ISSN: 0974-5823 Vol. 7 No. 5 May, 2022

International Journal of Mechanical Engineering

An interpretive structural modeling approach to lean manufacturing obstacles

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Abstract:
Lean manufacturing [LM] has developed as a vital aspect of corporate strategy in today's rapidly changing global business environment. Many SMEs have implemented LM, and many more are in the process of doing so. LM deployment is interrupt by a number of issues known as LM obstacles. The purpose of this research is to explore the connections between the discovered LM obstacles. Furthermore, this study aids in understanding the mutual affects of obstacles and identifying those obstacles that support (driving obstacle) and those obstacles that are most influenced by other obstacles (dependent obstacles). To develop mutual interactions among these obstacles, the interpretative structural modelling (ISM) methodology is applied. The suggested framework provides a systematic method for analyzing obstacles and also produces roadmaps for SMEs to implement lean manufacturing.
Keywords: Obstacles, Dependence power, Driving power, Interpretive structural modeling, Lean Manufacturing

1 Introduction:

Traditional sources of competitive advantage appear to be insufficient in the current environment of ever-increasing global competition. Engineering industries must rethink their tactics in order to be competitive and survive. LM is currently seen as a critical strategy for achieving these goals. During the post-World War II reconstruction period, Toyota implemented lean manufacturing, often known as lean production [1]. Toyota established the concept of lean manufacturing (LM) in the 1950s to challenge American productivity. The goal was to find and eliminate everything that was unnecessary. LM attempts to separate the inefficiencies and irrelevant aspects of each process. This is simply accomplished by closely monitoring people, equipment, materials, and production. Anything that is wasteful does not provide value; it merely adds to the cost and diminishes the customer's satisfaction. It is used to identify complex and subjective concerns. One of the main draws for researchers and practitioners is the deployment of LM. SMEs are increasingly concerned with developing lean assets to improve their competitiveness. If SMEs everywhere in the world are to compete successfully, LM effort is no longer an option, but rather a need. [2, 3]. The majority of small and medium businesses (SMEs) oppose the use of LM. Despite previous proof of the benefits of lean adoption, there are a number of obstacles to overcome, including perception, a lack of real benefits, and challenges with shop floor staff [4, 5]. The goal of this research is to use interpretative structural modeling (ISM) to build links between the observed obstacles and classify them based on their driving and reliance power. ISM is a well-known method for determining links between distinct components that characterize a problem or issue. The relationship matrix, which was later employed in the construction of the ISM model, was created using the opinions of a panel of specialists. Theoretically, these obstacles are generated from a variety of literature sources and expert conversation (See Tab. 1). Some obstacles have been extracted from the work of people who have researched LM in general or specifically addressed a specific obstacle. Although different academics have used different terms to describe these limitations, common themes can be utilized to characterize them. They have also been discussed in the literature, albeit with varying degrees of attention and coverage.

Table 1.1 LM obstacles

Obstacles Number	Describe the obstacle	Source
1.	Culture	10,18
2.	Leadership	11,20
3.	Strategic Planning	11,22
4.	Lean Resources	12.24
5.	Financial Resources	13,19
6.	Technological Infrastructure	14,23
7.	Innovation and Lean Manufacturing	15,17
8.	Integrations of Systems	16,21
9.	Lean Capture	17,25

2. Literature review

Various authors who have investigated and written directly on this topic have identified obstacles that prevent organizations from implementing LM. A Fraunhofer Stuttgart study highlighted one of the initial sets of impediments to LM implementation. The most significant impediments to LM implementation, according to this study, were a lack of time and awareness about LM [6]. Another study that looked into the practices discovered three key challenges to LM implementation, including a lack of time, lack of understanding, and lack of senior management support [7]. J. Warfield proposed ISM in 1973 as a method for analyzing complex social and economic systems. It's a computer-based learning technique that allows individuals or groups to create a roadmap for deciphering the intricate relationships between the criteria in difficult circumstances. The primary idea is to employ expert lean and practical experience to solve a complex system with several subsystem elements and build a multilevel structural model. The method is choosing a collection of criteria, comparing them in a binary relationship, and then generating a reachability matrix from the results. ISM is a system structure representation method that involves creating a hierarchy of system variables [8]. It is an interactive learning process in which a number of varied and closely connected elements are organized into a comprehensive system [9].The authors identified nine obstacles to LM activities in the organization based on their research review (See Tab. 1). The next sub-sections explain these obstacles.

2.1. Culture

Employees are motivated to work productively when the culture supports teamwork and initiative. Before beginning a project, it is necessary to have a plan. Any project's success is determined by the culture of those involved. The implementation process will be smooth if everyone in the organization is informed of the changes. [10]

2.2. Leadership

It means that top managers who provide a clear vision and value to promote lean manufacturing are more likely to succeed in developing a lean sharing culture. Leadership is critical for establishing a LM-friendly organizational culture. Senior executives must promote information exchange and set a good example through their actions. Human resource abilities are recognized by leaders, who understand that high motivation fosters creativity. They work on various proposals and research projects in order to develop new ideas. [11]

2.3 Strategic Planning

It is the definition of LM goals, the delineation of LM across multiple organizational working scopes, and the formulation of long-term plans for managing LM. The most common objectives of strategizing have been to create a plan of action and make it easier to respond to environmental changes. The determination of LM goals, the demarcation of lean across organizational activities, and the specification of long-term plans for managing LM are all part of strategic planning. The reasons for participating in strategic planning might be identified at various stages of the process. [11]

2.4 Lean Resources

Professional cognition and lean dwell in the minds of employees and are embedded in the organization's processes, products, and services. Organizations are seen as lean reservoirs. Organizational capacities for developing and transmitting lean are being recognized as a key component of competitive advantage. [12]

2.5 Financial Resources

It refers to finances and other resources used to support the LM program's infrastructure and staffing needs. For LM to be implemented, it refers to finances and other resources used to support the LM program's infrastructure and staffing needs. For LM to be implemented, an organization must set aside cash and other resources. [13]

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2.6 Technological Infrastructure

It implies information and communication technologies to facilitate the codification, conversion and management of lean. There are wide varieties of technologies to support LM activities. The selection of appropriate technology improves performance. [14]

2.7 Innovation and Lean

In a fast-changing environment, the competitive advantage of organizations is based on the decision to exploit and develop the power of lean creation and use. The innovation and lean creation are required for competitive initiatives such as improving customer satisfaction, developing new products and markets and providing faster response. [15]

2.8 Integration of Systems:

It is the integration of organizational system and its subsystems, which enables seamless flow of information and lean across the organization. [16]

2.9 Lean Capture

It is the process of identifying, documenting, and explaining organizational lean in order to make it more accessible and useable. The issue in LM is to figure out how to codify tacit lean. People's minds are full of tacit lean. Formalizing and communicating tacit lean to others in the company is extremely tough. Interpersonal meetings, mentoring, teamwork, chat sessions, intranets, and opportunities for face-to-face dialogues such as group discourse or personal reflections on experience and lessons gained can all help to convey tacit lean. [17]

3. ISM Methodology and Model Development

ISM is a collaborative learning experience. A comprehensive systemic model is composed of a number of varied and closely related aspects. The model depicts the structure of a complex topic or problem, a system, or a subject of study in a well-designed pattern that includes both pictures and words. The ISM methodology aids in imposing order and direction on the complexity of relationships between system pieces.

3.1 The ISM technique includes the following steps:

Various steps involved in the ISM technique are as follows:

1. List down variables, which can be Objectives, Actions, and Individuals etc.
2. Establish a contextual relationship among variables with respect to which pairs of variables would be examined.
3. Develop a Structural Self Interaction Matrix (SSIM) for variables, which indicates pair-wise relationship among variables of the system.
4. Develop a Reachability Matrix from the SSIM and check the matrix for transitivity.
5. Partition the Reachability Matrix into different levels.
6. Develop the Reachability Matrix in its conical form, i.e. with most zero (0) variables in the upper diagonal half of the matrix and most unitary (1) variables in the lower half.
7. Based on the above, draw a Directed Graph (Digraph) and remove transitive links.
8. Convert the resultant Digraph into an ISM by replacing variable nodes with statements.
9. Review the ISM model to check for conceptual inconsistency and incorporate makes the necessary modifications.

3.2 Structural Self-Interaction Matrix (SSIM)

In order to understand the nature of contextual interactions among the obstacles, a group of specialists from industry and academia were interviewed (see Tab. 1). The following four symbols have been used to signify the direction of relationship between obstacles I and j) in order to analyses the obstacles in creating SSIM: Four symbols are used for the type of the relation that exists between the two sub-variables under consideration:

V for the relation from *i* to *j* but not in both directions;
A for the relation from *j* to *i* but not in both directions;
X for both direction relations from *i* to *j* and *j* to *i*; and
O if the relation between the variables does not appear valid.
In order to understand the nature of contextual interactions among the obstacles, a group of specialists from industry and academia were interviewed (see Table. 1)

Table 3.2.1: Structural Self-interaction Matrix (SSIM)

Elements	9	8		7	6	5	4	3	2
1	O	V		V	O	O	O	O	A
2	V	V		O	O	O	V	V	
3	V	V		O	V	V	O		
4	O	O		X	O	O			
5	O	O		O	V				
6	O	V		O					
7	X	O							
8	O								

Elements 1 to 9 are already discussed in section 3.1 and are: culture (element 1), leadership (element 2), strategic planning (element 3), lean resources (element 4), financial resources (element 5), technological infrastructure (element 6), innovation and lean creation (element 7), integration of system (element 8), and lean capture (element 9).

3.3 Reachability Matrix

The SSIM format is transformed into a reachability matrix format by transforming the information in each entry of the SSIM into 1s and 0s in the reachability matrix. The situations are as follows:

1. If the (*i*, *j*) entry in the SSIM is V, then the (*i*, *j*) entry in the reachability matrix becomes 1 and the (*j*, *i*) entry becomes 0.
2. If the (*i*, *j*) entry in the SSIM is A, then the (*i*, *j*) entry in the reachability matrix becomes 0 and the (*j*, *i*) entry becomes 1.

3. If the (*i*, *j*) entry in the SSIM is X, then the (*i*, *j*) entry in the reachability matrix becomes 1 and the (*j*, *i*) entry also becomes 1.

4. If the (*i*, *j*) entry in the SSIM is O, then the (*i*, *j*) entry in the reachability matrix becomes 0 and the (*j*, *i*) entry also becomes 0.

Following these rules, initial reachability matrix for the variables is prepared as shown in Table 3.2.1.

Table 3.3.1:

ELEMENTS	1	2	3	4	5	6	7	8	9
1	1	0	0	0	0	0	1	1	0
2	1	1	1	1	0	0	0	1	1
3	0	0	1	0	1	1	0	1	1
4	0	0	0	1	0	0	1	0	0
5	0	0	0	0	1	1	0	0	0
6	0	0	0	0	0	1	0	1	0
7	0	0	0	1	0	0	1	0	1
8	0	0	0	0	0	0	0	1	0
9	0	0	0	0	0	0	1	0	1

Partitioning the Reachability Matrix

The matrix was partitioned by assessing the reachability and antecedent sets for each variable. The process was completed in six iterations as follows:

Table 3.3.2:

Element (P_i)	Reachability Set: R (P_i)	Antecedent Set: A (P_i)	Intersection R (P_i) A (P_i)	Level
1	1,7,8	1,2,8	1,8	
2	1,2,3,4,8,9	2	2	
3	3,5,6,8,9	2,3	3	
4	4,7	2,4,7	4,7	I
5	5,6	3,5	5	
6	6,8	3,5,6	6	
7	7,9	1,4,7,9	7,9	I
8	8	1,2,3,6,8	8	
9	7,9	2,3,7,9	7,9	I

In (Table 3.3,2), variables 4 (lean resources), 7 (Innovation and lean creation) and 9 (Lean capture) are put at level I.

Table 3.3.3:

Element (P_i)	Reachability Set :R (P_i)	Antecedent Set: A (P_i)	Intersection R (P_i) A (P_i)	Level
1	1,8	1,2,8	1,8	II
2	1,2,3,8	2	2	
3	3,5,6,8	2,3	3	
5	5,6	3,5	5	
6	6,8	3,5,6	6	
8	8	1,2,3,6,8	8	II

LM variables 1 (culture) and 8 (integration of systems) are at level II (Table 3.3.3).

Table 3.3.4:

Element (P_i)	Reachability Set: R (P_i)	Antecedent Set: A (P_i)	Intersection R (P_i) A (P_i)	Level
2	2,3	2	2	
3	3,5,6	2,3	3	
5	5,6	3,5	5	
6	6	3,5,6	6	III

Variable 6 (Technological infrastructure) comes at level III (Table 3.3.4).

Table 3.3.5:

Element (P_i)	Reachability Set: R (P_i)	Antecedent Set: A (P_i)	Intersection R (P_i) A (P_i)	Level
2	2,3	2	2	
3	3,5	2,3	3	
5	5	3,5	5	IV

From (Table 3.3.5), it is observed that financial resources (element 5) are at level IV.

Table 3.3.6:

Element (P_i)	Reachability Set: R (P_i)	Antecedent Set: A (P_i)	Intersection R (P_i) A (P_i)	Level
2	2,3	2	2	
3	3	2,3	3	V

Fifth iteration (Table 3.3.6) puts element 3 (strategic planning) at level V.

Table 3.3.7:

Element (P_i)	Reachability Set: R (P_i)	Antecedent Set: A (P_i)	Intersection R (P_i) A (P_i)	Level
2	2	2	2	VI

Sixth and final iteration (Table 3.3.7) gives the level of leadership (element 2) as VI.

All the six levels thus identified using ISM methodology are shown in Table 3.2.8.

TABLE 3.3.8:

S.N	Level	Elements
1	I	4,7,9
2	II	1,8
3	III	6
4	IV	5
5	V	3
6	VI	2

3.4 Developing Conical Matrix

A conical matrix is developed by clubbing together elements in the same level, across rows and columns of the final reachability matrix, as shown in Table 3.4.1.

Table 3.4.1: Conical Form of Reachability Matrix

ELEMENTS	4	7	9	1	8	6	5	3	2
4	1	1	0	0	0	0	0	0	0
7	1	1	1	0	0	0	0	0	0
9	0	1	1	0	0	0	0	0	0
1	0	1	0	1	1	0	0	0	0
8	0	1	0	0	1	0	0	0	0
6	0	0	0	0	1	1	0	0	0
5	0	0	0	0	0	1	1	0	0
3	0	0	1	0	1	1	1	1	0
2	1	1	1	1	1	0	0	1	1

3.5 MICMAC ANALYSIS

The objective of MICMAC analysis is to analyze the driver power and dependence power of lean manufacturing variables (Mandal and Deshmukh, 1994). The LM variables are classified into four clusters. First cluster includes “autonomous variables” that have weak driver power and weak dependence. These variables are relatively disconnected from the system, with which they have only few links, which may be strong. Second cluster consists of the dependent variables that have weak driver power but strong dependence. Third cluster has are unstable. Any action on these variables will have an effect on others and also a feedback effect on themselves. Forth cluster includes independent variables having strong driving power but weak dependence. It is observed that a variable with the very strong driving power, called as the key variables, falls into the category of independent or linkage variables. In the Table 7.11, an entry of "1" along the columns and rows indicates the dependence and driving power respectively.

TABLE 3.5.1: DRIVING POWER AND DEPENDENCE IN REACHABILITY MATRIX

ELEMENTS	4	7	9	1	8	6	5	3	2	Driving power	Ranks
4	1	1	0	0	0	0	0	0	0	2	IV
7	1	1	1	0	0	0	0	0	0	3	III
9	0	1	1	0	0	0	0	0	0	2	IV
1	0	1	0	1	1	0	0	0	0	3	III
8	0	1	0	0	1	0	0	0	0	2	IV
6	0	0	0	0	1	1	0	0	0	2	IV
5	0	0	0	0	0	1	1	0	0	2	IV
3	0	0	1	0	1	1	1	1	0	5	II
2	1	1	1	1	1	0	0	1	1	7	I
Dependence	3	6	4	2	5	3	2	2	1		
Ranks	IV	I	III	V	II	IV	V	V	VI		

The variables are categorized into ranks. For example, element 4 has forth rank in dependence as well as in driving power; while element 2 has sixth rank in dependence and first rank in driving power. Four categories are presented in Figure 3.5. Leadership (2) comes under category IV and therefore categorized as independent driver. Financial resources (5) is an autonomous variable and is kept under category I. Culture (1), lean resources (4), technological infrastructure (6), lean capture (9), integration of systems (8), strategic planning (3) and innovation and lean creation (7) are kept under the cluster of dependent variables.

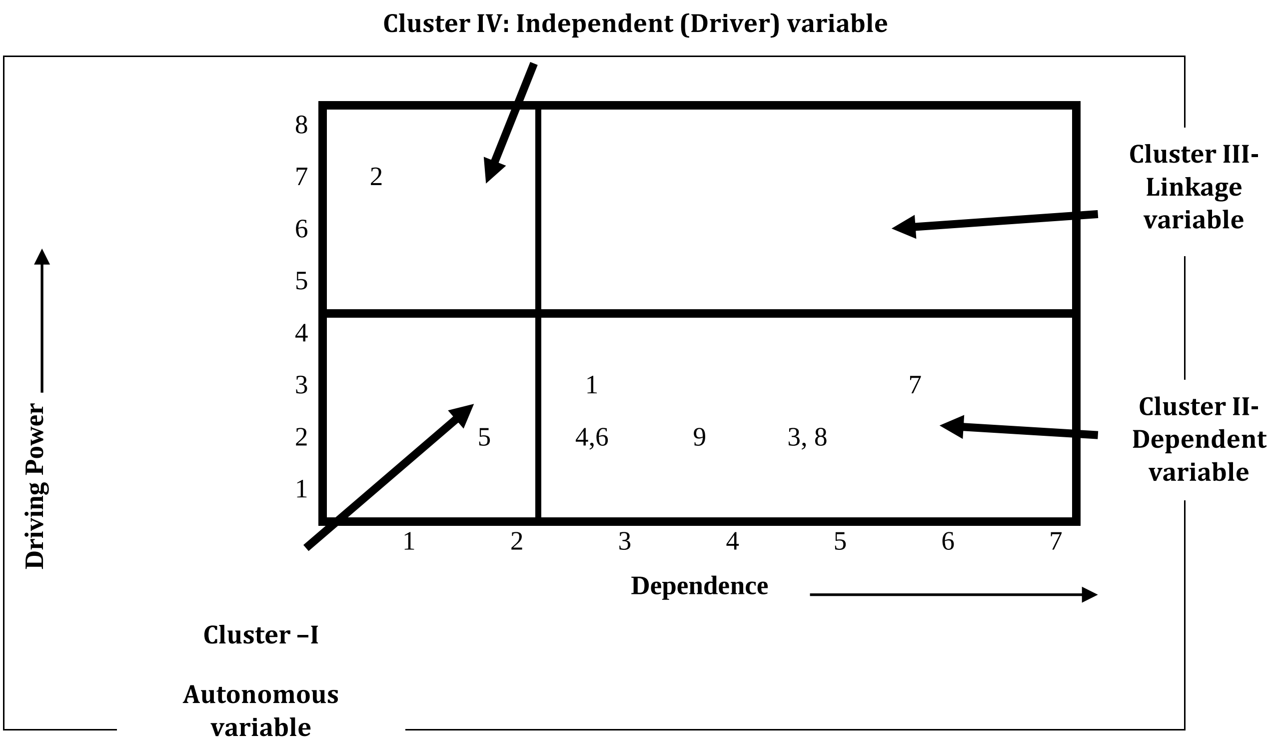

Figure 3.5 Cluster of LM obstacles

4. FINDINGS OF THE STUDY

Study and development of ISM for LM implementation in the Indian engineering industry result into following finding:

Leadership (element 2) is the important ingredient in adopting lean management in the engineering business, according to the rankings of the elements based on their driving strength. It has a lot of driving power, but it's not very dependent on the other variables being studied. Financial resource (element 5) is an autonomous factor in the LM implementation process, according to the "driver power-dependence matrix." This variable has a low dependence and is a weak driver. In the engineering industry, it plays a very minor role in the LM implementation process. So the idea that lean management is highly reliant on financial resources is false. Culture (element 1), lean resources (element 4), technical infrastructure (element 6), strategic planning (element 3), innovation and lean production (element 7) and lean capture (element 8) are all dependent aspects (element 9). These factors are weak drivers, but they are extremely interdependent. As a result, management should concentrate their efforts on developing strong lean resources through improved strategic planning. They should devise ways to improve technical infrastructure in order to foster innovation and lean production and capture. Combinations of these factors could produce similar interdependent action plans. There is no element under linkage that possesses both a strong driver power and a strong dependence. As a result, none of the nine LM variables chosen are unstable. Leadership (element 2) is an important factor to consider. It can condition the rest of the system and is referred to as independent elements or drivers of the LM system in engineering. The top-level factors for successful lean resources (element 4) are innovation and lean generation (element 7) and lean capture (element 9) . These are the objectives that must be met throughout LM implementation. These variables can also be used to create metrics for LM measurement. These are the visible components of a lean management system that are more process-oriented. The second-level criteria include system integration (element 8). This is essentially the system requirement for LM in the engineering business to thrive. The bottom-level variables are strategic issues such as strategic planning and leadership, as well as resource issues such as technical and financial resources.

5. Conclusions and future directions

Awareness variables in the LM implementation process requires an understanding of element levels. The essential bottom-line variables in the LM implementation process are lean resources, innovation and lean generation, and lean capture, thus these are at the top of the hierarchy. Employees in the Indian engineering business should share their lean and support top management in strategic planning to attain the organization's ultimate aim. Other factors such as leadership and strategic planning may have an impact on financial resources. However, it propels and hence aids in the development of technical infrastructure. The ability of the industry to apply the first three criteria, leadership, strategic planning, and financial resources, should be assessed initially. One of the most crucial factors to examine is lean culture. It is contingent on the employees' attitude and willingness. It is extremely difficult to quantify or measure the engineering industry's lean culture. Lean culture aids system integration, which is required to adopt LM across the entire enterprise. Leadership and strategic planning have a low amount of interdependence and are found at the bottom of the hierarchy. This means that in the engineering industry, leadership and strategic planning play a critical role in effective LM adoption.

In addition, the link model among the identified LM obstacles was not statistically confirmed in this study. The validity of such hypothetical models can be tested using structural equation modeling (SEM), often known as the linear structural connection approach. As a result, future research can use this approach to test the model's validity. ISM is a tool which can be helpful to develop an initial model whereas SEM has the capability of statistically testing an already developed theoretical mode. As a result, it has been proposed that future study focus on developing the initial model using ISM and then verifying it using SEM.

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