused exclusively on those activities, connections, and pathways that participants addressed during problem solving, attempting to understand changes in terms of the parameters for each design rule. An activity was defined as a contiguous set of tasks that a person does to accomplish an objective. A connection was defined as transfer of goods or services from an internal customer to an adjacent supplier, including the request for the good or service. If a set of tasks included a transfer of goods/services (including the request), then it was broken into two activities and one connection. A pathway was defined as the series of activities and connections along which the good or service traveled.

4.4. Quantification of variables

Our objective was to determine the degree to which the TPS design rules apply to healthcare operations. However, measuring how well hospital employees applied the rules to a particular instance is extremely difficult. Therefore, our approach was to study the process characteristics for the specific issue in question before and after problem-solving to determine the degree to which the redesigned process conformed better to the rules than the old process. If we can measure the change in work process in terms of parameters consistent with the design rules, we can then statistically model variations in performance enhancement using the design rule measures.

For this study, we defined three independent variables—activity specification, connection clarity, and pathway simplification—that correspond to the three TPS design rules and the hypotheses stated earlier; and one dependent variable—the degree of change realized from the problem solving effort. Each variable was measured according to carefully defined constructs as described below.

Activity specification. We borrow Spear's definition of activity as work that people or machines do to transform materials, information, and energy (1999: 56).

According to Spear and Bowen's Rule 1, workplace activities should be specified in terms of four parameters: content, sequence, timing, and outcome.

To measure the change in specificity of activities, we focused on the change in the degree of formalization since increasing levels of formalization generally correspond to making more details more explicit. Individual discretion is less formalized and explicit than group consensus, which is less formalized and explicit than a written procedure. We compared the states of each parameter before and after problem solving and assigned a value of 1 to each parameter that increased in specificity, that is, in formalization. For example, if the understanding of the content of an activity moved from the individual discretionary level (i.e., used own discretion to decide on what tasks to accomplish for an activity) to the group consensus level (e.g., all departmental staff members agreed upon the set of tasks required) or to written procedure, we interpreted that as an increase in activity specification for "content" and assigned "1" to that parameter. This process was repeated for the three other parameters (sequence, timing, and outcome).

The 0/1 parameter scores were then summed to obtain a measure of change in activity specification on a scale from zero to four, zero being no change in the level of specificity in any parameter, and four indicating increased specification in all four parameters. Thus, any non-zero positive value indicates that an activity has increased in specification in a way consistent with the design rule, with larger values indicating more of the parameters addressed. A sample analysis of one case was offered to the second author, who is experienced in qualitative research, to check for any interpretive errors. After he concurred, the process was repeated by the first author for other cases that dealt with activity specification during problem solving.

Theoretically, this binary approach to each parameter might pose some difficulties, as even the slightest change in process design could trigger a 1 versus a 0. However, practically speaking, if the practitioner decided to address activity design, s/he put some significant effort and attention to it; otherwise, s/he simply didn't address it. Thus, in this sample, ambiguous cases were virtually non-existent. The 0/1 scale simply means some minimal level of effort was devoted to specifying the parameter, e.g., topic was taken up in a staff meeting for consensus, or the author set aside time to create a written procedure.

Connection clarity. Again borrowing Spear's definition, a connection is the set of mechanisms by which a supplier transfers materials, patients, services, and information to an adjacent customer (1999: 66). Spear and Bowen's Rule 2 states that connections should be clear and direct. Through our prior action research in the hospital, and consistent with Spear and Bowen's description of connections, we found that connections can be clarified by specifying five parameters:

- requester - person who requests goods or services;
- responder - person who responds to the request;
- method of transfer - mechanism by which responder receives request and/or goods or services are delivered to the requester;
- notification - responder knows that a request has been made, and/or requester knows that the goods or services have been delivered; and
- response time – time from when a request is made to when it is met.

We measured change in connection clarity in a manner similar to activity specification, by assigning a 0 or 1 value for each parameter that was specified more explicitly (i.e., more formalized) after problem-solving than before. For example, if the understanding of "requester" moved from an individual discretionary level (i.e., anybody can request the particular goods or services) to a group consensus level, or to a level covered by codified procedures, and thus became amply clear to all on who should place the request, we interpreted that as an increase in connection clarity and assigned "1" to that parameter. The process was repeated for the remaining parameters. Increase in connection clarity, then, was measured on a 0-5 scale, with "0" indicating no change in any of the parameters and "5" indicating increased specification in all five parameters. Thus connection clarity measured the degree to which the new connection was designed to conform with the design rule. If a case addressed multiple "connection clarity" problems, we computed the mean value of total scores for the connections in the case.

Like activity specification, a sample analysis of one case was offered to the second author for checking any interpretive errors. After he was satisfied, the process was repeated for cases that dealt with connection clarity issues during problem solving.

Pathway simplification. A pathway is defined as a series of connected activities that create and deliver goods, services, and information (Spear, 1999: 74). Spear and Bowen's Rule 3 indicates that pathways should be "simple and direct." By simple, Spear and Bowen (1999) mean that a good or service always takes the same path through the system, without branches or decision points. By direct, they mean minimizing the amount of wait time, diversions, and intermediaries. This was consistent with our observations at the research site, so we developed three parameters to determine whether a pathway is simpler and more direct:

- branch reduction – decreasing the number of possible paths that goods or services could follow;
- loops reduction – decreasing the number of loops, defined by repeating a sequence of steps until a particular condition is met; and
- delay minimization – decreasing the amount of time of goods or services wait between process steps.

We measured increase in pathway simplification on a 0-3 scale using the three parameters above in a similar fashion as we did for activity specification and connection clarity by comparing the before and after states of the pathway. A score of zero meant no change in pathway simplification, while a score of three indicated increased simplification along all three parameters (i.e., fewer branches, fewer loops, and less delay).

A sample analysis of one case was offered to the second author to check for any interpretive errors. Once he agreed, the process was repeated for other cases that dealt with pathway simplification issues during problem solving.

Outcome. We defined outcome, the dependent variable in this study, as the change in the performance of the process due to problem solving. Outcome measures varied by case; for example: the number of denials from Medicare, the amount of lost charges on medical supplies, the number of over-aged bills outstanding, restraint documentation rate, and so on. We compared the performance level before (baseline performance) and after problem solving to measure change in performance. We used the average performance level in cases where multiple measurements were taken at different points in time. Because the measures were different in each case, we computed them in terms of percentages to provide a common datum for comparison across cases. The outcome variable was brought into perspective only when the codification and quantification of the independent variables were complete.

5. Analysis and Results

We treated the problem-solving instance, or case, as the unit of analysis. Of the 18 cases studied, two were excluded from analysis because the participants in those cases had not yet completed implementation when reviewed last; therefore, no results were available for analysis. The participants in the remaining cases addressed at least one of the independent variables depending on the problems they undertook. Table 2 displays the rule classification (independent variables), its associated parameters, and the percentage of cases addressing each parameter.

Table 2. Percent of Cases Addressing the Variable Parameters

Rule Classification	Parameters	% of cases addressing
Activity specification	Outcome	56
	Content	81
	Sequence	69
	Timing	0
Connection clarity	Requester	25
	Responder	44
	Method of transfer	50
	Notification	56
	Response time	94
Pathway simplification	Branched	38
	Looped	81
	Delay	69

Table 3 presents the correlations among the predictor variables and the criterion variable. In cases where one of the design rules was not applied during problem solving, we assumed no change and used "0" for subsequent computation. This occurred when the practitioner deemed that a particular building block (activity, connection, or pathway) was not a root cause of the problem. The results indicate that the activity specification and pathway simplification are significantly correlated with the outcome. Connection clarity is also positively correlated to outcome, but at a more moderate level ($r = 0.445$, $p = 0.08$). A strong positive correlation exists between connection clarity and pathway simplification.

Table 3. Pearson correlations

Variable	Activity Specification	Connection Clarity	Pathway Simplification	Outcome
Activity Specification	1			
Connection Clarity	0.16	1		
Pathway Simplification	0.38	0.83***	1	
Outcome	0.76***	0.44*	0.65***	1

***p < 0.01; ** p < 0.05; * p < 0.10

As we hypothesize that the level of process improvement (dependent variable) would depend on activity specification, connection clarity, and pathway simplification (independent variables), we conducted a multiple regression analysis on the 16 cases, using outcome as the dependent variable. Since connection clarity and pathway simplification are highly correlated, we created two models, each excluding one of the variables, to avoid potential problems with collinearity. The regression results are summarized in Table 5.

The first model includes activity specification and connection clarity as the independent variables. The overall model is significant at $p<0.01$, and explains 69% of the variation in the outcome as indicated by the R-squared statistic. Activity specification is found to be a significant predictor of outcome, thus lending strong support to H1. Connection clarity also predicts outcome, though weakly, providing some support for H2. The second model includes activity specification and pathway simplification as the independent variables. The overall model is also significant at $p< 0.01$, and explains 73% of the variation in the outcome. Both variables are significant predictors of outcome, supporting hypotheses H1 and H3. We checked the residual plots of both models for homoscedasticity, and found no obvious patterns.

Table 5. Results of regression analysis

Variable	Model 1	Model 2
Activity Specification	0.19***	0.16***
Connection Clarity	0.07*	
Pathway Simplification		0.12**
R^2	0.69	0.73
Adjustment R^2	0.64	0.69
F-value	14.44***	17.89***

***p < 0.01; **p < 0.05; * p < 0.10; N = 16

6. Discussion

The work presented here tests the applicability of a general model for designing "lean" work processes in the specific context of a hospital. Overall, the findings support the model's applicability to healthcare, leading to both theory advancement and practical implication.

6.1. Extending the TPS Design Rules

The empirical results indicate a strong positive association between activity specification and pathway simplification, and improved process performance. The results moderately support the hypothesis that increased connection clarity leads to better process outcomes. However, pathway simplification is highly correlated with connection clarity ($r = 0.827$ at $p < 0.01$). This is not terribly surprising, as pathways are defined as series of connected activities. The case study data strongly suggest a reason for this high correlation: clarifying connections within a pathway tends to simplify the pathway. For example, by specifying the method of transfer, branches are eliminated; by creating notification of receipt, delays are prevented; by making requestors and responders explicit, loops are diminished or eliminated. Developing clearer connections through our characterization appears to lead to simplified pathways, which in turn leads to improved outcome. On the other hand, the effect of clarifying connections that do not affect pathways is more ambiguous, possibly explaining why model 1 (pathway simplification + activity specification) has a better fit than model 2 (connection clarity + activity specification).

The results regarding activity specification imply that performance improvement is enhanced when more of the design parameters are addressed in redesigning work tasks. In simple terms, specifying "content" is good but specifying "content" and "sequence" is better. Furthermore, we found that participants tended to address parameters of activity specification in a typical progression. They first decided on the desired outcome, then designated the content required to achieve the desired end, and finally the sequence of steps. None of the participants in the sample timed the activities, though it is logical that timing could not precede content and sequence. This suggests an activity specification “ladder” of sorts (first outcome, then content, then sequence, and finally timing), rather than a binary construct (activity is specified or not) with benefits accruing with each increase in specification, even if full specification (e.g., to the point of timing) is not reached.

In order to operationalize Spear and Bowen’s definition of a “clear” connection, we defined five distinct parameters (Requester, Responder, Method of Transfer, Notification, and Response Time). This provides a more concrete characterization, useful for assessing and redesigning connections. However, this work does not address how important that connections be “direct,” that is, not passing through an intermediary. This is left to future work.

In a similar vein, we refined Spear and Bowen’s description of the ideal pathway as “simple and direct” to mean eliminating branches, loops, and delays. Such a characterization closely resembled the pathways we observed in practice, which were exceedingly complex, so much so that even describing them internally within the organization was often challenging. As one informant summed up her efforts to capture the current pathway in a diagram:

> I started with the actual current state drawing, which the RNs did not like it, as it was very complicated to understand [SIC]. Too confusing! They could not see any process…. I had to simplify my drawing of the current state to make it understandable to the RNs.

From the case studies, we learned that participants gained an in-depth and holistic understanding of the total pathway by diagramming and interacting with other functional departments. This understanding lead to insights on how to develop an integrated process with minimum complexity, supporting Roberts and Bea’s (2001) argument that high reliability organizations continuously provide their employees with the bigger picture and attempt to get everyone to communicate about how they fit into it. The finding would also seem to address concerns that researchers have voiced over the lack of communication and integration across departments in healthcare settings (Adler et al., 2003; Shortell et al., 2000; Begun and Kaissi, 2004).

6.2. Systems of Accountability

One of the issues that informants persistently raised during interviews concerned a general lack of accountability, which led actors in the process to accept poor performance without much upheaval. In some cases, roles and responsibilities were simply not clear to the actors; but in other cases, responsibilities were overlapping. Given the nature of the healthcare work environment, overlapping responsibilities seems plausible because patient care is the primary concern and needs to be delivered without delay. On the other hand, often a task that is anybody's responsibility becomes nobody's responsibility (Spear, 2005). As one informant mentioned, "The activities in the process were not clearly defined. The registration clerk never saw the insurance cards. It was not there in their job description."

Interestingly, from the case study data we observe that application of the TPS design rules, particularly the first two, often creates more clearly delineated roles and responsibilities of the key actors in the process. With expectations made explicit, actors tended to assume greater responsibility for their behavior and performance, and ensured greater consistency in their tasks. More than 50% of the informants felt their old policies and procedures were inadequate and revised them using the TPS design rules to create better defined responsibilities. As one informant commented:

> I have compiled different notebooks to centralize speech therapy information and have written protocols for procedures we do that

> haven't been written down before. These types of improvements have reduced run around and non-productive time. It greatly improved communication of typical procedures to staff who don't normally do them.

6.3. Limitations

The results here should be interpreted with caution as they are derived from the experience of one mid-sized hospital and may not generalize to other organizations. Future research should strive to broaden the sample of organizations to replicate and extend these findings. Furthermore, since it is essentially an observational study, correlation does not necessarily imply causality. While the qualitative analysis of the case data supports the assertion that appropriate application of the three TPS design rules produces improved performance, additional work should be conducted to more firmly establish a causal relationship. Also, the sample size is fairly small. The findings would be more robust with a larger sample size.

The measurement scheme for each variable has fairly coarse granularity, and could represent a limitation to this study. In each case, the variable measures how much of the rule, so to speak, was taken into account in the process redesign. Future work could attempt to measure changes in activity specification, connection clarity, and pathway simplification using a scale with finer granularity than the binary system used here. However, greater rater subjectivity can be expected in such a case, so extra measures would be required to obtain reliable measures.

An additional limitation of this study is that we were able to track sustainability of outcome over a maximum of one year. However, the organization may still regress to old ways. Therefore, as Speroff and O'Connor (2004) suggest, ideally one should study such interventions over time to reinforce the conclusion that the change in outcome was indeed due to the intervention effect.

7. Conclusions

Experts claim that healthcare organizations fail to reliably deliver proper care due to poor systems (Kohn et al, 1999). Such understanding highlights the problem but does not provide a solution. Spear and Bowen's model on Toyota's work practices provides a framework to examine the work processes more closely by deconstructing them into activity, connection, and pathway, then examining each in depth. At a micro-level analysis, the research revealed that the basic ingredients of designing work processes were often missing within this healthcare institution, a finding which likely would not have surfaced otherwise. We suspect this a fairly common throughout the industry.

The work reported here makes several contributions to the existing body of knowledge by extending and validating Spear and Bowen's model in a non-manufacturing context. We introduced sets of parameters that characterize clear connections and simplified pathways, and measured activity specification, connection clarity, and pathway simplification on a continuum as presumably differing degrees of specification, clarity, and simplicity are possible. Though our quantification scheme may be somewhat crude, it nonetheless provided us a way to objectively compare the before and after states of a process due to problem solving. Finally, we found that the success of process improvement is positively related with process redesigns that were consistent with the Rules-in-Use as postulated by Spear and Bowen.

The implications from this research are straightforward, yet powerful. When facing an operational problem, at its root is likely to be a faulty organizational routine:

one or more poorly specified activities, unclear connections, or complex pathways. The problem can be remedied by first characterizing the root cause(s) as stemming from one of these, then redesigning the routines as follows:

1. Make activity designs (i.e., how the work is to be carried out) explicit through group consensus and ultimately codified procedure by agreeing, in this order, on:
    - The desired outcome,
    - The individual tasks required,
    - The sequence of the tasks, and
    - How long each should take and their relative timing.
2. Make critical connections in the pathway seamless by explicitly planning:
    - Who sends the request and to whom,
    - How the request is to be transmitted and how the response is to be delivered, and
    - Acknowledgement of when requests and responses are received.

Additional pathway redesign may be needed for more complex problems. However, addressing even a subset of the items will lead to improved operational performance (although the more items addressed, the better the likely performance improvement). Furthermore, this research borrowed work design rules derived from one sector (high-volume manufacturing) and tested their apparently applicability in a very different context (a hospital), which suggests that the findings may be generally applicable to the work routines of many, perhaps any, organization.

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References

Adler, P.S., Goldoftas, B. and Levine, D.L. (1999) Ergonomics, employee involvement, and the Toyota production system: a case study of NUMMI's 1993 model introduction. Industrial and Labor Relations Review, 50 (3), 416-437.

Adler, P.S., Riley, P., Kwon, S.W., Signer, J., Lee, B. and Satrasala, R. (2003) Performance improvement capability: keys to accelerating performance improvement in hospitals. California Management Review, 45 (2), 12-32.

Arndt, M. and Bigelow, B. (1995) The implementation of total quality management in hospitals. Health Care Management Review, 20 (4), 7-14.

Bailey, D.E. and Barley, S.R. (2005) Toward post-industrial engineering. IIE Transactions, 37 (8), 737-752.

Barley, S.R. (1990) Images of imaging: notes on doing longitudinal field work. Organization Science, 1 (3), 220-247.

Barley, S.R. (1996) Technicians in the workplace: ethnographic evidence for bringing work into organizational studies. Administrative Science Quarterly, 41, 404-441.

Barley, S.R. and Bechky, B. (1994) In the backrooms of science: the work of technicians in science labs. Work and Occupations, 21, 85-126.

Barley, S.R. and Kunda, G. (2001) Bringing work back in. Organization Science, 12 (1), 76-95.

Becker, M.C. (2004) Organizational routines: a review of the literature. Industrial and Corporate Change, 13 (4), 643-677.

Begun, J.W. and Kaissi, A.A. (2004) Uncertainty in health care environments: myth or reality? Health Care Management Review, 29 (1), 31-39.

Blumenthal, D. and Kilo, C.M. (1998) A report card on continuous quality improvement. The Milbank Quarterly, 76 (4), 625-648.

Cusumano, M.A. (1988) Manufacturing innovation: lessons from the Japanese auto industry. Sloan Management Review, 30 (1), 29-39.

Feldman, M.S. (2000) Organizational routines as source of continuous change. Organization Science, 11 (6), 611-629.

Feldman, M.S. (2003) A performative perspective on stability and change in organizational routines. Industrial and Corporate Change, 12, 727-752.

Feldman, M.S. and Pentland, B.T. (2003) Reconceptualizing organizational routines as a source of flexibility and change. Administrative Science Quarterly, 48, 94-118.

Feldman, M.S. and Rafaeli, A. (2002) Organizational routines as sources of connections and understandings. Journal of Management Studies, 39 (3), 309-331.

Gilson, L.L., Mathieu, J.E., Shalley, C.E. and Ruddy, T.M. (2005) Creativity and standardization: complementary or conflicting drivers of team effectiveness? Academy of Management Journal, 48 (3), 521-531.

Hines, P., Holweg, M. and Rich, N. (2004) Learning to evolve: A review of contemporary thinking. International Journal of Operations and Production Management, 24 (10), 994-1011.

Hopp, W.J. and Spearman, M.L. (2000) Factory Physics. Irwin/McGraw-Hill, New York.

Huq, Z. and Martin, T.N. (2001) Workforce cultural factors in TQM/CQI implementation in hospitals. Quality Management in Health Care, 9 (2), 43-57.

Jimmerson, C., Weber, D. and Sobek, D.K. (2005) Reducing waste and errors: piloting lean principles at Intermountain Healthcare. Joint Commission Journal on Quality and Safety, 31 (5), 249-257.

Kohn, L.T., Corrigan, J.M.. and Donaldson, M.S. (1999) To Err is Human: Building a Safer Health System. Institute of Medicine, National Academy Press.

Krafcik, J.F. (1988) Triumph of the lean production system. Sloan Management Review, 30 (1), 41-51.

Liker, J.K. (2004) The Toyota Way. McGraw-Hill, New York.

Mango, P.D. and Shapiro, L.A. (2001) Hospitals get serious about operations. Mckinsey Quarterly, 2 74-84.

Merry, M.M. and Brown, J.P. (2002) From a culture of safety to a culture of excellence. Journal of Innovative Management, 7 (2), 29-45.

Miles, M.B. and Huberman, M.A. (1994) Qualitative Data Analysis. Sage Publications, California.

Nelson, R. and Winter, S.G. (1982) An Evolutionary Theory of Economic Change. Harvard University Press, Cambridge, MA.

O'Dell, C. and Grayson, C.J. (1998) If only we knew what we knew: identification and transfer of internal best practices. California Management Review, 40 (3), 154-174.

Ohno, T. (1988) Toyota Production System: Beyond Large Scale Production. Productivity Press, Porland, OR.

Patel, V.L., Branch, T. and Arocha, J.F. (2002) Errors in interpreting quantities as procedures: the case of pharmaceutical label. International Journal of Medical Informatics, 65, 193-211.

Pentland, B.T. and Rueter, H. (1994) Organizational routines as grammars of action. Administrative Science Quarterly, 39, 484-510.

Pfeffer, J. and Sutton, R.I. (1999) Knowing 'what' to do is not enough: turning knowledge into action. California Management Review, 42 (1), 83-108.

Porter, M.E. and Teisberg, O. (2004) Redefining competition in health care. Harvard Business Review, 82 (6), 64-76.

Revere, L. and Black, K. (2003) Integrating six sigma with total quality management: a case example for measuring medication error. Healthcare Financial Management, 48 (6), 377-391.

Roberts, K.H. and Bea, R. (2001) Must accidents happen? lessons from high-reliability organizations. Academy of Management Executive, 15 (3), 70-79.

Rother, M. and Shook, J. (1998) Learning to See. Lean Enterprise Institute, Boston, MA.

Shingo, S. (1989) A Study of the Toyota Production System from an Industrial Engineering Viewpoint. Productivity Press, Portland, OR.

Shortell, S.M., Bennet, C.L. and Byck, G.R. (1998) Assessing the impact of continuous quality improvement on clinical practice: what it will take to accelerate progress. The Milbank Quarterly, 76 (4), 593-623.

Shortell, S.M., Gillies, R.R., Anderson, D.A., Erickson, K.M. and Mitchell, J.B. (2000) Remaking Health Care in America. Jossey-Bass, San Francisco, CA.

Sobek, D.K. and Jimmerson, C. (2003) Applying the Toyota production system to a hospital pharmacy. Proceedings of the Industrial Engineering Research Conference, Portland, OR.

Sobek, D.K. and Jimmerson, C. (2004) A3 Reports: Tool for Process Improvement. Industrial Engineering Research Conference Proceedings, Houston, TX.

Spear, S.J. (1999) The Toyota Production System: An Example of Managing Complex Social/Technical Systems. DBA dissertation, Harvard University, Cambridge, MA.

Spear, S.J. (2005) Fixing healthcare from the inside, today. Harvard Business Review, 83 (9), 78-91.

Spear, S.J. and Bowen, H.K. (1999) Decoding the DNA of the Toyota production system. Harvard Business Review, 77 (5), 97- 106.

Speroff, T. and O'Connor, G.T. (2004) Study designs for PDSA quality improvement research. Quality Management in Health Care, 13 (1), 17-32.

Sugimori, Y., Kusunoki, K., Cho, F. and Uchikawa, S. (1977) Toyota production system and kanban system materialization of just-in-time and respect-for-human system. International Journal of Production Research, 15 (6), 553-564.

Szulanski, G. and Winter, S. (2002) Getting it right the second time. Harvard Business Review, 80 (1), 62-69.

Thompson, D.N., Wolf, G.A. and Spear, S.J. (2003) Driving improvement in patient care. Journal of Nursing Administration, 33 (11), 585-595.

Torres, J.E. and Guo, K.L. (2004) Quality improvement techniques to improve patient satisfaction. International Journal of Health Care Quality Assurance, 17 (6), 334-338.

Tucker, A.L. (2004) The impact of operational failures on hospital nurses and their patients. Journal of Operations Management, 22 (2), 151-169.

Tucker, A.L. and Edmondson, A.C. (2003) Why hospitals don't learn from failures: organizational and psychological dynamics that inhibit system change. California Management Review, 45 (2), 55-71.

Uhlig, P.N. (2001) Improving patient care in hospital. Journal of Innovative Management, 7 (1), 23-45.

Westphal, J.D., Gulati, R. and Shortell, S.M. (1997) Customization or conformity? an institutional and network perspective on the content and consequences of TQM adoption. Administrative Science Quarterly, 42, 366-394.

Winter, S.G. and Szulanski, G. (2001) Replication as strategy. Organization Science, 12, 730-743.

Womack, J.P. and Jones, D.T. (1996) Lean Thinking. Simon & Schuster, New York.