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Structural Equation Modelling based Empirical Analysis of Technological Factors for Lean Implementation

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Abstract

The purpose of this paper is to explore the technological factors towards successful implementation of lean manufacturing (LM). An extensive literature survey is carried out. An attempt is made to build an exhaustive list of all the input manifests related to the technological factors necessary for LM implementation, coupled with a similar exhaustive list of the benefits accrued from its successful implementation. A structural model is thus conceptualized, which is empirically validated based on the data from the Indian manufacturing sector. This empirical research is thus carried out in the Indian manufacturing industries. The structural model presented in this paper may be treated as a guide to integrate the technological factors to successfully implement lean, leading to an optimum utilization of resources. This work is one of the very first researches to have a survey-based empirical analysis of the role of such technological input factors towards an effective lean implementation in the Indian manufacturing sector.

Keywords: Lean Manufacturing, Lean Implementation, Technological Factors, Structural Model.

1. Introduction

Lean Manufacturing (LM) focuses on maximizing customer value while minimizing waste. In other words, LM helps to create more value for customers with fewer resources. A lean organization understands customer value and its key processes are focused to continuously increase it. The ultimate goal is to provide perfect value to the customer through a perfect value creation process that has minimum waste. To accomplish this, lean thinking changes the focus of management from optimizing separate technologies, assets and vertical departments to optimizing the flow of products and services through entire value streams that flow horizontally across technologies, assets and departments to customers. Eliminating waste along entire value streams, instead of at isolated points, creates processes that need less human effort, less space, less capital, and less time to make products and services at far less costs and with much fewer defects, compared with traditional business systems. Companies are able to respond to changing customer desires with high variety, high quality, low cost and with very fast throughput times.

Lean transformation is a long-term perspective and perseverance. The term "lean" was coined by Krafcik (1988) to describe Toyota's business during the late 1980s by a research team headed by Jim Womack, Ph.D., at MIT's International Motor Vehicle Program. In his landmark paper, Krafcik introduced the term “lean” to describe a production system that uses less resources of everything compared to mass production. Derived originally from the Toyota Production System or TPS, the principles, methods and tools of LM became immensely popular after the release of the book ‘The Machine that Changed the World’ (Womack et al., 1990).

In the last two decades, there have been numerous studies for the various aspects of lean implementation. However, there is no comprehensive study of the technological factors which are significantly important for its implementation. The purpose of this work is to have a detailed study of the effect of such factors for the implementation of lean manufacturing, towards satisfaction of the customer and the organizational objectives, as well. This work entails an empirical research on a model for LM implementation based on profound literature survey. This study provides an insight in a realistic situation in LM implementation where practically all considered input manifests related to technological factors and all considered output manifests have been assimilated to formulate the research problem. Therefore the challenge is to undertake a research combining all the stated manifest variables in a comprehensive manner to gain an insight of an integrated model to provide direction for LM implementation.

This paper is organized as follows. Section 2 discusses the related literature and develops the hypotheses, based on which the research model is established. Section 3 outlines the research methodology and the model validation is carried out in Section 4. Section 5 discusses the theoretical and managerial implications of the results and finally Section 6 concludes the study with a summary, limitations and suggestions for future research.

2. Literature Review and Hypotheses Development

This research article is based on a systematic literature review. By a different combination of key words, 418 publications in refereed journals were finally shortlisted for this research work. The target journal articles for this review were those published after 1990 that is, post publication of the book, 'The Machine that Changed the World' (Womack et al., 1990).

2.1. Literature Review

Although there are instances of rigorous process thinking in manufacturing all the way back to the Arsenal in Venice in the 1450s, the first person to truly integrate an entire production process was Henry Ford. He designed the fabrication steps in a process sequence wherever possible using special-purpose machines and this was a truly revolutionary break from the shop practices that consisted of general-purpose machines grouped by process, which made parts that eventually found their way into finished products. However, the problem with Ford's system was its inability to provide variety. As Kiichiro Toyoda, Taiichi Ohno and others at Toyota looked at this situation in the 1930s, and more intensely just after World War II, it occurred to them that a series of simple innovations might make it more possible to provide both continuity in process flow and a wide variety in product offerings. This new system in essence shifted the focus of the manufacturing engineer from individual machines and their utilization, to the flow of the product through the total process. Toyota concluded that by this new process, it would be possible to obtain low cost, high variety, high quality and very rapid throughput times to respond to changing customer desires.

In the book, Lean Thinking (1996), Womack and Daniel T. Jones distilled the lean principles to five basic principles:

a) Specify the value desired by the customer
b) Identify the value stream for each product providing that value and challenge all of the wasted steps currently necessary to provide it
c) Make the product flow continuously through the remaining value-added steps
d) Introduce pull between all steps where continuous flow is possible
e) Manage toward perfection so that the number of steps and the amount of time and information needed to serve the customer continually falls

There is no such fixed practice for companies to become lean. So and Sun (2011) confirm that researchers seldom adapt these approaches systematically to perform evaluation on lean implementation in manufacturing. A study to provide a comprehensive list of all the input technological enablers and output manifests to guide the lean practitioner is not available in the extant literature. Since an integrated holistic approach is necessary for lean implementation, this paper is an endeavour to bridge the gap and provide an exhaustive list of the technological input parameters and output parameters. More specifically, based on empirical research on Indian manufacturing industries, the present study seeks to have a comprehensive model for successful lean implementation, which can be used by academicians and practitioners to effectively administer the implementation process.

2.1.1. Identification of technological input manifest variables and latent constructs

In the first phase of the research, an intense literature survey revealed thirty two various terminologies related to OTFs as enablers for LM implementation. Since all of these 32 items were not distinct in nature, these were verified and based on the similarity of the attributes, combined into 12 manifest variables through a Delphi exercise with seven practitioners and researchers known for their knowledge and experience in lean production. These 32 manifest variables were conceptually mapped onto 3 distinct latent constructs, considering the salient inherent similarities between them. Finally, through an Exploratory Factor Analysis (discussed in Section 4.1 below), the grouping of the manifests matched with the 3 latent constructs. The latent constructs and their respective manifest variables are enumerated in Table 1.

Table 1. Input manifests and latent technological factors for LM implementation

Latent Construct	**Manifest Variables / Measures**
Product Design and Development (PDD)	Research and Development (PDD1)
	Concurrent Engineering (PDD2)
	Parts Standardization / Modularization (PDD3)
	Market Research (PDD4)
	Product Data Management Systems (PDD5)
Quality Governance (QG)	TQM and Kaizen (QG1)
	SPC and Process Capability (QG2)
	Quality Tools and Techniques (QG3)
	Quality Practices (QG4)
Role of Technology (RT)	Cellular Manufacturing (RT1)
	Focused Factory Production (RT2)
	Technological Development (RT3)

2.1.2. Identification of output manifest variables and latent constructs

Many studies have enumerated the benefits of lean. In the first phase, this study identified 215 various terminologies as output attributes from literature survey. These were again verified and based on the similarity of the attributes, combined into 13 manifest variables through a Delphi exercise with seven lean experts and researchers. The 13 manifest variables are conceptually mapped onto three distinct latent constructs, considering the salient inherent similarities between them. These are: Successful LM Implementation, Organizational Goal Satisfaction and Customer Satisfaction. From past literature, it may be inferred that successful LM implementation will lead to satisfaction of both the customer as well the organizational goals. Exploratory Factor Analysis (discussed in Section 4.1 below), confirms the said conceptual mapping. The latent constructs and their respective manifest variables are enumerated in Table 2.

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Table 2. Output manifests and latent constructs of successful LM implementation

Latent Construct	Manifest Variables / Measures
Successful LM Implementation (SLM)	Quality Improvement (SLM1)
	Reduction of Defects, Scrap and Rework (SLM2)
	Cycle / Lead Time Reduction (SLM3)
	Operational Flexibility and Performance Improvement (SLM4)
	Work Ethos and Working Conditions Improvement (SLM5)
	Productivity Practices Implementation (SLM6)
Organizational Goal Satisfaction (OGS)	Economic Parameters (OGS1)
	Strategic Competitiveness (OGS2)
	Cost Reduction and Efficiency Improvement (OGS3)
Customer Satisfaction (CS)	Maximize Customer Value (CS1)
	Increased Responsiveness to Demand Change (CS2)
	Streamlining Customer Service Functions (CS3)
	Perfect Order Fulfillment (CS4)

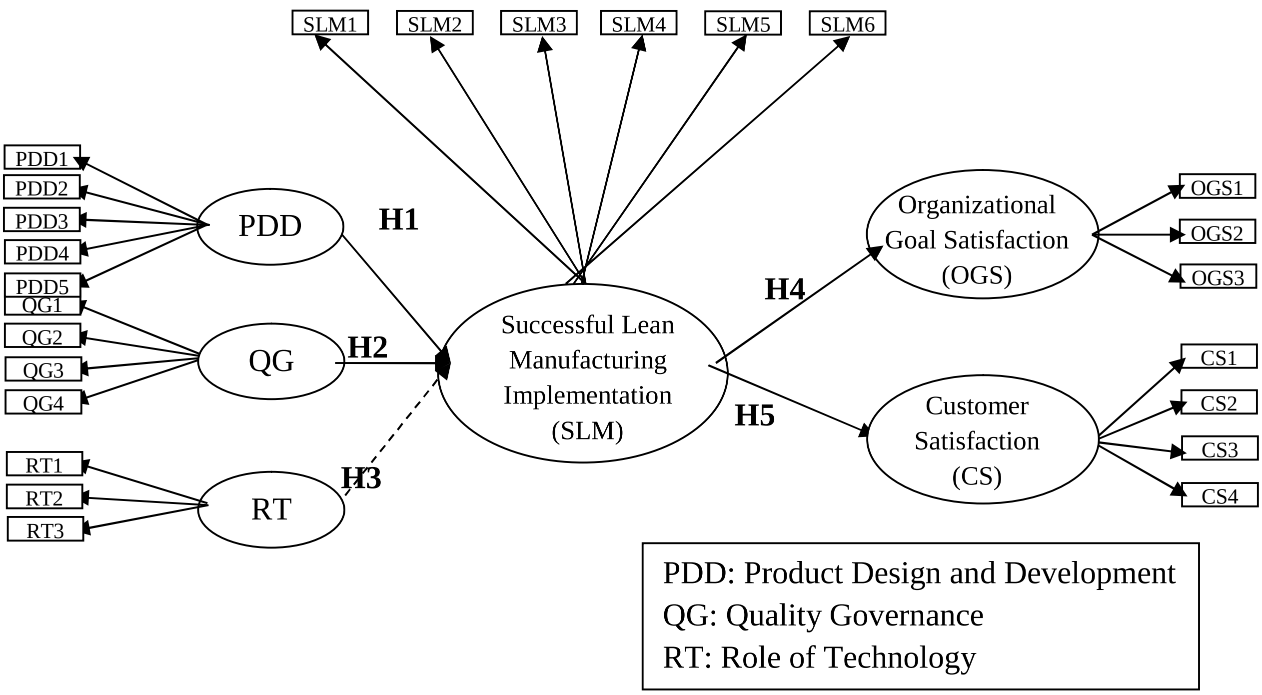

Figure1. Structural Model for Technological Factors for LM Implementation

2.2. Hypotheses development

Our study is built on the conceptual foundations of the literature followed by Delphi technique and EFA, on the input and output variables of LM implementation, and combines both to propose the theoretical research model of the study as illustrated in Figure 1. The model conceptualized in this study is based on the technological input factors and has 5 hypotheses which are being tested for validity. Based on past literature, the hypotheses posited in this study include the following:

H1. Product design and development is positively related to successful LM implementation.

H2. Quality governance is positively related to successful LM implementation.

H3. Role of technology is positively related to successful LM implementation.

H4. Successful LM implementation is positively related to organizational goal satisfaction.

H5. Successful LM implementation is positively related to customer satisfaction.

3. Research Methodology

The objective of this work is to have an empirical study on the comprehensible list of technological input variables and outcomes related to LM implementation in the Indian manufacturing context. The basic steps of the research methodology, based on the outline provided by Singh Sangwan et al. (2014), are: identification of input and output manifest variables and latent constructs, model proposition and hypotheses development, development of survey instrument, sampling and data collection and model validation (EFA, CFA and SEM). Identification of the input and output manifest variables and latent constructs, thereby proposing the research model and developing the hypotheses have been presented in the last section. This section focuses on the development of the survey instrument, sampling and data collection.

3.1. Development of Survey Instrument

An extensive questionnaire covering the input and output manifest variables was developed. The survey questionnaire was divided into three major parts: The first part of the survey questionnaire was designed to capture the personal information and organization profile of the respondent. The second and third parts captured the responses on the input and output manifests. The present study used five-point Likert scale (1 = Strongly disagree, 2 = Disagree, 3 = Indifferent, 4 = Agree, 5 = Strongly agree) to get the responses for each item on the perception about the importance/significance of a manifest variable involved in LM.

3.2. Sampling and Data Collection

The empirical research is focused on lean implementation in the Indian manufacturing sector. The list of manufacturing companies was obtained from Capitaline Plus, one of India's most popular and up-to-date databases. The population of interest was all industries with manufacturing facilities in India and having number of employees exceeding 100 (Chavez et al., 2015; Shah and Ward, 2003). This excluded those involved in agriculture, forestry, fishing and services. A total of 340 respondents were contacted and after three to four follow-up contacts, a total of 305 usable filled-in (complete) questionnaires were received, ignoring 35 questionnaires consisting of missing responses on various manifests.

4. Results and Model Validation

We examine our hypotheses using a structural equation model (Figure 1) populated with survey data from 305 responses from the Indian manufacturing sector.

4.1. Exploratory Factor Analysis (EFA)

A principal-components-based EFA was conducted on both input and output manifests to develop a parsimonious representation for the various constructs in the survey (Fullerton et al., 2014), to rule out variables not appropriately related to the constructs (Moori et al., 2013) and to reduce and summarize the data (Fullerton and Wempe, 2009). Factors were extracted using maximum likelihood method followed by varimax rotation. Kaiser criterion (Eigen values > 1) was employed to extract factors. For all items to contribute well to the represented factors, the minimum factor loading value of 0.45 was considered (Hair et al., 2009). The same 3 input latent constructs (with Eigen values > 1) emerged from the input manifests and 3 output latent constructs (with Eigen values > 1) emerged from the output manifests.

EFA alone is not sufficient to assess all the essential measurement properties of the constructs (Singh Sangwan et al., 2014). There are two measurement models which are to be evaluated – a measurement model for the input constructs and another measurement model for the output constructs. Each of these measurement models are evaluated with a confirmatory factor analysis (CFA) and then the full model is evaluated using a structural equation model (SEM). To test both the measurement model and structural model, the maximum likelihood approach in AMOS 21 was used.

4.2. Confirmatory Factor Analysis (CFA)

Results from CFA for individual manifests indicate that the t-values are all significant to $p<0.000$. The factor/latent correlation matrix indicates that the factors are positively and significantly correlated with one other. Construct validity is assessed by both convergent and discriminant validity (Ghobakhloo and Hong, 2014). Convergent validity is found to be adequate because AVE (Average Variance Explained) of all variables are significantly greater than 0.5 (Fornell and Larcker, 1981). For satisfactory discriminant validity, a construct is considered to be distinct from other constructs if the square root of the AVE for it is greater than its correlations with other latent constructs (Barclay et al., 1995). The square root values of the AVE for each construct are found to be larger than the correlation of that construct with all other constructs in the model. Hence the results satisfy the discriminant validity. Cronbach's α-coefficients are used to test internal consistency or reliability of each construct (Cronbach, 1951) and the acceptable standard of Cronbach's α-coefficient is 0.70 (Nunnally, 1978). Since, all the α-coefficients are found to have values more than 0.7, they are acceptable.

4.3. Structural Equation Modelling (SEM)

Table 3 exhibits the results of the structural model. Before the path coefficients can be assessed, we evaluate the fitness of the structural equation model. The ratio of $\chi 2$ to degrees of freedom is found to be 1.812, indicating an acceptable fit (Kline, 2015). Value of RMSEA is 0.031 which is much less than the acceptable upper limit of 0.08 (Browne and Cudeck, 1992). The remaining fit indices (GFI, AGFI, NFI and CFI) exceed the acceptable fit level of 0.8 (Hair et al., 2009). Hence the goodness of fit statistics generally indicate a good fit to the data.

Table 3. Results of structural equation modeling

Path / Structural Relationships	Hypotheses	Standardized Coefficient	t-Values	Significance	Decision
PDD→SLM	H1	0.468	4.762	***	Supported
QG→SLM	H2	0.374	4.114	***	Supported
RT→SLM	H3	0.012	0.269	Not Significant	Not Supported
SLM→OGS	H4	0.513	4.084	***	Supported
SLM→CS	H5	0.471	4.327	***	Supported

5. Discussion

The lean implementation model, discussed above, is expected to be very useful to the lean practitioners. It helps to integrate all the technological factors in one model into a unified coherent complete manufacturing system; LM implementation entails optimization of the manufacturing process to satisfy both customer requirements and organizational goals. On one hand, this model attempts to frame an exhaustive list of all the technological inputs (Table 1) for LM implementation. On the other hand the output manifests (Table 2) for successful LM implementation will guide the lean implementer to assess the effect of implementation. The SEM results and their implications are briefly summarised below.

This research strongly supports the hypothesis (H1) that Product Design and Development (PDD) has a positive influence on successful LM implementation. According to lean protagonists, Quality tools, techniques and practices are the pillars of the LM implementation. TQM, Kaizen, Statistical Process Control and other Quality tools or practices are considered as enablers of LM by many researchers. Results of our study are also in conjunction with this view of lean experts and the hypothesis (H2) that Quality Governance (QG) positively affects successful LM implementation is strongly supported. However, among the input latent constructs, there is no indication that Role of Technology (RT) positively affects successful LM implementation in the Indian manufacturing context. This hypothesis (H3) is not supported by the data possibly because introduction of new technology often involves an initial financial outlay, which many small and medium enterprises are not willing to undertake in the Indian context. In our research, both the hypotheses (H4 and H5) that successful LM implementation positively affect satisfaction of organization goals and customer satisfaction are strongly supported by the data.

6. Conclusion

A comprehensive study of the technological input manifest variables, along with the output manifest variables for successful lean implementation, has been focussed upon in this work. Based on literature survey, followed by Delphi exercise, a structural model is suggested for administering lean implementation. The model thus conceptualized is then validated with the use of appropriate statistical tools with the help of empirical data from the Indian manufacturing sector. Certain limitations of this work confine the interpretation of our findings. This study is limited to the manufacturing sector and has scope for extending the concept to the service sector as well. Finally, survey studies with a larger sample size (considering the total number of variables involved) and a larger cross-sectional random sample may provide better understanding of the results found in this study.

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