Uncertain Supply Chain Management 4 (2016) 83–92

Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

Analysis of significant lean manufacturing elements through application of interpretive structural modeling approach in Indian industry

Rakesh Kumar[a*] and Vikas Kumar[b]

[a]*Research Scholar, Mechanical Engineering Department, YMCA University of Science and Technology, India*
[b]*Associate Professor, Mechanical Engineering Department, YMCA University of Science and Technology, India*

CHRONICLE

Article history:
Received April 18, 2015
Received in revised format May 10, 2015
Accepted June 25 2015
Available online
July 3 2015

Keywords:
Lean manufacturing
Lean manufacturing elements
ISM
SSIM
Diagraph

ABSTRACT

Lean Manufacturing is being adopted by many Indian industries based on its capability of improving manufacturing performance. Lean Manufacturing supports the concept of delivering the low cost and good quality product to customer by focusing on elimination of waste. Lean Manufacturing employs various elements which aspire to involve the employees to create a customer centric organization. This paper is an attempt to examine the significance of various lean manufacturing elements in Indian industries. Interpretive Structural Modeling (ISM) approach is used to examine their inter-relationship and ranking based on their driving power and dependence powers through development of diagraph and structural model in the Indian industry context.

1. Introduction

Lean Manufacturing (LM) is a well-recognized manufacturing approach which emphasis on improving manufacturing efficiencies through identifying and removing waste from the manufacturing system. India is emerging as a focal point for global manufacturing and hence Indian industries are facing the heat of global competition. To stay alive in competitive environment, Indian industries need to reinforce their strengths and improve based on their weakness. LM has turn out to be a subject of the attention for Indian manufacturing companies based on its capability of improving competitiveness by reducing manufacturing lead time, improving product quality, reducing manufacturing costs, reducing material handling. It also creates an environment of delivering product with reduced delivery time, lower cost, reduced waste and improved customer satisfaction (Deif, 2012; Taj & Morosan, 2011). Organizations which have implemented lean are able to work with reduced cost of manufacturing, lower inventories, reduced quality defects and making product available based on the customer requirement (Kumar & Kumar, 2014). LM recommends the identification and segregation of value-adding and non-value-adding activities. A value adding activity is one for which customer is willing pay for (Nordin et al., 2010). Researchers have studied the different elements of lean in the context of Indian industry. The

* Corresponding author
E-mail address: Rakesh.Kumar2@federalmogul.com (R. Kumar)

doi: 10.5267/j.uscm.2015.7.001

purpose of this study is to distinguish the correlation and ranking of various LM elements. An inter-relationship is established among the different LM elements based on the impact of the interdependencies of the LM elements on each other. An ISM model is constructed to recognize the relationship among the LM elements. The aim of this paper is to identify

I. The relationship between the lean elements
II. Analysis of LM elements based on their deriving power and dependent power
III. Rank of hierarchy of the lean elements
IV. To provide guideline to Indian industry for focusing on elements with high impact to gain more benefits.

2. Identification of LM Elements in Indian context

India is rising as an international hub for manufacturing. So existence of multinational companies in India is growing on yearly basis. Therefore Indian manufacturing organizations are now facing global competition in Indian market itself and hence they are aggravated to take serious step forward to keep them competitive and one such step is LM implementation. The key purpose of LM is to improve utilization of resources and space more effectively consequently increasing more yield from their existing resources. Lean Manufacturing is put into practice to improve the competency through eliminating the waste and non-value adding activities from the manufacturing system. Waste can be present in the manufacturing system in many ways like overproduction, excess inventory, over processing, unnecessary transportation, defects, waiting and avoidable motion (Womack et al., 1990). After implementation of LM organizations are expected to have improved operational efficiencies, product quality and overall performance (Kumar & Kumar, 2012). Manufacturing industries over the global have understood the implications of high inventories so they are rapidly shifting their manufacturing process from batch production to a new manufacturing approach with lesser inventories, called lean manufacturing (Kumar & Kumar, 2012). Lean manufacturing is a manufacturing style which highlights the identification and elimination of all types of wastes from the processes making it more efficient (Mohan raj et al., 2011).

In a study conducted by Kumar and Kumar (2015) a two tailed t- test with a significance level of five percent was carried out to establish the significance of various LM elements. The hypothesis was developed that if the Lean manufacturing elements given in Table 1 are not significant for LM in Indian industry the null hypothesis (H_0) will be rejected and alternate hypothesis (H_{a1}) will be accepted.

It was observed that nine LM elements out of total 29 elements are significant lean manufacturing elements over other lean elements in Indian industry based on survey results. Followings are the observed significant LM elements:

I. Total Employee Involvement
II. Inventory reduction
III. Wastage identification
IV. Continuous improvement
V. Load leveling
VI. Small lot size
VII. Cycle time reduction
VIII. Lead time reduction
IX. Standardization

Table 1
Significance of Lean manufacturing elements in Indian industry (adopted from Kumar & Kumar, 2015)

S.No.	LM elements	1 (Low)	2	3	4	5 (High)	Mean	Std. dev.	t-value	Results	
1	Inventory reduction	0	1	13	23	22	4.119	gf	**2.0807**	H_o rejected	H_{a1} accepted
2	Total Employee	0	1	12	26	20	4.102	0.781	**1.9943**	H_o rejected	H_{a1} accepted
3	Error proofing/poka-Yoke	1	8	20	26	4	3.407	0.873	-4.3282	H_o accepted	
4	Set up reduction.	0	3	15	25	16	3.915	0.857	0.1467	H_o accepted	
5	Improve OEE.	0	4	13	31	11	3.831	0.813	-0.6463	H_o accepted	
6	De-bottlenecking	0	1	11	35	12	3.983	0.682	0.9478	H_o accepted	
7	Line pace	2	15	27	15	0	2.932	0.807	-9.2064	H_o accepted	
8	Wastage identification	0	1	14	20	24	4.136	0.84	**2.1647**	H_o rejected	H_{a1} accepted
9	Equipment uptime	1	20	27	11	0	2.814	0.754	-11.0606	H_o accepted	
10	Quality at source.	0	2	7	38	12	4.017	0.682	1.3295	H_o accepted	
11	Takt Time working	2	6	11	30	10	3.678	0.99	-1.7136	H_o accepted	
12	Small lot size	0	0	9	31	19	4.169	0.673	**3.0864**	H_o rejected	H_{a1} accepted
13	Continuous improvement	0	1	9	29	20	4.153	0.738	**2.6385**	H_o rejected	H_{a1} accepted
14	Good Housekeeping	0	3	13	30	13	3.898	0.803	-0.0056	H_o accepted	
15	Manpower reduction	0	1	9	37	12	4.017	0.656	1.3817	H_o accepted	
16	Load leveling (Heijunka)	0	2	7	33	17	4.102	0.736	**2.1175**	H_o rejected	H_{a1} accepted
17	Reduced information	0	11	10	24	14	3.695	1.038	-1.5092	H_o accepted	
18	Cycle time reduction	0	3	5	34	17	4.102	0.759	**2.0531**	H_o rejected	H_{a1} accepted
19	Quick changeovers	0	3	10	27	19	4.051	0.839	1.3909	H_o accepted	
20	Process control.	0	4	9	34	12	3.915	0.794	0.1583	H_o accepted	
21	Lead time reduction	0	0	13	28	18	4.085	0.726	**1.9662**	H_o rejected	H_{a1} accepted
22	Safe working	0	2	12	28	17	4.017	0.799	1.1356	H_o accepted	
23	Standardization.	0	0	10	33	16	4.102	0.662	**2.3545**	H_o rejected	H_{a1} accepted
24	Reduce variability.	0	5	13	27	14	3.847	0.887	-0.4454	H_o accepted	
25	JIT deliveries	0	1	10	32	16	4.068	0.716	1.8122	H_o accepted	
26	Flexible manufacturing.	0	0	11	33	15	4.068	0.666	1.948	H_o accepted	
27	Layout improvement.	2	4	10	34	9	3.746	0.921	-1.2772	H_o accepted	
28	Line Balancing	0	4	10	28	17	3.983	0.861	0.7509	H_o accepted	
29	Pull System	0	2	14	18	25	4.119	0.892	1.8919	H_o accepted	
						Population mean	3.8989		N=59		

3. Research methodology

Interpretive Structural Modeling (ISM) technique is used for development of a Structural model for LM elements. The purpose of this study is to examine the relationships among the various significant LM elements and presenting a rank to LM elements in the Indian industries context. The LM elements are observed for their inter-relationship and ranks in terms of their driving power and dependence power. Reachability matrix is achieved to assign the rank to the elements. It is difficult to examine all twenty-nine element of LM so nine significant LM elements recognized by Kumar and Kumar (2015) are considered for study.

4. Interpretive structural modeling (ISM)

Interpretive structural modeling (ISM) approach was developed by Warfield (1974) and Sage (1977) and is employed for analyzing the correlation between various variables which influences the system under study. It helps in assigning the rank for the variables in the order with which order they affects the entire structure. The significance of ISM is to make a decision about if variables are interconnected or not. If yes then is to know through ISM that how they are connected with each other. The decision in relation to their present correlation is taken by a team having detailed understanding about the system under study. This includes discussion of ISM method and MICMAC analysis. The following are the steps involved for implementing the ISM approach:

Step i: Identification of LM elements: Primary step in using ISM is to recognize the variables. For this study various elements of LM are considered as variables in the lean environment within the Indian industry. Following nine elements of LM are selected in preceding section.

a) Total Employee Involvement
b) Inventory reduction
c) Wastage identification
d) Continuous improvement
e) Load leveling
f) Small lot size
g) Cycle time reduction
h) Lead time reduction
i) Standardization

Step ii: Development of Structural Self-Interaction Matrix (SSIM): Relationship between LM elements is studied with the construction of SSIM matrix. Structural Self-Interaction Matrix (SSIM) is constructed for various LM elements as variables signifying the pair- wise relationship among the variables in the system. Four symbols are employed to indicate the correlation among the LM elements in the following order:

V - LM Element *i* affects LM element *j*.
A - LM Element *j* effects the LM element *i*.
X - LM Elements *i* and *j* affects each other.
O - LM Elements *i* and *j* are not related.

Table 2
Structural self-interaction matrix for LM elements

S. No	Description of LM barrier	1	2	3	4	5	6	7	8	9
1	Total Employee Involvement		V	X	V	V	V	V	V	V
2	Load levelling			A	A	X	A	A	V	V
3	Continuous improvement				X	V	V	V	V	V
4	Wastage identification					V	V	V	V	V
5	Standardization						V	V	X	V
6	Small lot size							A	V	V
7	Cycle time reduction								V	O
8	Lead time reduction									A
9	Inventory reduction									

Step iii: Development of initial reachability matrix: The Initial reachability matrix is derived from the Structural self-interaction matrix (SSIM) by replacing the V, A, X and O initials by either “0” or “1” based on following hypothesis:

i. If the cell (i, j) has symbol “V”. It is substituted by “1” and the corresponding cell (j, i) is assigned “0” in initial the reachability matrix.
ii. If the cell (i, j) has symbol “A”. It is substituted by “0” and the corresponding cell (j, i) is assigned “1” in initial the reachability matrix.
iii. If the cell (i, j) has symbol “X”. It is substituted by “1” and the corresponding cell (j, i) is assigned “1” in initial the reachability matrix.
iv. If the cell (i, j) has symbol “O”. It is substituted by “0” and the corresponding cell(j, i) is assigned “0” in initial the reachability matrix

Table 3
Initial reachability matrix

S. No	Description of LM barrier	1	2	3	4	5	6	7	8	9	Driving power
1	Total Employee Involvement	1	1	1	1	1	1	1	1	1	9
2	Load levelling	0	1	0	0	1	1	0	1	1	5
3	Continuous improvement	1	1	1	1	1	1	1	1	1	9
4	Wastage identification	0	1	1	1	1	1	1	1	1	8
5	Standardization	0	1	0	0	1	1	1	1	1	6
6	Small lot size	0	1	0	0	0	1	0	1	1	4
7	Cycle time reduction	0	1	0	0	0	1	1	1	0	4
8	Lead time reduction	0	0	0	0	1	0	0	1	0	2
9	Inventory reduction	0	0	0	0	0	0	0	1	1	2
	Dependence power	2	7	3	3	6	7	5	9	7	

Step iv: Level identification: Reachability matrix is used for identification of different levels for various LM elements. Reachability set and antecedent set are determined for LM elements from the reachability matrix. The element in the matrix affecting the other element are contained in reachability and antecedent set. Consequently, the intersection is achieved for these sets for every LM elements. High rank LM elements in the hierarchy of ISM model are considered as elements that are common in the intersection and reachability sets. The high ranked elements do not facilitate supplementary elements to get the level higher than their individual level. The top level of elements is recognized through this method and the same method is repeated in iterative way until level for all the elements is recognized see from Table 4 to Table 10. The final structure of the system as ISM model and diagraph are drawn on the basis of determined levels for the elements.

Table 4
1st Iteration of reachability matrix to estimate the rank of LM element

LM element	Reachability set	Antecedent set	Intersection	Level
1	123456789	13	13	
2	25689	1234567	256	
3	123456789	134	134	
4	23456789	134	34	
5	256789	123458	258	
6	2689	1234567	26	
7	2678	13457	7	
8	58	123456789	58	I
9	89	1234569	9	

Table 5
2nd Iteration to estimate the rank of LM element

LM element	Reachability set	Antecedent set	Intersection	Level
1	12345679	13	13	
2	2569	1234567	256	
3	12345679	134	134	
4	2345679	134	34	
5	25679	123458	25	
6	269	1234567	26	
7	267	13457	7	
9	9	1234569	9	II

Table 6

3rd Iteration to estimate the rank of LM element

LM element	Reachability set	Antecedent set	Intersection	Level
1	1234567	13	13	
2	256	1234567	256	III
3	1234567	134	134	
4	234567	134	34	
5	2567	123458	25	
6	26	1234567	26	III
7	267	13457	7	

Table 7

4th Iteration to estimate the rank of LM element

LM element	Reachability set	Antecedent set	Intersection	Level
1	13457	13	13	
3	13457	134	134	
4	3457	134	34	
5	57	123458	5	
7	7	13457	7	IV

Table 8

5th Iteration to estimate the rank of LM element

LM element	Reachability set	Antecedent set	Intersection	Level
1	1345	13	13	
3	1345	134	134	
4	345	134	34	
5	5	123458	5	V

Table 9

6th Iteration to estimate the rank of LM element

LM element	Reachability set	Antecedent set	Intersection	Level
1	134	13	13	VII
3	134	134	134	VI
4	34	134	34	VI

Table 10

Final ranking matrix for all LM elements

LM element	Reachability set	Antecedent set	Intersection	Level
1	123456789	13	13	VII
2	25689	1234567	256	III
3	123456789	134	134	VI
4	23456789	134	34	VI
5	256789	123458	258	V
6	2689	1234567	26	III
7	2678	13457	7	IV
8	58	123456789	58	I
9	89	1234569	9	II

5. The MICMAC analysis

MICMAC analysis is employed in analyzing the driving power and dependence powers for all the LM elements. Driving power of a LM element as a variable is achieved by adding all ones assigned for supplementary variable in the columns beside a variable in a row and dependence power is calculating by adding all ones assigned for supplementary variable in rows assigned for a variable in the column as shown in Table 3. LM elements has been categorized for their dependence power and driving power they are categorized into four group as autonomous elements, linkage elements, dependent elements and independent elements. The diagram depicting the dependence power and driving power for LM elements is shown in below

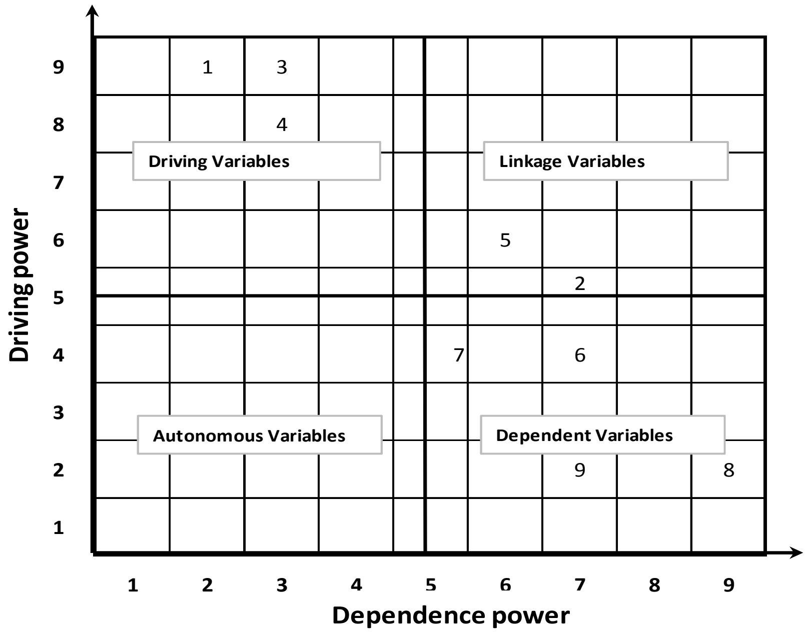

Fig. 1. Diagram showing the driving power and dependence power for LM elements

LM element no. 1 has a driving power to the tune of 9 and highest in the system and the dependence power of 2 hence it is placed at the corresponding cell. In the same manner all the LM elements are allocated the cells based on their driving power and dependence power. The intention of classification of the LM elements is to examine the dependence power and the driving power of the individual LM elements. The independent elements are those LM elements that have strong driving power but their dependence power is weak. In the given figure 1, 3 and 4 are the independent LM elements. The dependent elements are those with high dependence power but low in driving power and in this case LM variable no.8 is dependent variable. LM element no 6, 9 and 7 also lies in the same segment with different order. Autonomous variable or LM element in this case are those LM elements which has low deriving and low dependence power. The autonomous elements remains comparatively disengaged from the organization and they may not have any impact on other LM elements. In the studied no LM element is autonomous variable. The linkage variable segment has strong driving and dependence power and the LM elements lying into this segment is element no 5 and 2. Whatever action is taken for these LM elements will affect the supplementary LM elements.

6. Construction of digraph and ISM model

The interpretive structural model (ISM) is constructed base on initial reachability matrix depicted in Table 3. The present relation among various LM elements is indicated by drawing an arrow from LM element i to LM element j. Construction of the graph is known as initial directional graph. The final ISM model is obtained from initial directional graph by subsuming the LM elements names in place of the LM element numbers.

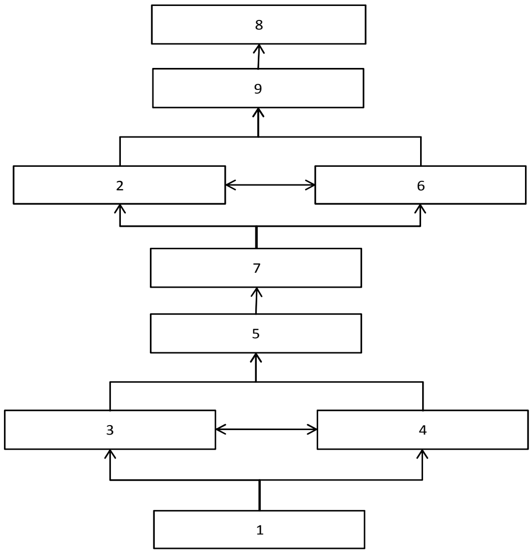

Fig. 2. The digraph illustrating the relationship between the LM elements

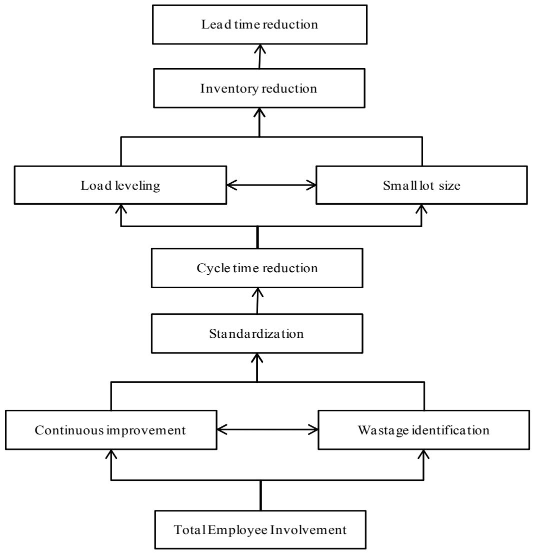

Fig. 3. Final ISM based model for LM elements

7. Results

The ISM model shown in Fig. 3 reveals the position of all the significant LM elements regarding based on the importance of their role in the implementation of LM. The directional arrows indicate that a particular element is dictated by other one or is dictating to others as shown in the diagram. The positioning of elements is based on their ranking in context with their driving power and dependence power. Element having more driving power may impact the element with low value of driving power. In the studied case elements of lean manufacturing in Indian context are analyzed and it is evident from interpretive structural model that lead time reduction is the top ranked LM element. This can be achieved by achieving inventory reduction which is supported by load leveling and introducing smaller lot sizes, reducing cycle time and with standardization of processes. Wastage identification and continuous improvement helps in achieving above mentioned elements with the support of total employee’s involvement.

8. Conclusions

Successful implementation of LM can be ensured by knowing the LM elements and their level. Total employee’s involvement, continuous improvement and wastage identification are independent elements LM because of low level of dependence and high driving power among all the LM elements and so it is placed at the down most level in ISM model. The lead time reduction is placed at the highest level being a dependent LM element because it has high dependence power and comparability low driving power. It may not have impact on other element at its own but is dependent on many elements to get achieved. There is no autonomous element indicates that each element has its active role in LM implementation. Linkage elements are load leveling and standardization of processes. The understanding about relationship and levels of different LM elements is important for Indian industry to make step forward in LM implementation. In Fig. 3 it is indicated that companies must focus on engaging their employee’s to work for continuous improvement and wastage identification so that lean implementation can be made easy in the Indian industry.

Ranking of various LM elements with diagraph and development of ISM model based on their ranking has significant relevance for researchers and practiceners. The study of LM elements and knowing their status can be helpful in knowing the significant elements of LM for the Indian industries. The Indian industry should identify the priority of the area for improvement in order to enhance the impact of elements in LM and consequently improve upon their competitiveness.

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