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The DNA of Toyota Revisited: Issues and Challenges of Lean Implementation

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INTRODUCTION

Lean manufacturing has been long hailed as the source of Toyota's outstanding performance as a manufacturer (Spear and Bowen, 1999; Shah and Ward, 2003). The distinctive practices behind the prosperity of Toyota have been widely analyzed and documented. Hundreds of thousands of managers have toured Toyota plants to look for the secrets of Toyota's success. Sparkled by the superior performance thousands of firms in diverse fields have attempted to emulate observed shop-floor tools and techniques. However, so many of these early efforts showed only localized impact and fell short to generate competitive advantage (Spear and Bowen, 1999; Holweg and Pil, 2001; Childerhouse and Towill, 2004).

In this period the main shortcoming of successful Lean implementation was adopters' focus on tools and techniques. This view however was missing any explanation of how these individual tools and techniques function as an integrated system that stimulates workers to constantly challenge activities and processes to a higher level of performance. This is why Spear and Bowen (1999) attempted to codify the Toyota Production System, aka Lean Manufacturing. They describe four principles: three rules of design, which show how Toyota sets up all its operations as experiments; and one rule of improvement, which describes how Toyota teaches the scientific method to workers at every level of the organization. To reflect that these patterns guide behavior though they are not stated outright Spear (1999) has termed them "Rules-in-Use". They state that: 1) all work shall be highly specified as to content, sequence, timing, and outcome; 2) every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses; 3) the pathway for every product and service must be simple and direct; and finally 4) any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization. According to Spear and Bowen

(1999) it is these four Rules, and not the individual tools and techniques, that form the essence of Lean manufacturing.

However, despite these efforts to unveil what Lean manufacturing is and how it works companies in diverse fields still struggle to replicate Toyota's success (Childerhouse and Towill, 2004). Results of numerous surveys shockingly show that two thirds of the industrial sample is still struggling with Lean implementation (The Lean Manufacturing Report 2007). This triggers a question what causes such shortcomings. Proponents of the Rules-in-Use would argue that the shortcomings lie in the adopters not devoting enough time and energy to mastering these Rules. Though, there has been limited research to validate this proposition. In fact to this end no study appears to even verify the unsubstantiated conclusions of Spear's seminal work (1999).

Such gaps exist in many fields of scientific inquiry, including operations management, mainly because scholars focus more on the development of new theories rather than on the extension and validation of existing work (Berthon et al., 2002). Starting from these considerations the motivation for this research is to close this gap by replicating the original study. It aims to determine whether the findings of Spear's seminal work (1999) are still applicable when the study is repeated a decade after publishing the Rules for general consensus. So doing will not only increase the validity of these Rules, which is a major weakness of many published studies in operations management, but also extend the original findings with observations from the studied context – British automotive engine industry, given a 10-year lag.

This paper is based on a broader research project investigating number of plants. Due to the given limitation of a conference paper it however only presents a single case study of a

leading automotive engine re-manufacturer. The structure of the paper is as follows. First, it describes connections to currently available literature. Second, it addresses the methodology of the study, including the research design used to address the research questions. Next, it presents the data collected through first hand participation in and observation of work at the studied company. And finally the implications, contributions and limitations of this paper are highlighted.

LITERATURE REVIEW

The original streams of inquiry in the administrative theory literature focus on technical levers. However from 1974, when Skinner published “The Focused Factory” to 1988 when Hayes et al. published “Dynamic Manufacturing”, there was a pronounced change in how academics framed the challenges posed in managing organizations that produce and deliver goods, services, and information. As a result the original perspectives shifted to issues of individual and organizational learning, problem solving, process improvement, and effective coordination.

This research will build upon these later precedents, in particular on the perspectives succinctly expressed by Jaikumar who concludes that the new role of management in manufacturing is to create and nurture project teams whose intellectual capabilities produces competitive advantage. Thus what gets managed is intellectual capital, not equipment (Jaikumar, 1986). Automotive industry studies reach similar conclusions. Academics make persuasive arguments that there is pronounced difference between the performance of Toyota plants and those of its competitors (Cusumano, 1988; Krafcik, 1988; Womack, Roos and Jones, 1990). This difference in cost, quality, efficiency, and flexibility are directly attributable to differences in management systems within the individual plants. Through these

distinctive managerial practices, Lean offers advantages both to employers and to employees (Adler, 1993).

More specifically, Cusumano (1988) attributes the superior performance to process innovations that led to greater flexibility in equipment and labor, lower in-process inventories, and higher overall turn over rates, more attention to process quality, and ultimately, higher levels of productivity. Some of the innovations identified by Cusumano include the pull system and the removal of intermediate inventories in the engine plant; the introduction of the kanban system; synchronization of body and final assembly shops; lights to indicate problems; company wide small lot production; increase in worker flexibility; and set-up time reduction. In his account of Lean tools and practices, Cusumano emphasizes elements of Just in Time production. However, he does not include other tools considered critical elements of the Toyota Production System.

Separately, Krafcik (1988) identifies differences among production systems and distinguishes between craftsmanship, Fordism, and Toyota Production System. He finds differences in work standardization, worker span-of control, inventory levels, buffers, repair areas, and teamwork. These differences include many of the features associated with Lean Manufacturing such as small inventories and buffers, team-based problem solving, cross training, and moderate spans of control.

These findings from automobile assembly plants were extended by the book “The Machine that changed the world” (Womack, Roos and Jones, 1990), to include product design, supply chain management, and customer relations. This research played a tremendous role in showing that differences in management practices cause superior organizational performance.

In turn, this research explored the fundamental principles underlying the tools such as kanban and pull systems; and practices such as work standardization, moderate spans of worker control, small buffers and repair areas, and high teamwork.

Adler (1993), in particular, has explored the issues affecting the experience of workers in organizations managed according to the Toyota Production System. He makes the case that the productivity advantages provided by Lean manufacturing to the employer are not gained at the expense of employees. Rather, the employer enjoys the advantages of low cost, high quality, and flexibility identified by the previously cited researchers while at the same time, employees gain greater motivation and satisfaction than offered in other systems. Furthermore, Alder, provides insights into the use and effect of standardized work as a critical feature of Lean manufacturing.

RULES-IN-USE

The research of Spear and Bowen (1999) builds upon the insights of the preceding findings by providing actionable guidelines to generate competitive advantage. The suggested Rules add to the earlier findings by explaining the extent to which work is standardized, and by codifying the routines and other learning mechanisms. Table 1 presents the role of each of these Rules.

Table 1. Role of each of the Rules-in-use (Spear, 1999)

	<i>Design</i>	<i>Operation</i>	<i>Improvement</i>
<i>Activities</i>	Rule 1		Rule 4
<i>Connections between Activities</i>	Rule 2		
<i>Flow-paths</i>	Rule 3		

Rule 1 – Activity Design and Operations

First of the Rules guides the design and performance of work activities done by people and machines that transform material, energy, and information. It plays a critical role in creating opportunities for problem solving and learning. It reflects that performing an activity is a mean to verify the assumptions implicit in the design of the activity. Thus when Rule 1 is followed, every activity is performed as an experiment and it is an information source about the process and the person doing the process.

Colocating activity, monitoring, and response has number of consequences. First, it keeps the physical doing of an activity and the information about the activity coupled together. This is particularly important for control and improvement. Second, it ensures that all outcome sent from one activity doer to another is as expected. And finally, it provides each activity doer with the means to determine if he has or has not performed his work in a way that contributes to meeting the needs of the firm's external customer.

Rule 2 – Connection Design and Operations

The second Rule guides the design and operation of the connections through which adjacent customers and suppliers transfer material, energy, and information. It is the guideline for designing and operating the interface between each customer and supplier. It requires that requests travel directly from customer to supplier and that responses travel directly from supplier to customer over the same pathway. Connecting customer and supplier directly reduces the risk that the supplier receives multiple, possibly conflicting requests.

Furthermore, following the second Rule customer's request must be interpretable as a simple signal to DO or DELIVER goods, service, or information in a pre-specified form, quantity,

and response time. Likewise, the supplier's response must be interpretable as a signal that the delivery activity has been DONE, providing the goods, service, or information in the pre-specified form, quantity, and response time.

Rule 3 – Pathway Design and Operations

The third Rule guides the design and operation of the pathway over which the final goods, service, and information are created. It plays an important part in reducing the number of interactions in the system, thus making the cause and effect more obvious, reducing cognitive burdens, and decreasing the difficulty of system operation and improvement. Rule 3 also determines that every good and service must have one and only one pathway over which it can travel as it takes form. By requiring that every pathway be specified, the third Rule ensures that an experiment will occur each time the path is used.

Rule 4 – Activity, Connection, and Pathway Improvement

And finally, Rule 4 provides a standard to judge the merit of improvement efforts and it prescribes a mechanism for improvement. The mechanism for improvement is also the mechanism by which people are trained. Therefore Rule 4 plays a critical role in developing an ability to design, operate, and improve.

Furthermore, according to Rule 4 all improvement efforts are attempts to improve toward the individual activities and systems of activities in order to always produce and deliver goods, service, and information that are IDEAL, namely: a) defect free; b) always produced and deliver on-demand; c) in batch sizes of one; d) with immediate response to customer's requests; e) with no waste; and finally f) with no threats to the supplier's physical, emotional,

or professional safety. And thus every improvement effort is to be designed as an experiment of specific changes moving an activity, connection, or pathway closer to the IDEAL.

Summary

Despite these attempts to unveil what Lean manufacturing is and how it works, Spear and Bowen (1999) did not discuss the underlying assumptions of their conclusions. Further more they fail to validate or verify the unsubstantiated conclusions, leaving this theory scientifically unfinished. However, without verification and validation of these findings adopters have no way of ensuring that devoting time and energy to mastering these Rules will deliver expected performance advantages. In order to close this gap, this research sets to empirically validate the rules.

RESEARCH METHODOLOGY

The primary goal of this research is not theoretical discovery. It rather aims to verify and elaborate upon existing theory developed by Spear and Bowen (1999) in the specific context of British automotive engine industry given a 10-year time lag. This industry was chosen mainly because Britain leads as a global centre of excellence for automotive engine production (Success and Sustainability in the UK Automotive Industry, 2006), which increases the likelihood of finding plants complying with observable traits.

Research Design

Having recognized that the analysis of adopter's operations cannot be detached from the context in which Lean manufacturing is applied, and following the philosophical issues underlying management research, the authors accepts the social constructionism view. This view stems from the idea that the reality is not objective and exterior, but is socially

constructed and given meaning by people. The idea of social constructionism then, focuses on the ways that people make sense of the world especially through sharing their experiences with others via the medium of language.

Accepting this particular epistemological position leads social scientists to adopt methods characteristic of that position. Here the case study was chosen as the research method due primarily to the nature of the research questions (Yin, 1994). Yin (1994) recommends this method, as the most appropriate when contextual conditions are believed to be highly pertinent to the phenomenon of study.

Data collection

Replication has been identified as an acceptable method when verifying and extending the tenets deduced by the original study in a specific population and context (Tsang and Kwan, 1999). Typically, the aim of replication research has been to determine whether the findings of one study are applicable when the study is repeated. Since this research sets to verify the above described Rules-in-Use in a specific context it will analyze adopter's operations along dimensions comparative to Spear's seminal work (1999). These dimensions, deduced from the Rules, are as follows:

- Is work highly specified as to content, sequence, timing, and outcome?
- Is every customer-supplier connection direct, with an unambiguous yes-or-no way to send request and receive response?
- Is the pathway for every product and service simple and direct?
- Is improvement made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization?

Through the extensive observations Spear (1999) concluded that it is not to say that following the Rules-in-Use is strictly a yes or no proposition. The degree to which individuals and groups follow each of the four Rules varies even at Toyota plants. This however appears to depend on managerial factors (experience, motivation, skill) rather than on technical (product, process) or market (mix and volume of customer demand) factors (Spear, 1999). And thus beside classic replication (Frohlich and Dixon, 2006) a further aspect of this research aims to understand factors affecting the applicability of these Rules in the selected context.

CASE STUDY – BRITISH AUTOMOTIVE ENGINE RE-MANUFACTURER

This paper is based on a broader research project investigating number of plants in the British automotive engine industry. Due to the given limitation of a conference paper it however only presents a single case study of a British automotive engine re-manufacturer. Automotive engine re-manufacturing has been selected because re-manufacturing is the ultimate form of product recycling. It balances products within their life-cycle with minimum energy, material resource and emissions, all of which are considered to be a critical part of a sustainable policy (Automotive Parts Remanufacturers Association, 2009).

After providing brief background information on the studied company, this section presents answers to each of the exploratory research questions presented above. Data to provide these answers were collected by one of the authors who became part of the studied context for a period of 18 months. Selected extensive data collection efforts enabled not only to understand in detail how the studied company designs, operates, and improves activities, connections, and pathways but also factors affecting the applicability of these Rules in the selected context.

Company background

The studied company is currently the largest independent automotive engine re-manufacturer in Europe. It works on behalf of the Original Equipment Manufacturers (OEMs) such as Ford, Jaguar Land Rover, Aston Martin, and others. The company specializes in re-manufacturing of automotive engines with capacity ranging from three to eight cylinders. Herewith it overhauls a wide range of light, medium and heavy-duty vehicle applications. It employs seventy-four direct employees in a one-shift pattern to deliver the current average daily output of thirty-five engines. The company started with Lean implementation in 2002 when changes such as re-structuring to dedicated value streams or re-laying the factory floor according to Lean principles took place. The resulting main flow of its re-manufacturing process is generic for all value streams and is composed of following operations: engine strip and clean; machining of engine components; assembly; test; paint; and finally pack. Engine strip, clean and component machining are operations particularly focusing on recovery of material from used engines. The content of these operations, which are representative of a re-manufacturing facility, are highly dependent on the state of these incoming engines. Further downstream operations however are identical to other engine assembly plants.

Q1: Is work highly specified as to content, sequence, timing, and outcome?

The detailed observation of material recovery demonstrated that the pre-determined flow-path of individual components is very often affected by the contamination of used engines. While studying the work of operators in the cleaning area, the author observed that the effect of each cleaning operation is evaluated by the operator performing the operation at the time when and the place where the operation occurs. However, if the operator identifies that the component does not match the expected outcome due to excessive contamination, he repeats the cleaning

operation in order to deliver the expected outcome. The time of the additional cleaning cycle is unpredictable and highly dependent on the contamination of the incoming engine.

More specifically, let us consider how an operator removes drain plugs of a BMW cylinder head at strip. The work is designed as a sequence of 10 steps, all of which are expected to be completed in 1 minute and 57 seconds. However, if the incoming engine was in particularly bad condition this operation may take up to 10 minutes, even though the operation is performed as it was designed to be done.

Thus following Spear's (1999) reasoning the operations at the studied company are highly specified as to content, sequence and outcome. Meaning that if the actual outcome does not match the expected outcome, activities to remediate the output to satisfy expected result are triggered. However, due to the nature of the re-manufacturing operations the outcome of certain operations is not always delivered in the specified time. This means that improving operations so that they are capable of producing the expected outcome, will not necessarily deliver the expected outcome in the specified time.

Q2: Is every customer-supplier connection direct, with an unambiguous yes-or-no way to send request and receive response?

Where the first question analyzed how people work, the second question analyzes how they connect. According to Spear's (1999) observations connecting two activities directly, through a clearly defined, over-lapping request and response channels reduces the risk of receiving multiple, possibly conflicting requests.

Let us return to the operator on the strip. When he needs any of the scrap bins to be emptied, he gives a request to a material handler, who is the designated person to remove scrap. Such a request is however only verbal on delivery of the next engine for strip. As a result, even though there are no gray zones in deciding who provides what to whom and when, the request is not as unambiguous as it would be with a kanban card.

The possibility of variance is further extended by the way people respond to requests. That is especially true in service requests. An operator encountering a problem is expected to ask for assistance. The designated assistant is then expected to respond immediately and resolve the problem. However, there is no time frame specified within which the problem is to be resolved. Thus failure to resolve a problem in less than the cycle time does not challenge the hypothesis of the customer-supplier connection for service. Even though these observations reflect a theme common to the second Rule, they also unveil that the expected time in which request will be met is not specified.

Q3: Is the pathway for every product and service simple and direct?

According to the Rules all production lines at Toyota are set up so that every product and service flows along a simple specified path. This was also observed at the studied company, where every engine follows a dedicated re-manufacturing process. To provide a concrete idea of what that means, let us return to the operator on strip. If any of the engine components fall out at strip, he gives a request to a specific material handler. He immediately requests injection of the same component from the over-strip supermarket, which results in a request to over strip a particular engine variant. In this way, the system directly links operators who contribute to the product to those who support the production.

This however does not only apply to products. If the operator on strip needs assistance in the course of performing his work it only comes from his cell leader who responds to this request. If he cannot provide the necessary assistance, he in turn triggers help from the value stream manager. This means that there is a clear assignment of responsibilities as to who is to help when. Thus assistance, similarly to products, does not flow from the next available person but from a specific person.

Q4: Is improvement made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization?

The studied company shows many features of Lean manufacturing. However, the major problem is that the value added time is only a fraction of the total lead-time required to provide a remanufactured engine to the customer. Since deliveries of new material and engine core are customer's responsibility and so out of company's control, for managers shortening the total lead-time is doubly problematic. Nevertheless, the study of on-site processes discovered a problem that could be remedied on site. This study led to development of an over-strip supermarket, which stored parts with high fall out rate and low injection rate. As a result significant reduction of wasted effort in processing unnecessary engine components was achieved.

From the observation it also became evident that the development and implementation of the over-strip supermarket was achieved by the way cell leaders and operators are trained on how to identify problems and develop counter-measures to eliminate them. This makes the operators not only capable of but also responsible for doing and improving their own work. However, despite closely collocating the design of work and the doing of work, improvement

activities at the studied company do not show any traces of the scientific method as described by Spear (1999).

Summary

In summary the case study describes how work is specified; how internal customers and internal suppliers connect; what is the pathway for every product and service; and finally how improvement is made and guided. Moreover it shows that improvement efforts at the studied company are attempts to improve toward defect-free product produced and delivered on-demand with no waste. Whenever there is any specific problem, which causes defects, wastes material, motion, or energy the company introduces a countermeasure to eliminate the particular problem so that production and outcome are closer to their initial anticipation. However, despite these efforts the way people work, connect and improve their work at the studied company shows differences to what Spear describes in the Rules. These differences will be discussed in the next section.

RESULTS AND ANALYSIS

Spear and Bowen (1999) suggest that the Rules-in-Use are the systemic framework that underpins Lean tools and techniques. They explain the extent to which work is standardized and codify the routines and other learning mechanisms of Toyota. The first of these Rules states that all the work shall be highly specified as to content, sequence, timing, and outcome. The second and third Rules concentrate on the connection between activities and pathway respectively. These Rules state that every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses; and that the pathway for every product and service must be simple and direct. The last of these Rules

states that any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization.

The extensive study, presented above, reveals that the studied company has many features in common with those described in the Rules. It pays significant attention to a) standardizing work; b) connecting internal customers and internal supplier; and c) specifying simple and direct pathway for every product and service, all in order to achieve expected outcome. However, the study also shows that due to the nature of re-manufacturing operations work cannot be fully specified for time. This is because the state of incoming used engines determines the level of contamination of certain components, which results in inconsistent times of certain operations. Specifying the time exactly will result in over processing of the majority of components and still under processing of a few. This observation hence refutes the first of the Rules for this re-manufacturing environment. It suggests that when recovering material from any used product work shall be highly specified only as to content, sequence and outcome.

Observation also shows that time is also not specified when it comes to the connection between internal customers and internal suppliers. Even though there are no gray zones in deciding who provides what to whom, the timing of the delivery is not specified to be within the cycle time. This is a result of the variability in time required for material recovery, which again results in a contradiction to the Rules-in-Use.

Furthermore in contrast to the Rules the studied company does not create a community of scientists. To make changes it does not use a rigorous problem solving process, which in effect is an experimental test of proposed changes. Nevertheless when making improvements

it assesses the current state of affairs and plans for improvement. Indeed, observation of operators doing their work revealed that the studied company actually does stimulate operators to constantly improve their work, which Spear and Bowen (1999) recognize as the distinguishing factor between Toyota and adopters of Lean. Table 2 summarizes above presented observations and provides direct comparison to the Rules-in-Use.

Table 2. Summary table: comparison of the findings from the case study to the rules-in-use

	Rules-in-Use	Case study observations
1	all work shall be highly specified as to content, sequence, timing, and outcome	work is specified as to content, sequence and outcome though due to the nature of re-manufacturing environment processing time of certain operations is not specified
2	every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses	even though the customer-supplier connections are direct, the way to send requests and receive responses is not unambiguous and specified for time
3	the pathway for every product and service must be simple and direct	there is a simple, direct, and pre-specified pathway for every product and service
4	any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization	improvement as well as the resolution of problems is guided and pushed to the lowest possible level but not in accordance with the scientific method

CONTRIBUTIONS, LIMITATIONS, AND DIRECTION FOR FUTURE RESEARCH

Since until now no study verified the unsubstantiated conclusions of Spear's seminal work (1999), the objective of this research is to empirically validate the Rules-in-Use in the specific context of a British automotive engine industry given the 10-year lag. Using replication research, this paper evaluated the validity of these Rules using similar data and similar methods in a single case study. Operations of the studied automotive engine re-manufacturer were systematically compared to the dimensions presented in the initial study.

The findings of this research support Spear and Bowen (1999) conclusions that adopters have some features in common with those specified in the Rules. However, they also report the presence of conflicting evidence that questions the applicability of these Rules in the re-manufacturing environment. The findings suggest that when recovering material the work shall only be highly specified as to content, sequence, and outcome while leaving time as a fluctuating variable. Hence, according to the classification schemes of replication studies as proposed by Tsang and Kwan (1999) and Berthon et al. (2002), this research can be categorized as a replication study that extends the initial framework.

In addition to reporting observed similarities and dissimilarities with the Rules, the paper also explains how these are affected by the studied context. These findings in essence could be generalized to a population of similar contexts (Samaddar and Kadiyala, 2006). The authors however accept the use of a single case study to gather data as one of the limitations of this research. Nevertheless at the same time they point out that participation and participant observation on a large scale would be costly, time consuming and so highly problematic.

Although Spear and Bowen (1999) emphasize that companies dedicated to mastering the Rules have a better chance of replicating Toyota's success, they have not directly investigated an example that has all features in common with those described in the Rules. Since this research quite similarly fails to do so, to confirm or refute this proposition calls for further research in this area.

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