Effect of Lean Manufacturing on Operational Performance: An Empirical Study of Indian Automobile Manufacturing Industry

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Abstract - *Lean manufacturing (LM) technique, though old concept, is gaining importance in recent years in manufacturing industries. The principles and practices of Lean manufacturing are widely used by industries to eliminate waste and make the process more efficient. It has been recognized as one of the key approaches in enhancing the organizational performance. In India LM has been widely implemented in the automotive industry, prompted by the challenging and competitive business environment. The purpose of this research is to, identify the critical factors responsible for the success of LM and verify the influence of LM on Operational Performance (OP), in Indian automobile manufacturing industry. Based on excessive literature review and expert opinion, 10 success factors have been identified. A conceptual framework listing these factors was proposed with the research hypotheses. The empirical data, collected using a self-administered questionnaire, was analyzed using factor analysis and structural equation modeling. The study proves that a positive significant relationship exist between LM and OP. The model fitted with adequate goodness of fit revealed that the overall relation between LM and OP are statistically valid.*

Key Words: Lean Manufacturing, Operational performance, Principal Components Factor Analysis, Structural equation modelling

1. INTRODUCTION

The ever changing globalized environment has been posing challenges of competitiveness and survival to all manufacturing industries. Manufacturers are always embracing changes and improvements in their key activities or processes to cope with the challenges. To stay competitive in this globalized market, it is essential to become more efficient. Hence organizations have started the reorientation of their competencies by means of implementation of varied practices. Lean manufacturing is a system that is focused on reconfiguration of the manufacturing systems by means of streamlining the processes which facilitate waste reduction, minimizing variations and thereby facilitating cost reduction (Shah and Goldstein 2006). The basics of lean manufacturing employ continuous improvement processes to focus on the elimination of waste or non-value added steps within an organization. The challenge to organizations utilizing lean manufacturing is to create a culture that will create and sustain long-term commitment from top management through the entire workforce. The researchers all around the world were studied and commented on possible benefits of implementing LM concepts and its effects on organizational performance. Studies were also done to identify various factors which lead to a successful lean implementation. Being in a developing country, so many Indian industries are struggling to be world class. Hence lean manufacturing has been receiving a lot of attentions in the Indian industry. But the adoption of lean principles is still found to be difficult. Also number of researches in the Indian context is very few. So there exists a possible scope to identify the relationship between lean factors and operational performance. This study evaluates the same, using the lean success factors which are selected based on the literature review. This will help any manufacturing company, implementing or plans to implement lean principles, to identify the essential factors they should take care of for the success of lean manufacturing in the context of Indian automotive sector.

2. LITERATURE REVIEW

2.1 Lean Manufacturing

Reviewing the existing literature provides a starting point in defining lean production. Lean manufacturing, as a concept, was originally developed by Toyota in Japan. It is a manufacturing strategy to minimize or eliminate the non-value added activities (waste) in the production and operation system. The concept was introduced by Taiichi Ohno and Shigeo Shingo at Toyota as "Toyota Production System" (TPS) (Pavnaskar et al., 2003). Essentially, the term "lean" was used by Womack and his colleagues (1990) to denote a system that uses less, in terms of all inputs, to create outputs similar to those of the traditional mass production system, while offering increased choices for the final consumer. In short, lean thinking is lean because it provides a way to do more and more with less and less – less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want" (Womack and Jones, 1996). Lean manufacturing has its focus on cost reduction, waste minimization and better material management (Seth and Gupta 2005). According to TPS, the seven most common wastes are overproduction, waiting, transport, inappropriate processing, unnecessary inventory, waste of motion and defects (Hines and Rich 1997, Hines et al. 1999). Shah and Ward (2007) defined Lean manufacturing as an integrated system composed of highly inter-related elements and a wide variety of management practices, including Just-in-Time (JIT), quality systems, work teams, cellular manufacturing. There are various tools and techniques to implement lean principles to an industry; Total Productive Maintenance (TPM), Total Quality Management (TQM), Failure Mode and Effect Analysis (FMEA), 5S, Quality Function Deployment (QFD), Kaizen, Kanban, Value Stream Mapping (VSM), etc (Braglia et al. 2006; Salem et al. 2006, Shah and Ward 2007).

2.2 Lean Success Factors

Many researchers are contributed in identifying various success factors or enablers for lean manufacturing (Khadse et.al. 2013, Chaple et.al. 2014, Puvanasvaran et.al. 2009, Sanchez and Perez 2001, Hofer et.al. 2012). Panizzolo (1998) divided the lean practices into six areas which are process and equipment; manufacturing, planning and control; human resources; product design; supplier relationships; and customer relationships. Achanga et.al. (2006) suggested that the success of Lean Manufacturing implementation depends on four critical factors: leadership and management; finance; skills and expertise; and supportive organizational culture of the organization. S.J. Thanki and Jitesh Thakkar (2013) conducted a study in Indian industries to analyse status of lean awareness and degree of lean implementation. The major barriers for the lean practices in Indian industries are identified as inadequate lean training and lack of lean awareness programs for employees, poor application of statistical tools for process improvement and uncertainty regarding the appropriate lean tool. Higher commitment levels, stronger belief in the system being implemented, more communication and better work methods can increase the likelihood that workers will perceive the transformation as successful (Losonci et.al. 2011). Successful lean implementation by the company is supported by a systematic communicative approach. Communication is an important aspect of lean process in order to successfully implement lean manufacturing (Puvanasvaran et.al. 2009). Vinodh and Joy (2011) tested a conceptual model of lean practices and success factors using Structural Equation Modeling (SEM). Manufacturing management, manufacturing strategy and manufacturing responsibility leanness have been identified as important drivers for lean manufacturing.

Lean Success factors selected for present study are;

1 Employee awareness (EA)
2 Top management commitment (TM)
3 Continuous improvement (CI)
4 Visual Management (VM)
5 Standardization (ST)
6 Supplier relationship (SR)
7 Inventory leanness (IL)
8 Communication (CO)
9 Elimination of waste (EW)
10 Lean Tools (LTS)

3. RESEACH FRAMEWORK AND HYPOTHESIS

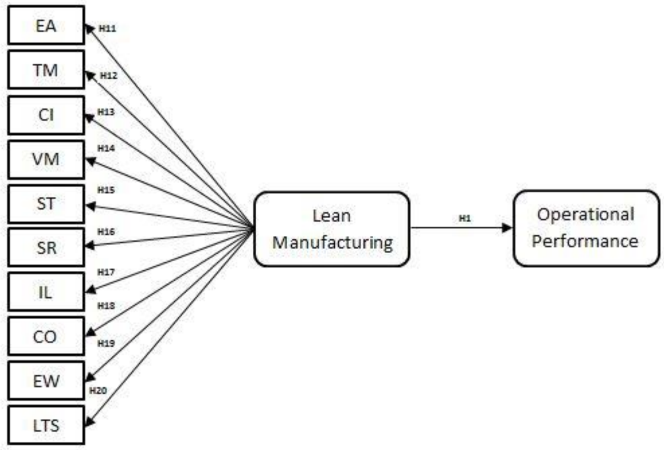

Fig-1 Conceptual research framework

From various success factors identified through comprehensive review of lean literature, ten most prominent factors are selected for the present study. Operational performance (OP) is selected as the output performance indicator. The variables influencing OP are also identified. Jabbour et.al. (2013) investigated the operational performance variables in automotive companies in Brazil. They suggested that the cost of product, time-to-market, introduction of new products into market, quality of products, manufacturing flexibility and reliability in quick delivery together indicate the relative measure of operational performance.

Based on the literature review, a conceptual framework is developed to investigate the relationship between selected lean factors and company's operational performance. The framework is depicted in Fig-1. Based on the research objective the research hypothesis is developed as;

Null hypothesis: H0

There exist no significant relationship between lean success factors and operational performance of Indian automobile manufacturing companies.

Alternate hypothesis: H1

There is a significant positive relationship between lean success factors and operational performance of Indian automobile manufacturing companies.

4. METHODOLOGY

4.1 Industrial Sector Studied

Indian automobile manufacturing industry is the target selected for present study. In the last decade, the Indian automotive industry has grown at a Compound Annual Growth Rate (CAGR) of 4 per cent per annum over the last five years (Ganatra and Varia, 2013). India has established itself as a manufacturing hub for global automobile manufacturers. So there is an urgent need to infuse new process improvement techniques to the product development cycle, to stay ahead of the global competition. Many automobile manufacturing companies have adopted some type of lean initiatives. Panizzolo et al. (2012) investigated the adoption of lean production in India. The Indian Automotive sector has the very high level of lean implementation followed by Electronics / IT / Engineering sector.

4.2 Questionnaire Building and Survey

The study was conducted in 10 automobile manufacturing companies in India. Data collection was completed with the help of self-structured questionnaire. The survey instrument consists of two parts; first part deals with lean success factors and the second evaluates operational performance. A 5-point Likert scale was adopted, where 1 represents "strongly disagree" and 5 represents "strongly agree". Before the full survey pilot study was conducted to check reliability of questionnaire. 153 valid data are obtained in the survey and was tabulated in Microsoft Excel. IBM SPSS Statistics v.23 was used for data analysis and Structural Equation Modeling (SEM) was done using AMOS 23.0 software.

5. ANALYSIS AND DISCUSSION

5.1 Reliability Analysis

Reliability refers to the consistency of measure. The data collected in survey are evaluated for reliability using Cronbach's alpha-coefficient method. The test was conducted in SPSS Statistics v.23 software. Reliability tests were performed separately for the items of each lean factors (10 independent variables) and dependent variable (operational performance). The generally acceptable value for Cronbach's alpha is 0.7 but it can be as low as 0.6 in the case of exploratory research (Field 2005, Gliem and Gliem, 2003). The Cronbach's alpha values of the variables are summarized in Table 1 and Table 2. The alpha values ranges from shows good internal consistency of the data collected.

Table-1 Reliability Analysis-Lean Success Factors

Lean Success Factors	No. of Items	Cronbach's Alpha
EA	4	0.718
TM	4	0.720
CI	4	0.735
VM	4	0.735
ST	3	0.716
SR	4	0.728
IL	4	0.720
CO	3	0.765
EW	4	0.723
LTS	4	0.752

Table-2 Reliability Analysis–Operational Performance

Operational Performance	No. of Items	Cronbach's Alpha
OP	6	0.771

5.2 Validity Analysis

Validity is the extent to which a measurement tool measures what it's supposed to measure. Kelly (1927) developed the concept of validity, stated that a test is valid if it measures what it claims to measure. There are two types validity. Content validity and construct validity. A category was considered to have content validity if there was general agreement from the literature that the model had measurement items that cover all aspects of the variable being measured. Here in our study selection of the initial 10 lean success factors and operational performance were based on the extensive review of literature. Therefore our measures were generally considered to have content validity. A measure has construct validity if it measures the theoretical construct that it was designed to measure. Principal Components Factor Analysis was used to evaluate the construct validity of each category (Hair et al., 1992).

5.3 Factor Analysis

Factor analysis (FA) is statistical tool that measures the impact of a few unobserved variables called factors on a large number of observed variables. Factor analysis can be used to explain the interrelationships among a large no. of variables and also to explain these variables in terms of their common underlying dimensions (constructs). It also helps reduce data that do not correlate with any of the underlying dimensions. In the present study, principal component analysis method of FA followed by the varimax orthogonal rotation was adopted on 10 lean success factors comparing of 38 items by using SPSS Statistics v.23.0 software. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.703, which is greater than the minimum score of 0.50, indicate sufficient intercorrelations. The Bartlett's test of sphericity indicates that all the criteria are significant ($\chi2$=5180.584, $p=0.000< 0.01$). To assess the construct validity, factor loadings are verified for each item. Here in this study only items with loading 0.4 and higher on factor (Hair et al., 1998) were considered. 7 items were deleted due to low loadings. The total variance explained was 78.513 percent. Similarly, another FA was undertaken to see the dimensionality of the dependent variables (operational performance). A one factor solution emerged with explaining 47.373 percent of variance in the data. The KMO measure of sampling adequacy was 0.760 indicating sufficient intercorrelations, while the Barlett's test of sphericity was significant ($\chi2$= 250.395, $p=0.000<0.01$). One item is eliminated due low loading (<0.4). Now the total data set is reduced into 36 items. It can be concluded that all the criteria and sub-criteria are reliable and valid and thus can be used for further analysis.

5.4 Structural Equation Modeling (SEM)

Structural Equation Modeling, or SEM, is a very general statistical Modeling technique, that takes confirmatory (i.e.; hypothesis-testing) approach to the analysis of a structural theory bearing on some phenomenon. Structural relations can be modeled pictorially which helps to get a clearer concept of the theory under study. This method uses a confirmatory rather than an exploratory approach to the data analysis. Structural Equation Modeling (SEM) has its roots in path analysis, which was invented by the geneticist Sewall Wright (Wright, 1921). The general SEM model considered as a combination of two sub models: a measurement model, and a structural model. The measurement model defines relations between the observed and unobserved variables. In other words, it provides the link between scores on a measuring instrument (i.e., the observed indicator variables) and the underlying constructs they are designed to measure (i.e., the unobserved latent variables). The measurement model, then, represents the Confirmatory Factor Analysis (CFA) model, in that it specifies the pattern by which each measure loads on a particular factor. While the structural model shows the relations among the unobserved variables and it specifies the manner by which particular latent variables directly or indirectly influence changes in the values of certain other latent variables in the model.

Here in this study AMOS v.23.0 software was used for examining the relationship between a set of lean success factors and operational performance. The measurement model and structural models are shown in Fig-2 and Fig-3. This assessment of the model was done by examining the standard errors, t-values, modification indices, and a number of goodness-of-fit statistics (Fuentes-Fuentes et al., 2004). The different fit indices considered in this study are GFI, CFI, $\chi 2/df$ and RMSEA.

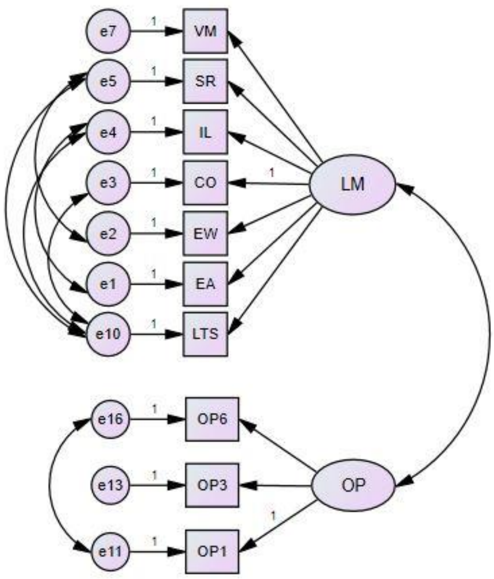

Fig-2 Measurement model for effect of Lean Manufacturing on Operational Performance

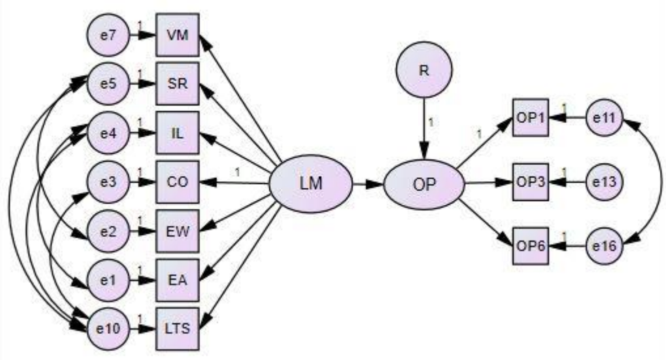

Fig-3 Structural model for effect of Lean Manufacturing on Operational Performance

Table-3 Test results of the measurement model and structural model (OP on QP)

Goodness of fit statistics	Measurement model	Structural model	Recommended value for satisfactory fit
χ^2/df	1.84	1.78	<3.0
GFI	0.934	0.943	>0.90
CFI	0.942	0.937	>0.90
RMSEA	0.078	0.072	<0.08

A comparison of goodness-of-fit statistics relating to measurement model and structural model to the recommended values of these fit indices (Table 3) reveals satisfactory fit of the both models. Some practices, top management commitment, continuous improvement and standardization, were eliminated due to low loading in the measurement model. GFI and CFI value for structural model was 0.943 and 0.937 and RMSEA value was 0.072. $\chi 2/df$ value for structural model was obtained as 1.78 which is below the upper threshold value of 3.0.

Table-4 Construct Structural Model (LM on OP)

Links in the model	Hypotheses	Standardized parameter estimate	T value	P value
LM→OP	H1	0.958	4.599	***
IL→LM	H17	0.218	2.222	0.026
SR→LM	H16	0.313	2.972	0.003
VM→LM	H14	0.447	3.820	***
CO→LM	H18	0.437	3.154	***
EW→LM	H19	0.589	4.399	***
EA→LM	H11	0.478	3.967	***
LTS→LM	H20	0.526	3.776	***

Table 4 shows that the hypothesis H1 is significant at $p < 0.05$. This indicates lean strategy has significant and direct effect on operational performance. Also according to hypotheses H11 to H17, the success factors selected has significant positive effect on Lean Manufacturing.

6. CONCLUSION

This work has accomplished stated objectives of the study successfully. The main objective of the study was to identify critical factors of lean success in Indian automobile manufacturing industry and also to determine the influence of these success factors on operational performance. The results of the analysis showed that lean success factors have positive and significant effect on operational performance. Lean tools, Elimination of waste, Employee awareness & involvement, visual management were found to contribute more on success of lean manufacturing in Indian automobile manufacturing industry. Lean tools are the back bone for lean manufacturing strategy. It includes total productive maintenance, JIT practices, value stream mapping, takt time, Ishikawa (cause-and-effect) diagram, Heijunka (load balancing) etc. These tools may drive other factors also, indirectly, which makes it a crucial one among success factors. Elimination of waste, employee awareness & involvement and visual management are related to the basic culture of the company. They can be achieved comparatively with less effort and expenses. Hence companies should target these factors from initial stages of lean implementation itself. So based on this it can be concluded that companies implementing lean strategy have to focus more on the above mentioned factors, in order to attain good operating performance. Improvements in operational performance thus lead to defect free superior quality products and ultimately customer satisfaction.

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