



Developing a Hierarchical Relation among the Lean Criteria for Manufacturing Sector

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Abstract — Manufacturing sector comprises of automotive industry, machine tools industry, consumer goods, chemicals, fabrication etc. Due to time constraints, we chose machine tool sector as part of manufacturing sector for analyzing lean. The lean production is considered as one of the most powerful manufacturing systems in the world. Lean concepts have been used across industries and regions to improve supply chain performance. The objective of this paper is to explore the approach of adopting lean in manufacturing units and to develop a structure for analyzing the relations among the major criteria of lean manufacturing in machine tool industry. Lean performance indicators were identified through literature review and finalized after seeking opinion of experts from industry and academia. This paper utilizes the interpretive structural modelling (ISM) to understand the mutual influences of different lean criteria among each other. After deciding the contextual relation among the criteria, a structural self-interaction matrix (SSIM) is evolved based on pairwise relation among each variables. SSIM is then converted into a reachability matrix (RM). Level partitioning establishes the lean criteria at various levels. MICMAC analysis is used to analyze the driving power and dependence of lean criteria which were obtained using the reachability matrix. The analysis brings out certain valuable managerial implications on lean implementation. The results presented in this paper can be emulated by different companies of manufacturing sector to improve their operational performance.

Index Terms — Value Stream Mapping (VSM), Single minute exchange of Die (SMED), Computer Integrated Manufacturing (CIM), Enterprises Resource Planning (ERP), Just In Time (JIT)

Introduction

In India, manufacturing has been observed as the emerging sector, as many companies are seeking ways to enhance their productivity and increase the value of their products by curbing the unnecessary production method, wasteful practices and incorporating lean criteria in their firms. Under the lean lens, all non-value adding activities, which is a waste in one form or another, are removed. Lean comprises of variety of criteria depending on the nature of industries. The lean criteria not just affect the operations of the firm but influence each other too, making it difficult to understand the concept of mutual influence among each other. Major lean criteria are divided into 1. Driving criteria 2. Driven criteria, depending on which, management can implement lean program.

In order to increase the production throughput, many firms have inclined towards implementing lean program [9], but not all of them have succeeded in implementing the lean practices. Balle [2] in his report 'Lean attitude' quoted many failures in an attempt to implement lean, which are mostly due to the fundamental misunderstanding of how to acquire lean.

Interpretive Structural Modelling (ISM) can be used to relate several issues in the process to acquire lean [10]. We derive this methodology to analyze various lean criteria related to machine tool sector. The inter-criterion relationship matrix is established on the basis of mutual influence, the criteria have on each other. The matrix so framed is then used to design the ISM model for aiding the employment of lean practices in machine tool industry. The prime objectives of this paper are:

1. To highlight the use of ISM in manufacturing sector
2. To imitate the hierarchal lean implementation in industry
3. To disclose their interaction through ISM.

The remaining of the paper is organized as follows: Section 2, briefly converses the various criteria used for lean implementation. Section 3 contains the ISM methodology and development of model. At the end, Section 4 is there, in which MICMAC analysis is carried out. And the results, managerial implications, limitations are concluded at the last.

CRITERIA FOR LEAN IMPLEMENTATION

A variety of techniques are involved in order to implement lean. All of these practices aim not only to eliminate waste but also the non-value-adding activities at every production process in order to provide maximum satisfaction to the customer.

Table 1: list of major lean manufacturing criteria:

S. No.	Lean Criteria	Key Points
1	Pull system (JIT)	Low inventory management
2	VSM	Eliminate over production
3	Information technology (IT)	Technological stability
4	SMED	Reduce action time
5	CIM	Computer integrated manufacturing process
6	ERP	Business management
7	Standardised work	Managing Human Resources
8	Fixed position layout	Reducing manufacturing space
9	Cellular manufacturing (CM)	Connecting each manufacturing process efficiently
10	Smart processes	Using less resources for maximum optimization
11	Total quality management	Incorporate quality discipline in the organization

The leanness basically deals with achieving more from less. This model involves many strategies and principles which are to be dealt with for achieving the leanness. Some criteria for achieving leanness are enumerated as follows:

1. Pull System (JIT) - It begins with the customer order. Inventory depend on the customer's need. As a result no extra inventory is to be managed, which results in cost reduction of carrying and storing goods. But it might be difficult as it requires a lots of coordination with supply chain partner.
2. Value Stream Mapping (VSM) – It is a production path comprising of all value adding and non-value adding factors required to complete the manufacturing process. Its major use is to eliminate the over-production in any industry [3].
3. Information Technology (IT) - It deals with the technical devices used to transmit and retrieve information. Use of IT has simplified the task of inventory management. At every instant users are able to receive updates at different location which has decreased the documentation issue along with removing unnecessary motion. Using IT the task of inventory management becomes easy. Also it is used to eliminate unnecessary motions.
4. SMED- Single Minute Exchange of Die or SMED is used for time reduction in equipment changeover. Its main objective is to reduce the changeover time.
5. CIM- A computer integrated method to design the products, exchange information within and to streamline manufacturing process. Its major applications are Computer Aided Design (CAD), Computer Aided Engineering (CAE) and Computer Aided Manufacturing (CAM) and Robotics.
6. ERP- The aim of ERP is to expedite the flow of information between all business functions inside the boundaries of the organization [4]. ERP software is very useful in incorporating all levels of an operation, product planning, and development, manufacturing, sales and marketing.
7. Standardized Work: It includes schedule of job of each employ thus utilizing each person on board and removal of wastage of time and human resource.
8. Fixed Position Layout: It is the means in which complete manufacturing processes including development, testing and packaging should accommodate at one location. As a result transportation cost is reduced.
9. CM: Eliminating unnecessary operation cost by creating a smooth flow of products from various stage of development and heading towards the end without the wastage of time in between the process.
10. Smart Process and Automation: It is the minimum time and least stages needed to avoid processing waste.
11. Total Quality Management: Way to attain long term success through customer satisfaction. It should be managed by each department of the industry. It utilizes data, strategy and effective communications to incorporate the quality discipline into the culture and activities of the organization.

METHODOLOGY

ISM is a technique where different and directly related variables are structured and framed into comprehensive hierarchical model. The best part of ISM is that complex issues are also portrayed in a defined graphical manner [8].

Various steps for development of ISM model are defined below:

Step 1: Structural self-interaction matrix (SSIM)

The SSIM is established on contextual relationship among the variables and its analysis is based on nature of their interactions. The relationship between the criterion (i) and the existence of relationship (j) is made in pairwise manner as:

- A. V denotes factor i will influence factor j
- B. A denotes factor i will be influenced by factor j
- C. X denotes factors i and j will influence each other
- D. O denotes factors i and j are unrelated

Table 2: Structural self-interaction matrix												
Lean Criteria	Element	1	2	3	4	5	6	7	8	9	10	11
JIT	1		V	A	A	A	A	A	O	O	A	O
VSM	2			A	A	A	A	A	A	A	A	A
IT	3				O	V	V	O	O	O	V	V
SMED	4					O	O	O	O	O	V	O
CIM	5						X	O	O	O	X	V
ERP	6							O	O	O	V	O
Standardised work	7								O	O	O	V
Fixed Position	8									O	O	O
CM	9										O	O
Smart Process	10											V
TQM	11											

Step 2: Development of initial reachability matrix

The established SSIM is now converted into reachability matrix:

Now, for generating the final reachability matrix we apply the principle of transitivity according to which if one variable affects second and the second affects the third, then first and the third variables are related. And, the final reachability matrix will be used to generate MICMAC analysis for classifying them in groups.

Table 3: Relation to convert SSIM into Reachability		
(i, j) Denoted By	(i, j) marked as	(j, i) marked as
V	1	0
A	0	1
X	1	1
O	0	0

Table 4: Final reachability matrix												
Element	1	2	3	4	5	6	7	8	9	10	11	Driving power
1	1	1	0	0	0	0	0	0	0	0	0	2
2	0	1	0	0	0	0	0	0	0	0	0	1
3	1	1	1	0	1	1	0	0	0	1	1	7
4	1	1	0	1	1	0	0	0	0	1	1	6
5	1	1	0	0	1	1	0	0	0	1	1	6
6	1	1	0	0	1	1	0	0	0	1	1	6
7	1	1	0	0	0	0	1	0	0	0	1	4
8	0	1	0	0	0	0	0	1	0	0	0	2
9	0	1	0	0	0	0	0	0	1	0	0	2
10	1	1	0	0	1	1	0	0	0	1	1	6
11	0	1	0	0	0	0	0	0	0	0	1	2
Dependence	7	11	1	1	5	4	1	1	1	5	7	

Step 3: Level partitioning

By finding the convergence point of the reachability set and the antecedent set, we can divide the set into different levels. The reachability set consists of factors it may impact, whereas the antecedent set consists of factors that may impact it. Level partitioning is used to build the diagram for ISM model.

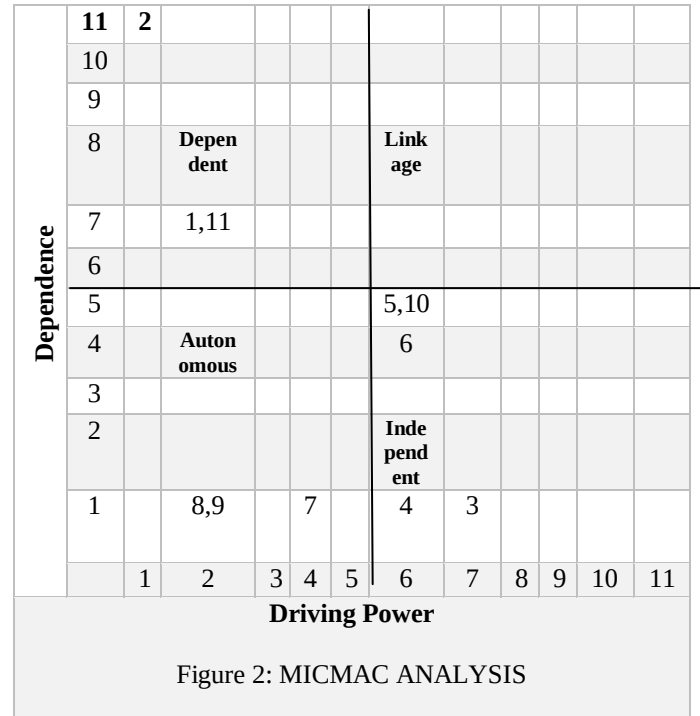
Step 4: Development of ISM

Now the final reachability matrix is used to generate the hierarchical model. Depending on the level attained from reachability matrix digraph is constructed. Element with level 1 is placed at the top, Element with level 2 is placed at the below it and so on until the last level is obtained.

Now, if we analyze this hierarchical model of ISM, we get to know that Single Minute Exchange of Die (SMED) (criteria 4) and Information Technology (criteria 3) is the most significant factor as it forms the base. Then comes the Computer Integrated Manufacturing (criteria 5), Enterprises resource planning (criteria 6), Standardized Work (criteria 7) and Smart Process and automation (criteria 10) at level 2 which influence the Pull System (criteria 1), Fixed Position layout (criteria 8), Cellular Manufacturing (criteria 9) and Total Quality Management(criteria 11) which lies at level 3. At the top i.e. level 4 contain Value Stream Mapping.

Table 5: Summary of levels assigned to lean manufacturing practices				
Element	Reachability set	Antecedent Set	Intersection	Level
1	1,2	1,3,4,5,6,7,10	1	II
2	2	1,2,3,4,5,6,7,8,9,10,11	2	I
3	1,2,3,5,6,10,11	3	3	IV
4	1,2,4,5,10,11	4	4	IV
5	1,2,5,6,10,11	3,4,5,6,10	5,6,10	III

6	1,2,5,6,10,11	3,5,6,10	5,6,10	III
7	1,2,7,11	7	7	III
8	2,8	8	8	II
9	2,9	9	9	II
10	1,2,5,6,10,11	3,4,5,6,10	5,6,10	III
11	2,11	3,4,5,6,7,10,11	11	II



MICMAC ANALYSIS

Driving Power and dependence are analyzed using MICMAC analysis. All the variables are segmented into 4 clusters dependent, autonomous, independent and linkages.

Elements 7, 8 and 9 in the autonomous section have negligible influence on machine tool Sector. In independent section element 3 i.e. Information Technology has maximum driving power and minimum dependence. Element with high driving power should be handled at high priority. Elements 1, 2 and 11 have low driving power and high dependence and have a key role in implementing lean.

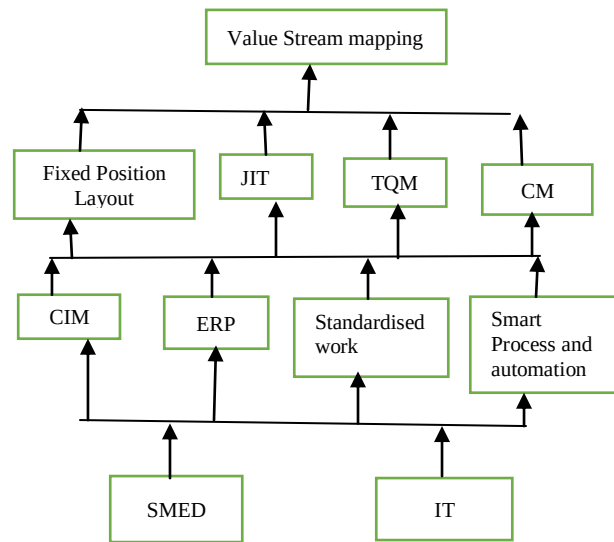


Figure 1 ISM-based lean implementation model

CONCLUSION

There is a tough competition in manufacturing sector due to several reasons. Political instability and economic recessions too have created urgent need for the manufacturing sector to adopt lean manufacturing. By the use of above mentioned 11 criteria, we have developed the ISM methodology's hierarchical model, and by bringing out the driving and dependence power, we have assigned autonomous, dependent, linkages and independent categories.

The research helps to provide the machine tool sector a critical model for realizing the lean implementation to its full potential. And this proposed ISM model can assist them to divert their priorities accordingly to improve their operational performance. Thus, the ISM model put forward in this work provides the decision makers with a model for identification of problems in lean manufacturing. This model generated using ISM, highlights the intricacy of relationship among different lean elements. The research has developed the criteria for lean implementation in machine tool industry using the ISM methodology.

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