A Test of the Design Rules in Health Care

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Abstract

This paper presents a field research study involving application of the first three design Rules-in-Use of Toyota Production System in a health care setting, which like many other health care organizations resembles a broken system. Qualitative research is used to collect the data and a combination of qualitative and quantitative approaches are used to analyze the data. A regression model reveals a significant association between proper application of the rules and outcomes of process improvement efforts. The results confirm that with some refinement, the Rules-in-Use are transportable to health care and may provide an answer to health care's systemic issues.

Keywords

Toyota, lean health care, process improvement

1. Introduction

Today, the growing body of health care literature suggests that the health care industry is in a serious crisis and does not have sound systems in place. A recent study [1] reports that nearly 100,000 people die of preventable medical related errors annually in the U.S. Many scholars attribute this poor performance of health care organizations to their inability to manage operations [2-3]. Decades earlier, in order to fix the broken systems, health care leaders had adopted different continuous process improvement initiatives such as the Total Quality Management and Six Sigma but have met with limited success. In short, systems in health care are still broken, and the industry needs a model to address them.

A third continuous improvement philosophy, lean manufacturing, also called Toyota Production System (TPS) has been gaining popularity in the U.S over the last 10 or so years because of its ability to produce the same output with a fraction of the organizational resources. Some scholars believe that TPS succeeds because of its relentless effort to eliminate waste in any form [4]. Others [5] reason that Toyota succeeds because it uses specific tools indispensable for production. In a recent study, two researchers discover that Toyota's success is not due to the specific tools. Rather they attribute its success to four so-called Rules-in-Use (we call the first three "TPS design rules" in this paper) that it uses in designing work processes [6]. 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 [7]. In fact, to our knowledge, its applicability in health care is scarce, and has very recently been applied. The central purpose of our research, therefore, is to apply the rules in a health care setting and find if the three TPS design rules are indeed applicable, and if so, why. The second objective is to refine those design rules in light of their applicability in health care.

This paper is structured as follows. We start a review of the relevant literature, and then explicate the TPS design rules or constructs as propounded by Spear and Bowen and the related hypotheses. Next, we propound our research approach. This section develops measures for the constructs and we provide explanation on how we developed those measures. We then analyze the data and report our findings. The results of our analysis suggest that the three TPS design rules with some refinement are transferable outside manufacturing, i.e., health care, and may be at least a partial answer to fixing its broken systems.

2. Literature Review

Leading scholars describe work in organizations in terms of "routines" as a "repetitive pattern of activity in an entire organization" [8]. Since the evolution of the concept more than twenty years ago, many researchers have studied and researched its various characteristics. Despite extensive studies on routines and their pervasive nature in organizations, they have still been difficult to conceptualize [9]. These studies on routines are riddled with ambiguities and their effects are less understood [10]. Furthermore, if we try to understand how routines are constructed or if we want to imitate the same routine in a different setting to achieve a similar level of performance, we can't replicate it exactly or easily [11-12] because we do not have satisfactory knowledge about its inner working. Nonetheless, with the rapidly changing global marketplace and increased market demands, change of routines has become mandatory to meet those demands.

One of the noteworthy contributions of the past research on routines has been the conceptualization of routines to explain organizational change [9,13]. Some scholars offer the concept of meta-routines to explain organizational change. Meta-routines, they define, are standardized procedures for changing existing routines and for creating new routines. From their empirical work at New United Motor Manufacturing, Inc (NUMMI), a Toyota-General Motors joint venture, they note the usage of meta-routines by the workers to change routines thus remaining creative in work [14]. These research findings are corroborated by Spear and Bowen's work who, from their 4-year field research, observe that Toyota and TPS driven plants are successful because they use three Rules-in-Use for designing organizational routines and a meta-routine (a fourth Rule for changing routines through problem solving) for improvement and adaptation. This paper concerns the first three TPS design Rules-in-Use that Toyota and TPS driven organizations use to create new routines or to improve old ones.

2.1. Spear and Bowen's Design Rules-in-Use

Spear and Bowen posit that Toyota designs production systems around three basic building blocks: activities, connections, and pathways. Each building block can be construed as a different type of routine. The design Rules-in-Use provide guidance on how these three routines should be designed for gaining maximum efficiency.

The first building block, an activity, is defined as work tasks that people or machine do to transform materials, information or energy. Toyota specifies an activity in terms of four parameters: content, sequence, timing, and outcome. Content refers to the specific tasks within an activity. Sequence refers to the sequential order in executing the tasks. Timing refers to the time taken by individual tasks, and outcome refers to the results of the task. Spear and Bowen define Rule 1 as:

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

The second building block, a connection, is the mechanism by which adjacent customers and suppliers transfer material, information, and energy. Thus, Spear and Bowen define Rule 2 for connection as:

> **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 create and deliver goods, services, and information. Thus Spear and Bowen define Rule 3 as:

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

Spear and Bowen's research posits some basic principles to understand the inner working of routines better. What makes their study stand apart from others is that the design rules capture in sufficient depth the specificity that is needed in describing the inner working of a routine. Yet, they are simple to understand and are actionable in real world settings, suggesting that these principles are transferable not only across organizational boundaries but also across diverse sectors, thus alleviating the difficulties associated with transferring the best practices or routines to another setting.

2.2 Hypotheses

Our initial work in the research site suggests that nearly all failing processes can be explained by a violation of one or more of these design rules, resulting in errors and wasted time and resources. Based on our field investigations, we induce three hypotheses related to the Rules-in-Use.

> **H1:** Increased activity specification leads to better process outcome in a health care setting.

> **H2:** Increased connection clarity leads to improved process outcome in a health care setting.

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

3. Research Approach

The setting of this research was Community Medical Center (CMC), a 137-bed facility located in Missoula, Montana, offering services in obstetrics, pediatrics, rehabilitation, surgery, neonatal intensive care, nuclear medicine, emergency, cardiology, and general medical care.

3.1. Data Collection

The first author stayed for nine months in CMC and spent approximately 1600 hours studying work processes, conducting action research, and then performing formal research. In the first stage he observed work processes across functional specialties, coaching participants at every level, and assisted them in conducting problem solving. In the second stage (June-August 2004), he formally selected and interviewed 18 participants (purposive sampling) from various functional departments who had attempted to solve process-related problems. Prior to the interview, an expert checked the questionnaire for validity. The questions were based on the research question posed in the study. At each interview, the first author asked specific questions about "activity", "connection", and "pathway" and a few open-ended questions were also asked to augment understanding. After the interview, he typed an interview report based on notes and his memory and gave it to the informants to check factual errors. In all the cases, the informants reviewed and approved the document within 48 hours. As the interviews were based on the problem they addressed using an A3 report, he collected the A3 report and other artifacts from each informant for triangulation.

3.2. Case Development

First, we developed eighteen case reports based on all the artifacts that were available: (1) the interview reports, (2) A3 problem solving reports, (3) minutes of meetings, (4) policies and procedures, and (5) 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 provided us with a comprehensive account of the problem we 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. As a check on the adequacy of the case reports, an expert read each case. 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.

3.3. Quantification of Variables

For this study, we defined three-independent variables - activity specification, connection clarity, and pathway simplification - and one dependent variable, the degree of change realized from each case as a part of the problem solving effort. In the following sections, we describe the four variables and the quantification process.

According to Spear and Bowen, workplace activities shall be specified in terms of four parameters: content, sequence, timing, and outcome. To measure the change in specificity for those activities addressed during problem solving, we compared the states of each parameter before and after problem solving. If the understanding of the "content" in 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, or to a level covered by codified policies and procedures, and thus the tasks needed to be accomplished for an activity became more explicit and clear to all, we interpreted that as an increased activity specification for "content" and assigned a score of "1" to that parameter. This process was repeated for the three other parameters. The scores of each parameter were then totaled to obtain a measure of change in activity specification on a range of "0" (which meant no change in the level of specificity in any parameter) to "4" (which indicated increased specification in all four parameters).

We define "connection clarity" as the mechanism by which a supplier transfers materials, patients, services, and information to an adjacent customer. Through our action research in the hospital, 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 - requester alerted when the goods or services are delivered by the responder and/or the responder knowing the request has been made; and
- response time - time to meet such requests by the responder.

We measured change in connection clarity in terms of above parameters in a manner similar to activity specification. For example, if the understanding of "requester" moved from an individual discretionary level (i.e. anybody can request goods or services in place of a designated individual) to a group consensus level, or to a level covered by codified policies, and thus became amply clear to all on who should request, we interpreted that as an increased connection clarity. In such case, we assigned "1" to that parameter. The process was repeated for the other four parameters. The individual scores were summed up to get a total score which varied between "0" (no change in any parameter for connection clarity), and "5" (which suggested change in all five parameters). If a case addressed multiple "connection clarity" related problems, we computed the mean value for total scores of each connection addressed in that case.

Based on Spear and Bowen's research, we define a pathway as a series of connected activities that create and deliver goods, services, or patients. Extending Spear and Bowen's characterization of a "simple" and "direct" pathway based on our action research, we define "pathway simplification" in terms of three parameters - branches, loops, and delay:

- branched pathway - supplier uses two or more paths to deliver goods or services to the adjacent customer in the process chain;
- looped pathway - a sequence of steps that is repeated until a particular condition is met; and
- delay - goods and services do not proceed immediately to the next process step.

Like "activity specification" and "connection clarity," we followed a similar procedure to measure the change in pathway simplification. We compared the before and after states of the pathway to measure the change in pathway simplification as a result of problem solving. If we observed a simplification of multiple paths (individuals followed two or more paths to deliver goods or services based on their personal discretion) to a single path (path designated by a group of individuals to deliver goods or services) due to problem solving and thus became explicit to all, we assigned "1" to that parameter. This exercise was repeated for loops and delays as well. The scores of each parameter were then summed up to obtain a measure of change in pathway simplification that varied between "0" (which meant no change in pathway simplification) and "3" (which indicated increased simplification in all of the three parameters).

Finally, 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 from one case to another. These variations include 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 the change in performance. 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.

4. Results

In total, 18 cases were studied. Two cases were excluded from the final analysis because the participants in those cases were still implementing the actions when reviewed last by the first author. Therefore, no results were available for analysis. The participants in the remaining cases addressed either one, two, or all three independent variables depending on the problems they studied.

The correlations among the variables were first calculated. The results indicate that the activity specification ($r = 0.764$, $p<0.01$) and pathway simplification ($r = 0.653$, $p<0.01$) are significantly correlated with the outcome. The connection clarity is positively correlated but moderate ($r = 0.445$, $p = 0.08$). However, given the nature of qualitative data used in the analysis, such p values cannot be ignored. A strong positive correlation exists between connection clarity and pathway simplification ($r = 0.827$, $p<0.01$) suggesting collinearity. Specifically, connection is the interaction between two adjacent suppliers and customers in the pathway, and pathway is a series of connected activities. In essence, connection clarity is confounded within pathway simplification.

As problem-solving outcome (dependent variable) depended on activity specification, connection clarity, and pathway simplification (independent variables), we conducted a multiple regression analysis on the 16 cases. In cases where an activity, connection or pathway was not addressed during problem solving, we assumed “no change” in those un-addressed parameters and used “0” for subsequent computation. Prior to running the regression analysis, the linearity of each independent variable with respect to the outcome variable was checked by drawing the bivariate scatter plot. The plots showed linearity. The normality of the data was ascertained statistically for each construct and the variables conformed to normality assumptions of regression analysis. Using Minitab 14.0 software, we constructed three models and performed three multiple linear regression models with outcome as the dependent variable and activity specification, connection linearity, and pathway simplification as independent variables. The regression results are summarized in Table 1.

Table 1. Results of regression analysis

Variable	**Model 1**	**Model 2**	**Model 3**
Activity Specification	0.186***	0.158***	0.157***
Connection Clarity	0.075*		0.000
Pathway Simplification		0.124**	0.124
R^2	0.69	0.733	0.733
Adjustment R^2	0.642	0.692	0.667
F	14.44***	17.89***	11.01***

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

The first model includes the activity specification and connection clarity as the independent variables and outcome as the dependent variable. The activity specification is found to be a significant predictor of outcome, thus lending significant support to H1. The connection clarity also predicts outcome, though weakly supporting the H2. The overall model is significant. The first model explains 69% of the variation in the outcome with an associated significance at p<0.01. The second model displays activity specification and pathway simplification as the independent variables and outcome as the dependent variable. The activity specification is a significant predictor of outcome, thus H1 is supported. Pathway simplification is also a significant predictor, thus supporting H3. The overall model is significant and explains 73% of the variation in the outcome at p< 0.01. The third model includes all the variables (independent and dependent). The activity specification is a significant predictor, thus supporting H1. The other two variables are insignificant predictors of outcome, most likely due to collinearity. The model explains 73% of the variation in outcome at p< 0.01. Though all the models are significant, the second model provides the best explanatory power for the variation in outcome, as indicated by the adjusted R^2 statistic.

5. Discussion

This paper points to a number of interesting and potentially important findings that can advance theory and inform practice. First, we examined the impact of increased activity specification on outcome and the empirical results (regression models 1, 2, and 3) provide evidence of strong positive association, thus supporting H1. It is implied from Spear and Bowen’s work that in specifying an activity, one would first define content, next sequence, and then timing. Undoubtedly, a high level in specificity is achieved when the tasks within an activity are timed. After all, timing of tasks is a critical aspect of superior performance. In a manufacturing set up, such specificity sounds logical and possible because processes are usually repetitive in nature and every task is very well defined. However, findings of our research suggest that for health care, increasing specification of activities seems to improve process performance even if timing is not done.

The results of the first regression model suggest that connection clarity moderately supports H2 (i.e., increased connection clarity leads to better process outcome). Our classification of “connection clarity” in terms of five distinct parameters (Requester, Responder, Method of Transfer, Notification, Response Time) is more effective in building better connections than the characterization (direct, send, and receive) provided by Spear and Bowen, thus refining their description of connection to suit the health care context.

The results of the second regression model indicate positive association between increased pathway simplification and outcome, thus lending support to H3 that increased pathway simplification leads to better process outcome. Spear and Bowen describe the ideal pathway as “simple” and “direct.” We defined the term “pathway simplification” in terms of “branch”, “loops” and, “delay” because such characterization closely resembled the pathways we observed and it was much simpler for us to compare changes due to problem solving using those terms.

The second regression model provides the best explanation for the variation in the outcome. In other words, specifying activities and simplifying pathways will lead to improved results. However, simplification of the pathways was possible because many unclear connections within the pathway were addressed during problem solving. In fact, the correlations between pathway simplification and connection clarity were found to be highly significant ($r = 0.827$ at $p < 0.01$). Put another way, designing activities and developing clear connection through our characterization will essentially lead to simplified pathways and improved outcome.

6. Conclusions

Our study provided several important contributions to the existing body of literature. Notably, by using TPS design Rules-in-Use in a non-manufacturing environment, i.e., health care, we extended and validated Spear and Bowen's model. We found that outcome of a process is positively related with design Rules-in-Use. Thus, an increase in activity specification, connection clarity, and pathway simplification is associated with improved performance. We refined their characterization of connection and pathway for use in a health care context. We induced the term "connection clarity" and "pathway simplification" to develop robust and clear connections and to create simplified pathways in a health care context respectively. We also attempted to define activity specification, connection clarity, and pathway simplification on a continuum to measure change. Though we agree such quantification to be a crude measure of performance, nonetheless it provided us with an objective way of comparing the before and after states of a process due to problem solving.

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References

1. 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.
2. Tucker, A.L., 2004, The impact of operational failures on hospital nurses and their patients, Journal of Operations Management, 22(2), 151-169.
3. Thompson, D.N., Wolf, G.A., and Spear S.J., 2003, Driving improvement in patient care, JONA, 33 (11), 585-595.
4. Womack, J.P., and Jones, D.T., 1996, Lean thinking, New York, Simon & Schuster.
5. Cusumano, M.A., 1988, Manufacturing innovation: Lessons from the Japanese auto industry, Sloan Management Review, 30(1), 29-39.
6. Spear, S.J., and Bowen, H.K., 1999, Decoding the DNA of the Toyota Production System, Harvard Business Review, 77(5), 97-106.
7. 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.
8. Nelson, R., and Winter, S.G., 1982, An evolutionary theory of economic change, Cambridge: Harvard University Press.
9. Feldman, M.S., and Pentland, B.T., 2003, Reconceptualizing organizational routines as a source of flexibility and change, Administrative Science Quarterly, 48, 94-118.
10. Becker, M.C., 2004, Organizational routines: A review of the literature, Industrial and Corporate Change, 13(4), 643-677.
11. 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.
12. Szulanski, G, and Winter, S., 2002, Getting it right the second time, Harvard Business Review, 80(1), 62-69.
13. Feldman, M.S., 2000, Organizational routines as source of continuous change. Organization Science, 11(6), 611-629.
14. 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.