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Assessment of Lean Manufacturing Practices in Coimbatore Machine Tool Industries

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***Abstract*—The purpose of this paper is to identify the critical lean manufacturing metrics that influence the adoption of lean practices in Coimbatore machine tool industries, Tamil Nadu. The research approach helps in identifying the important lean metrics through a questionnaire survey and the responses of the selected respondents are statistically validated for their reliability using Cronbach Alpha in SPSS 20.0 software. Further the constructed variables for lean adoption were theoretically tested for their relationship through correlation and regression analysis in SPSS 20.0. The approach follows a structured research methodology to statistically validate the model to identify those variables with high convergence and leverages for the organization to be completely 'lean' in their process. The research provides guidelines and direction for organizations to implement those prime lean metrics with high benefits and leverages suitable for organizations to implement lean in their machine tool industries. This research is confined only to machine tool industries and in future could be extended to other manufacturing firms such as automotive, electrical and electronics, pump, textiles and other service industries too.**

***Keywords*—Lean manufacturing, Reliability, Sampling, Correlation and Regression analysis.**

I. INTRODUCTION

In today's world of global competitiveness, every manufacturing firm has prompted to adopt new manufacturing management strategies in order to enhance the firms' efficiency and competitiveness. Every manufacturing industry has put in continuous efforts for its survival in the current volatile economy. These manufacturing industries play a crucial role in the overall, and especially the economic development of a country. A country's economic strength is measured or judged by the growth of its manufacturing industries. Manufacturing firms are important for an economy as they play a vital role in providing employment to the fast growing population especially for the developing countries like India. Hence, every organization are in a need to adapt and practice systems that help them to produce their products with higher efficiency, higher productiveness and less costs. The philosophy of Lean and its practices has been one of the most successfully used systems world-wide (Nihit Prakash & C.H.V.V.S.N.V. Prasad, 2014). Lean manufacturing is a creative process that consistently eliminates waste in various process stages. The objective of lean manufacturing is to identify and eliminate waste (non-value adding activities) by implementing lean practices and make the product flow at the pull of the customer in pursuit of perfection. This technique has been applied very successfully in various manufacturing sectors, resulting in enhanced productivity by simplifying the operational structure enough to understand, perform and manage the work environment. In India, many industries are struggling to stay in the market as they were not aware of new techniques despite the business conditions being positive. Lack of understanding of lean techniques, the management as well as the shop floor employees attitude towards lean and various other factors lead to very minimal adoption of lean concepts in Indian industries (Arvind Kumar Shrimali and V. K. Soni, 2017). Hence worth, we have tried to identify those factors accountable for lean practices. The intent of this research is to determine the critical lean manufacturing factors contributing for the implementation of lean manufacturing in the Coimbatore machine tool industries. Further, to combine these factors into a structural framework, this can represent the present status of lean practices in Coimbatore machine tool industries and also to identify the important factors contributing to its adoption. The Machine tool industry is the key to the government's flagship 'Make in India' and 'Skill India' initiatives, given that it makes the machines required for the manufacturing sector. It is part and parcel

of manufacturing, particularly discreet manufacturing segments such as automobiles, defense, railways, plastic machinery, medical and electronic goods. The approach of the research includes a literature review, hypothesis formulation and questionnaire surveys. A state-of-the-art review of lean manufacturing literature from the perspectives of lean manufacturing evaluation and performance assessment for development of survey tool for lean evaluation is provided. It contributes to the classification of literature in a manner which helps to identify strategies suitable for the adoption of lean concepts in manufacturing industries. Then, an extensive survey is conducted to determine the most important standards of lean manufacturing conducted in machine tool industries in and around Coimbatore, Tamil Nadu; the most important standards of lean manufacturing are identified. Statistical Package for the Social Sciences (SPSS) software is used for finding out the reliability and validating the results in order to fit in both tangible and intangible benefits of lean manufacturing. SPSS is a user friendly statistical software package used for statistical analysis of data for survey authoring, collaboration and deployment (Daniel Arkkelin, 2014). Statistically validate the model using SPSS helps in providing crisp and faster responses. Also, we believe this comprehensive survey will not only facilitate the adoption of lean techniques but will also provide agenda for further research by exposing the voids in the knowledge base.

II. REVIEW OF LITERATURE

A selective analysis of the previous published papers on lean assessment tool is done. While reviewing the literature, it was found only very minimal effort is committed for developing lean assessment tool. In order to assess the degree of leanness of the manufacturing firms, Vinodh et al (2012) analyzed lean manufacturing practices in different industries and identified the critical factors for its success implementation. A Structural Equation Modeling technique is used to build the measurement and structural models. Priti B. Khadse et al (2013) identified the critical lean manufacturing factors responsible for implementation of lean manufacturing in the Indian manufacturing sector through a questionnaire survey. The questionnaire developed consisted of two parts; (1)General information of the respondent companies, (2)Lean manufacturing implementation tools, benefits of lean manufacturing, and obstacles in adoption of lean practices. The final questionnaire constructed of 11 major criterion and 51 sub-criteria. During this study, it was observed that, improvement strategy was the most preferred criteria, followed by standardization and human relation management. Rakesh et al (2014) suggests the seven major attributed barriers of Lean implementation are Top Management, Resource, Knowledge, Conflicts, Employee morale, Financial, Past experience. Out of this Top management is rated 3.9/5 and others are less. Shams Rahman et al (2010) used multiple regression models to investigate the effect of Lean Production on operational performance for both the categories of firms – size and ownership. Natasa Vujica Herzog et al (2014) designed the questionnaire according to the Likert scales, ranging from 'strongly disagree' to 'strongly agree'. Then the resulting data were examined through reliability and validity analyses, and then analyze. Three different types of validity were typically measured: content validity, criterion related validity, and construct validity. Katarzyna Antosz and Dorota Stadnicka (2017) studied that enterprises (29%) applied 5S method. Several companies applied techniques such as: 5xWhy? (20%) and SMED, Team work (16%), Work standardization (12%) and RCA, TPM (12%). 10% of the enterprises planned to implement: OEE, Visual Management, Kaizen and Poka-Yoke. Other techniques were implemented in less than 10% of the case or not implemented at all. The key reasons for implementing LM are: the intention to improve the company's operation (81%) and the need to gain a competitive advantage (50%). A. MOEUF et al (2016) explored the associated difficulties such as the lack of resources, lack of expertise, short-term strategy, the lack of procedure and methods, and non-functional organization prevent the implementation of LM according to the 14 management principles set out by Liker (Liker, 2004). Nordin Norani et al (2012) studied 11 critical factors, and proposed framework of organizational change is intended to provide practitioners with a better understanding of the lean transition and a clear guidance to minimize the resistance and conflicts for the implementation of lean and thus improves its chance of success. The present study helps in identifying the research gap among the literatures providing guidelines and direction for organization to implement those critical lean factors that enhance the organization's quality performance and productivity.

III. RESEARCH METHODOLOGY

Choosing an appropriate research methodology to achieve the objectives of the study is most important. This particular methodology is divided into four parts for better understanding of the research and the strategies chosen to answer the research questions. The first part involved a thorough review of literature. The second part used a questionnaire survey for data collection approach. Based on the literature review, lean manufacturing tools were grouped under different norms. The final questionnaire was developed after pilot survey which was used to transform and eliminate the number of variables. Industrial professionals and academic experts were consulted for their remarks and feedback for developing the questionnaire. Based on their feedback, the questionnaire was modified and put into a structured/organized form.

Each criterion in the questionnaire was referred on a five point Likert Scale, where, 1 =strongly disagree, 2 =disagree, 3 =average, 4 =agree and 5 =strongly agree. Likert Scale is a psychometric response scale primarily used to obtain participant's preferences or degree of agreement with a statement or set of statements. Respondents are asked to indicate their level of agreement with a given statement by way of an ordinal scale. The third part adopted a case study approach centering on

hypothesis formulation, sampling procedure and data processing procedures. This part assisted the research for which portion of population the test analysis has to be carried out based on research questions by experts and hypothesis formulation.

Then, reliability assessment was conducted on Statistical Package for the Social Sciences (SPSS) software. In the core context, reliability explores how an experiment, test or any other measuring technique yields the same results and to which extent (Joseph A. Gliem & Rosemary R. Gliem, 2003). The responses were obtained from various machine tool industries in and around Coimbatore, Tamil Nadu. Manager/shop floor supervisor/worker in different levels of organizations was interviewed. This was made to obtain accurate/precise information and data to help in the formulation of the most practiced lean manufacturing tools. To measure internal consistency, Cronbach's alpha was used which was done using SPSS. It is a measure of internal consistency that shows how a set of items are closely related as a group. According to Uma Sekaran (2010), reliability measure is an indication of the stability and consistency of the instrument .The value ranges from 0 to 1, with higher values indicating greater reliability. Morgan et al (2004), recommended a minimum value of 0.7, although it may be as low as 0.60 in experimental researches.

A. OBJECTIVES OF THE RESEARCH

- To analyze the critical lean manufacturing factors contributing to successful lean transformation.
- To determine the most practiced lean tool in the organization.
- To identify the barriers and perceived lean benefits of the organization.

B. VALIDATION OF QUESTIONNAIRE

In Quantitative research, Validity is one of the most prominent inhibit of research method. Validity measures the extent to which the numbers obtained truly reflects the user's intention of the research process to measure (Nurul Fadly Habidin et al, 2015). One widely accepted classification of validity is: content validity; criterion validity; and construct validity. For the research purpose, content and construct validity were employed. The content validity ensured the research material was thoroughly discussed with highly acclaimed academicians as well as senior managers of the industries. Construct validity attempts to identify the underlying constructs being measured and determine how well the test represents it; also finds out the reasons for variance in measure and investigates adequacy of the instrument that the constructs are meaningful (Vikram Sharma et al, 2015). Then, the core content of the questionnaire was validated as above, by the industry and academic experts who are familiar with lean principles and its concepts. Based on their feedback, corrective actions been done before the circulation of questionnaire.

C. RESEARCH QUESTIONS

A set of research questions and hypothesis are developed through the review of relevant literatures to guide the research. Research questions help in determining "where the boundary between current knowledge and ignorance lies". Research questions helps in broadening our perceived knowledge about the research that sets out to guide the research to achieve the intended objective (R. Brian Haynes, 2006). The research questions framed relevant to the study are:

- Is the top management really committed towards lean transformation in the organization?
- Is there any proper communication of lean programs in the organization?
- Are training opportunities available to personnel?
- What are the most practiced lean tool in the organization?
- What prevents employees to work towards lean programs?
- What are the long-term benefits of lean program?

E. SAMPLING METHOD

A sample survey involves examining a portion of the population of the area of research, and inferring information about the population as a whole (Creswell, 2007, Kumar, 2011). According to Brewerton and Millward (2001), a sample of the population is more apt for study as it is often not possible to survey an entire population for practical and cost reasons.

The simple random sampling was considered because it assumes that the members of the population are given an equal and independent chance of selection (Kumar, 2011). A simple random sample is a subset of a statistical population in which each member of the subset has an equal probability of being chosen (P. W. West, 2016). Ease of use represents the biggest advantage of simple random sampling. Unlike more complicated sampling methods such as stratified random sampling and probability sampling, no need exists to divide the population into subpopulations or take any other additional steps before selecting members of the population at random.

The target sample respondent included project managers, contract managers, environmental managers, managers, quality managers, site managers and supervisors at different levels, ranging from the low to higher level. The following procedure was adopted in choosing the sample from directories and through personal contacts:

- Initially, the target samples were contacted in person for their response to the questionnaire.
- Telephone calls were made and e-mail sent to target respondents and been made clear/precise about the information in the questionnaire.
- It was made clear that the questionnaire should be answered by the person who has got more knowledge and exposed to lean concepts.

The criterion was that the target respondent must have the knowledge of lean and its concepts. The chosen respondents were included in the sample only after the researcher have done background checks(through e-mail and telephone conversations) that their organizations had implemented lean concepts that were going through the lean makeover process and were willing to vote their responses in the survey. Moreover, Organizations were of small/medium/multinational so that the response obtained shows a mixed feeling of the respondents.

IV. RESULTS AND DISCUSSION

A. MEAN METHOD

Mean method in SPSS is a way to summarize and compare differences in descriptive statistics across one or more factors, or categorical variables. It is the best used when we want to compare several variables with respect to one or more categorical variables (Andrew Garth, 2008).

TABLE 1.1 MEAN RANK FOR CRITICAL LEAN MANUFACTURING FACTORS

Critical lean manufacturing factors	Mean	Standard deviation	Rank
Top management commitment	2.00	1.922	3
Lean mgmt. strategies communicated throughout the organization	2.07	1.940	1
Imparting training program on lean concepts	2.07	1.979	1
Value stream mapping	1.89	1.783	5
5s	2.00	1.922	3
Total productive maintenance	2.04	1.971	2
Quality management system	2.00	1.941	3
Just-in-time	2.04	1.921	2
Visual Management	2.04	1.911	2
Employee's mindset to lean transformation	1.96	1.931	4
Lack of understanding of lean concepts	2.04	1.971	2
Better competitive advantage	2.04	1.931	2
Improved CSR	2.07	2.018	1
Face dynamic demand of customers	1.96	1.870	4
Workforce commitment	2.00	1.922	3

The results presented in the table shows that proper communication of lean manufacturing strategies and program results in enhanced lean adoption in the organization. Also imparting training programs to employees on lean concept results in better adoption and improved customer-supplier relationship proves to be a very good initiative for lean adoption. The least ranked thing is implementation of Value stream mapping in the organization. Nonetheless, these results suggest that all these factors are considered important by the respondents since the least issue mean is above 2.0. Successful management commitment and shop floor employees understanding of the lean practices help to identify the ways to improve/innovate the manufacturing process reduce defects and make sure that the manufacturing operations run efficiently. Also it is suggested in particular to have effective communication within the organization from top management to shop floor employees' enables effective workforce and improves the shop floor employees commitment toward his work.

B. CRONBACH ALPHA ANALYSIS

Cronbach's alpha is one of the most popular reliability statistics used for measurement of reliability of scale. The reliability of the 5-point Likert-type scale, which was the main scale in the study, is subjected to a reliability test using SPSS statistical software. Cronbach's alpha measures the internal consistency of items in a survey assessment tool to estimate its reliability. It should be noted that Cronbach's alpha is a coefficient of reliability or consistency rather than merely a statistical test (Santos, 1999). The alpha coefficient describes the reliability or internal consistency of factors extracted from multi-point formatted questionnaires or scales (Santos, 1999). In simple terms, Cronbach's alpha is the average value of the reliability coefficients one would obtain for all possible combinations of items when split into two half-tests providing a unique estimate of reliability for a given test (Joseph A. Gliem, Rosemary R. Gliem, 2003).

Case Processing Summary

		N	%
Cases	Valid	27	100.0
	Excluded[a]	0	.0
	Total	27	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.996	.996	15

FIGURE 1.1 CRONBACH'S RESULTS

Here, the reliability value of the survey as derived by the Cronbach's alpha was 0.996. Since, the Cronbach's alpha coefficient is in the range of 0.8 to 0.9 ensures the internal consistency of the data gathered, as its value is greater than 0.7. Morgan et al (2004) recommended a minimum value of 0.7, although it may be as low as 0.60 in experimental researches. Further it can also be concluded that the material is reliable.

C. REGRESSION ANALYSIS

Regression is a statistical measure that attempts to determine the strength of the relationship between one dependent variable and a series of other changing variables (known as independent variables). Regression helps to understand the relationships between variables, and attempt to predict the value of dependent variable based on the independent variables (Fahrmeir, L., Kneib, T., Lang, S., Marx, B., 2013).

TABLE 1.2 RELATIONSHIP BETWEEN CRITICAL LEAN MANUFACTURING FACTORS AND LEAN IMPLEMENTATION STATUS- MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.991[a]	.982	.960	.284

The SPSS model summary for the above correlations contains the following information: R = .991, R Square = .982 and Adjusted R Square = .960. The **R** column represents the value of *R*, the *multiple correlation coefficients*. *R* can be considered to be one measure of the quality of the prediction of the dependent variable. Value of 0.991 indicates a good level of prediction. The **R Square** column represents the R^2 value (also called the coefficient of determination), which is the proportion of variance in the dependent variable that can be explained by the independent variables. From the value of 0.982, Independent variables explain 98.2% of the variability of our dependent variable.

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	51.553	14	3.682	45.776	.000
	Residual	.965	12	.080		
	Total	52.519	26			

Source: Research Data

FIGURE 1.2 RESULTS OF ANOVA RELATING TO THE CRITICAL LEAN MANUFACTURING FACTORS

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.080	.082		13.209	.000
	Top_management_commitment	-.748	.205	-1.011	-3.653	.003
	Lean_mgmt_strategies_communication	-.067	.245	-.091	-.272	.790
	Imparting_training_program	-2.578	.711	-3.591	-3.629	.003
	Value_stream_mapping	1.392	.521	1.746	2.672	.020
	Five_S	-.605	.260	-.817	-2.326	.038
	Total_productive_maintenance	.546	.271	.758	2.018	.066

Quality_management_system	.144	.252	.197	.571	.578
Just_in_time	.514	.160	.712	3.219	.007
Visual_Management	-.132	.156	-.178	-.846	.414
Employee_mindset_lean	1.647	.483	2.238	3.408	.005
Lack_understanding_lean	-1.214	.572	-1.683	-2.123	.055
Better_competitive_advantage	.859	.419	1.167	2.050	.063
Improved_CSR	.776	.351	1.101	2.211	.047
Workforce_commitment	.295	.343	.399	.861	.406

a. Dependent Variable: lean_implementation_status

figure 1.3 relationship between critical lean manufacturing factors and lean implementation

Two independent variables are statistically significant: Imparting training program (p value = .003) and lack of understanding of lean concepts (p-value = .055). When evaluating the standardized beta values or "size of influence" (Vogt, 1993, p. 20), the greatest influence upon the dependent variable is in the order of Imparting training program (beta = -3.591), Lack of understanding of lean concept (beta = -1.683) followed by Employee's mindset towards lean transformation (beta = 2.238) and Value stream mapping (beta = 1.746).These factors have more impact on the dependent variable i.e, lean implementation status. Top managements concern regarding these issues help in successful transformation and long term sustainability of lean in the organization.

CONCLUSION

Though Lean Manufacturing is a well acknowledged concept for many of Indian industries, still the acceptance of Lean practice is not greatly encouraging. The present empirical study examined the implementation of Lean Manufacturing practices adopted by different industries in Coimbatore, India. The research provides instrument for the machine tool industries to implement those prime lean tools for successful transformation towards lean system. The findings from the research show that Lean manufacturing system is regarded as intended direction, rather than a steady state. The study also implies that many organizations involving top management people to the shop floor employees want to implement lean in their organization to realize enhanced efficiency and productivity. For the transformation towards lean system, people should have a better understanding about lean and also need to be aware about the change management principles. For successful organizational change towards lean organization, the critical factors are improved customer satisfaction, reduced scrap and inventory, adapt to changes by top level management. Top management's support is vital in supporting lean and its practices; initiating and for relishing its sustained benefits in the future run.

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