An Integrated Modeling Analysis of Enablers for Successful deployment of Lean Six Sigma in Indian manufacturing Industry

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Abstract: *Global competition, changing client demands, and a lack of natural resources have all made it difficult for industrial businesses to survive. To overcome such obstacles, manufacturing enterprises must use creative strategies. Manufacturing companies have used Lean Six Sigma is one of their primary business strategies to enhance operational performance. Indian Manufacturing companies have used Lean Six Sigma as one of their primary business strategies to enhance operational performance. Finding the enablers for a sustainable lean six sigma implementation is crucial for any manufacturing firm. The current study's aim is to identify and assess Sustainable Lean Six Sigma enablers. In the past, there hasn't been any research on sustainable Lean Six Sigma in Indian manufacturing industries; studies are what inspire the current case study. This Paper assist in recognizing and ranking the factors that encourage Sustainable Enablers for Successful deployment of Lean Six Sigma in Indian manufacturing Industry with an judgment toward sustainability using a numerical method. This Integrated Modeling Analysis approach will allow implementation experts and practitioners concentrate on enabling the most important dominating enablers and deploy LSS adoption with sustainable considerations.*

Keywords: **Lean Six Sigma (LSS), Enablers, Interpretive Structural Modeling (ISM), *MICMAC* Analysis.**

1. INTRODUCTION

Since from last two decades, Customers are putting more and more stress on companies to deliver orders quickly, with a large variety, and with customized goods while maintaining delivery and quality standards. They won't spend more, though; if they want something customized, high-quality, or delivered on time [1]. This challenge is made worse in the manufacturing sector where, in addition to declining margins, other issues such as rising quality requirements, waste reduction, inventory issues, variety issues, and service level constraints all predominate. Therefore, it has become important to implement technological managerial improvement options to aid industry on conflicting fronts. The challenges to effective Lean six sigma deployments in the Indian manufacturing industry would be the main subject of this study. Lean Six Sigma information based technique that combines Lean Manufacturing and Six Sigma, two powerful business optimization strategies, to boost a company's performance by reducing waste and process variation [2].

Need of the Study:

- Which Enabler factors facilitate the application of Lean Six Sigma in industrial manufacturing industry?
- How do you develop a contextual link between enablers?
- How can the Multi-criteria Decision Making (MCDM) approach be used to priorities enablers?
- How Interpretive Structural Modeling techniques is important to identify the correlation between each enablers while applying the LSS to any Indian manufacturing industry.

1.1 Lean Six Sigma in Manufacturing:

The increase in productivity and reduction in waste and complexity of the manufacturing process can be by accomplishment of Lean Manufacturing approach. While applying processes to improve quality and spotlight on the voice of the customer, has integrated by the Lean and Six Sigma methodology. [3]. This simply implies that Lean Six Sigma seeks to decrease waste and complexity internally while delivering the product to the client at the lowest possible cost. Acceptable quality level and speed as defined by market expectations Firms that use Lean Six Sigma will benefit from the capabilities of both Lean and Six Sigma [4].

Figure 1. Lean Six Sigma in Manufacturing

Lean Six sigma has been valuable method to fulfill the clients want via way of means of minimizing the versions in technique and lowering the Manufacturing defects. Lean Six Sigma as a technique that maximizes shareholder price via way of means of accomplishing the quickest price of development in purchaser satisfaction, cost, quality, technique speed, and invested capital. [5].

1.2 Objectives of the Study:

1. The aim of this study is to discover enablers for deployment of Lean Six Sigma in Indian manufacturing industry with a hierarchical model created using interpretative structural modelling.
2. Examine how the enablers interact with one another find out the most influence enablers for the successful implementation of LSS and assess the influence and reliance of enablers with the help of MICMAC approach.
3. For the effective adoption of LSS in manufacturing Industry, the enablers must be adopted in accordance with their impact and driving factors, thus giving emphasis on identification and propitiation of LSS enablers while taking into account
4. And last find out the prioritization analysis with MICMAC Approach in order to get more accurate results and a more useful model.

2. Literature Review

Lean and Six Sigma use distinct approaches to the utilization of an organization's human resources and culture. All personnel are viewed as process experts in the Lean technique, and they are encouraged to be critical of their own work. As a result, bottom-up improvement projects are originated by the employees themselves (intrinsic).

Table 1. Lean Six Sigma Implementation Enablers

Sr. No	Lean Six Sigma Implementation Enablers	Importance for			Reference
		Lean	Six Sigma	Lean Six Sigma	
1	Support, commitment & Involvement of Top management	High	High	High	6
2	Strategic Financial Resources & Planning	Moderate	High	High	7
3	Communication and information Management	High	High	High	8
4	Reward and recognition of team members	High	High	High	9
5	Environmental Management System	High	High	High	10
6	Effective Cross Function Management	High	High	High	11
7	Project Prioritization and Selection	Moderate	Moderate	Moderate	12
8	Understanding tools and techniques of Lean Six Sigma	High	High	High	13
9	Linking Lean Six Sigma to business strategies	High	High	High	14
10	Integrating Customer to Lean Six Sigma	Moderate	Moderate	Moderate	15
11	Quality of Human Resources and Linking to Lean Six Sigma	High	High	High	16
12	Extending LSS to Supplier & Supply Chain	High	Moderate	High	17
13	Competent Work Force and Employee Involvement	High	High	High	18
14	Organizational Culture, Change and Improvement	High	High	High	19
15	Market increase & Stakeholder pressure	High	High	High	20
16	Appropriate Quality of Manufacturing Materials & Facilities	High	Moderate	High	21
17	Effective scheduling & Reduction in Unnecessary Inventory	High	Moderate	High	22
18	Precise selection of LSS tools and techniques	High	High	High	23
19	Resource and skills to facilitate the implementation	High	Moderate	High	24
20	Improved Customer Satisfaction	High	High	High	25
21	Benchmarking System	High	Moderate	High	25
22	Optimization of Transportation and Material Handling	High	Moderate	High	26
23	Statistical Thinking	Moderate	High	High	27
24	Reliable Data Collection and Retrieval System	Moderate	High	High	27
25	Employee motivation and involvement	High	High	High	27
26	Firm’s reputation in the Market	High	High	High	27

Six sigma use the expert structure to complete improvement activities based on criteria like as quality improvement, increased shareholder value, or efficiency improvement. Lean six sigma execution empowering influences were recognized through a writing study and the significance of lean six sigma and lean six sigma was laid out through a meeting to generate new ideas with specialists after the dispersion of lean six sigma and lean six sigma writing among the specialists the specialists in this meeting chosen the 26 most huge empowering agents for carrying out lean six sigma table 4 shows the overall pertinence of these recognized empowering influences

3. Research Methodology

To begin with, the current writing on LSS execution in Indian Assembling ventures rehearses was analyzed with specialists utilizing conceptualizing and centered bunch techniques to decide the most powerful boundaries to LSS execution. The specialists comprised of administrators of various organizations who has been in the producing industry for over five years.

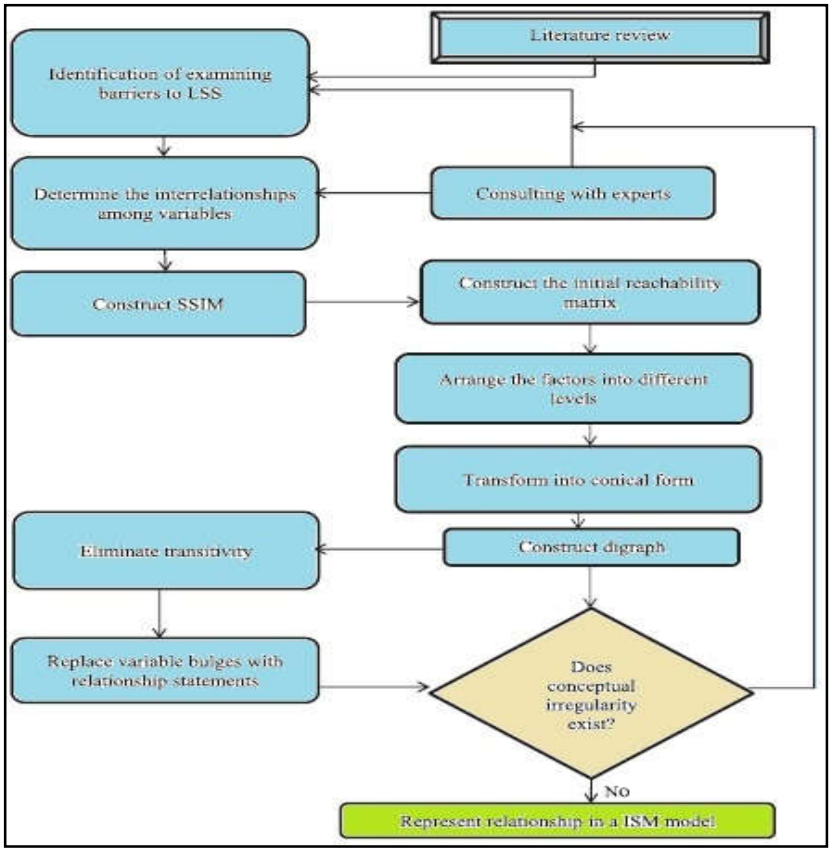

Figure 1. Research Methodology

In these meetings, the specialists were requested to examine the criticality from each component among themselves and rank them arranged by inclination. By dissecting their reactions, 20 hindrances were distinguished from the experts' criticism. To inspect the interrelationships of the chose LSS execution hindrances, an ISM philosophy was applied. Utilizing a MICMAC investigation, factors were arranged in light of driving and reliance power. Thought of these factors and suitable associations can help associations to go with informed choices. A graphical portrayal of the approach is shown **Figure 1.**.

4. Interpretive Structural Modeling

ISM is a demonstrated strategy which is applied to dissect the communications and relevant interrelationships of the components that characterize a framework. It is likewise applied for frameworks that has greater intricacy and makes a progressive model as a result for classification of variables (Farris and Wise, 1975).

- To recognize the factors that comprises the framework to be characterized. In the current case, the factors are the empowering agents influencing LSS reception with maintainability contemplations.
- Subsequent to perceiving the empowering influences, a context oriented relationship is shown in the middle between them. This is finished by making a primary self-communication lattice (SSIM) concerning pairwise examination among the distinguished empowering influences.
- A reach ability framework is developed concerning SSIM, where the images (V, A, X, O) are supplanted utilizing parallel digits (0 and 1) and its transitivity is checked. Level apportioning is finished in accordance with the got reachability lattice, to decide different levels in the model
- In light of the last reachability lattice, a digraph is developed through hubs and bolt lines and its transitivity joins are erased
- The resultant digraph is subsequently changed into an ISM model by subbing empowering agent hubs with explanations.

4.1 Data Collection

To analyze the identified enablers for implementation of LSS with sustainability considerations, an expert team was formed. The team comprises of academicians and industrial experts. The expert team included purchase managers, manufacturing engineers, quality engineers, R&D managers, marketing executives and maintenance engineers who are involved in the process of deploying LSS concepts with sustainability insights. The contextual relationship of each enabler is to be determined by the experts. After multiple discussions and iterations, the contextual relationship between for all enablers that supports LSS adoption with sustainability considerations is assigned. This relationship is based on “leads to type” which means that how the effect of one enabler leads to the effect on another enabler. Total 20 enablers are selected for the ISM based analysis.

Table 1. Lean Six Sigma Implementation Enablers

Variables	Lean Six Sigma Enablers
LSSE1	Support, commitment & Involvement of Top management
LSSE2	Linking LSS to business strategies
LSSE3	Resource and skills to facilitate the implementation
LSSE4	Quality of Human Resources and Linking to Lean Six Sigma
LSSE5	Precise selection of LSS tools and techniques
LSSE6	Effective Cross Function Management
LSSE7	Appropriate Quality of Manufacturing Materials & Facilities
LSSE8	Strategic Financial Resources & Planning
LSSE9	Employee motivation and involvement
LSSE10	Effective scheduling & Reduction in Unnecessary Inventory

LSSE11	Project prioritization and selection
LSSE12	Reliable data collection and retrieval system
LSSE13	Firm's reputation in the Market
LSSE14	Extending LSS to Supplier & Supply Chain
LSSE15	Reward and recognition of team members
LSSE16	Improved Customer Satisfaction
LSSE17	Market increase & Stakeholder pressure
LSSE18	Environmental Management System
LSSE19	Benchmarking System
LSSE20	Organizational culture, change and improvement

4.2 Development of Structural self-interaction matrix development

The contextual relationship is determined by examining the relationship between the two enablers (i and j) and their direction. To symbolize directions, four symbols have been utilized, and each symbol denotes a unique relationship based on the direction. The four symbols are:

(1) V: enabler i will lead to enabler j.
(2) A: enabler i will be achieved by enabler j.
(3) X: enabler i and enabler j will facilitate to achieve each other.
(4) O: enabler i and enabler j are not related.

Based on the contextual relationship between enablers, SSIM has been configured. Table 2 explains the usage of symbols V, A, X and O in creating SSIM.

Table 2. Structural Self-Interaction Matrix (SSIM)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
LSSE1		V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
LSSE2			A	A	A	A	A	A	A	V	A	A	A	V	A	A	X	V	V	V
LSSE3				A	A	A	A	A	A	V	O	V	O	V	A	V	V	V	V	V
LSSE4					V	V	A	A	V	V	V	V	O	V	O	V	V	V	V	V
LSSE5						A	A	A	V	V	V	V	O	V	O	V	V	V	V	V
LSSE6							A	A	V	V	V	V	O	V	O	V	V	V	V	V
LSSE7								A	V	V	V	V	V	V	V	V	V	V	V	V
LSSE8									V	V	V	V	V	V	V	V	V	V	V	V
LSSE9										V	O	V	O	V	A	V	V	V	V	V
LSSE10											A	A	A	X	A	A	A	V	V	V
LSSE11												V	O	V	O	O	V	V	V	V
LSSE12													O	V	A	O	V	V	V	V
LSSE13														V	O	V	V	V	V	V
LSSE14															A	A	A	V	V	V
LSSE15																V	V	V	V	V
LSSE16																	V	V	V	V
LSSE17																		V	V	V
LSSE18																			X	V
LSSE19																				V
LSSE20																				

4.3 Initial reachability matrix

The developed SSIM is transformed to a binary matrix after transforming V, A, X and O by 1 and 0 according to a given case. The resultant matrix is the initial reachability matrix as shown in Table 3.

Table 3. Structural Initial reachability matrix

ariables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Driving Power
LSSE1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
LSSE2	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	1	7
LSSE3	0	1	1	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	10
LSSE4	0	1	1	1	1	1	0	0	1	1	1	1	0	1	0	1	1	1	1	1	15
LSSE5	0	1	1	0	1	0	0	0	1	1	1	1	0	1	0	1	1	1	1	1	13
LSSE6	0	1	1	0	1	1	0	0	1	1	1	1	0	1	0	1	1	1	1	1	14
LSSE7	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	18
LSSE8	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
LSSE9	0	1	1	0	0	0	0	0	1	1	0	1	0	1	0	1	1	1	1	1	11
LSSE10	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	1	5
LSSE11	0	1	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	1	1	9
LSSE12	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	8
LSSE13	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	1	1	1	9
LSSE14	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	1	5
LSSE15	0	1	1	0	0	0	0	0	1	1	0	1	0	1	1	1	1	1	1	1	12
LSSE16	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	1	1	8
LSSE17	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	1	7
LSSE18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
LSSE19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
LSSE20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Dependence Power	1	15	9	4	6	5	3	2	8	17	7	11	4	17	4	11	15	19	19	20	

4.4 Final Reachability Matrix

After confirming for transitivity, the final reachability matrix should be generated based on the original reachability model. Where connections are based on assumptions,

transitivity is an important aspect of ISM. If there are three variables X, Y, and Z, and if variable X is connected to Y and variable Y is related to Z, then variable X must be related to Z.

Table 4. Structural Final reachability matrix

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Driving Power
LSSE1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
LSSE2	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	1	7
LSSE3	0	1	1	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	10
LSSE4	0	1	1	1	1	1	0	0	1	1	1	1	0	1	0	1	1	1	1	1	15
LSSE5	0	1	1	0	1	0	0	0	1	1	1	1	0	1	0	1	1	1	1	1	13
LSSE6	0	1	1	0	1	1	0	0	1	1	1	1	0	1	0	1	1	1	1	1	14
LSSE7	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	18
LSSE8	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
LSSE9	0	1	1	0	0	0	0	0	1	1	0	1	0	1	0	1	1	1	1	1	11
LSSE10	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	1	5
LSSE11	0	1	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	1	1	9
LSSE12	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	8
LSSE13	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	1	1	1	9
LSSE14	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	1	5
LSSE15	0	1	1	0	0	0	0	0	1	1	0	1	0	1	1	1	1	1	1	1	12
LSSE16	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	1	1	8
LSSE17	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	1	7
LSSE18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
LSSE19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
LSSE20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Dependence Power	1	15	9	4	6	5	3	2	8	17	7	11	4	17	4	11	15	19	19	20	

Transitivity is validated for the original reachability matrix using this connection. The final reachability matrix is generated after imposing transitivity, as shown in Table 4, and transitivity connections are marked by 1*. In the current study, variables represent various enablers, and transitivity is tested for all specified relationships.

4.4 Level Partitions

Level partitioning is being used to define the hierarchy of enablers. After analysing the final reachability matrix, the reachability and antecedent set for each enabler must be found. The top of the ISM hierarchy specifies enablers with identical reachability and antecedent sets.

Table 5. Level Partitions

Elements (Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
LSSE1	1,	1,	1,	13
LSSE2	2, 17,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15, 16, 17,	2, 17,	4
LSSE3	3,	1, 3, 4, 5, 6, 7, 8, 9, 15,	3,	6
LSSE4	4,	1, 4, 7, 8,	4,	10
LSSE5	5,	1, 4, 5, 6, 7, 8,	5,	8
LSSE6	6,	1, 4, 6, 7, 8,	6,	9
LSSE7	7,	1, 7, 8,	7,	11
LSSE8	8,	1, 8,	8,	12
LSSE9	9,	1, 4, 5, 6, 7, 8, 9, 15,	9,	7
LSSE10	10, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17,	10, 14,	3
LSSE11	11,	1, 4, 5, 6, 7, 8, 11,	11,	6
LSSE12	12,	1, 3, 4, 5, 6, 7, 8, 9, 11, 12, 15,	12,	5
LSSE13	13,	1, 7, 8, 13,	13,	6
LSSE14	10, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17,	10, 14,	3
LSSE15	15,	1, 7, 8, 15,	15,	8
LSSE16	16,	1, 3, 4, 5, 6, 7, 8, 9, 13, 15, 16,	16,	5
LSSE17	2, 17,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15, 16, 17,	2, 17,	4
LSSE18	18, 19,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,	18, 19,	2
LSSE19	18, 19,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,	18, 19,	2
LSSE20	20,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20,	20,	1

4.5 Development of ISM model:

Improvement of ISM model the acquired primary model is determined in light of the last reachability network and is assigned as digraph the digraph shows the relationship among empowering agents and is addressed by bolts later subsequent to wiping out the transitivity and by subbing hubs with factor proclamations the digraph is changed into the ism model as portrayed in figure1

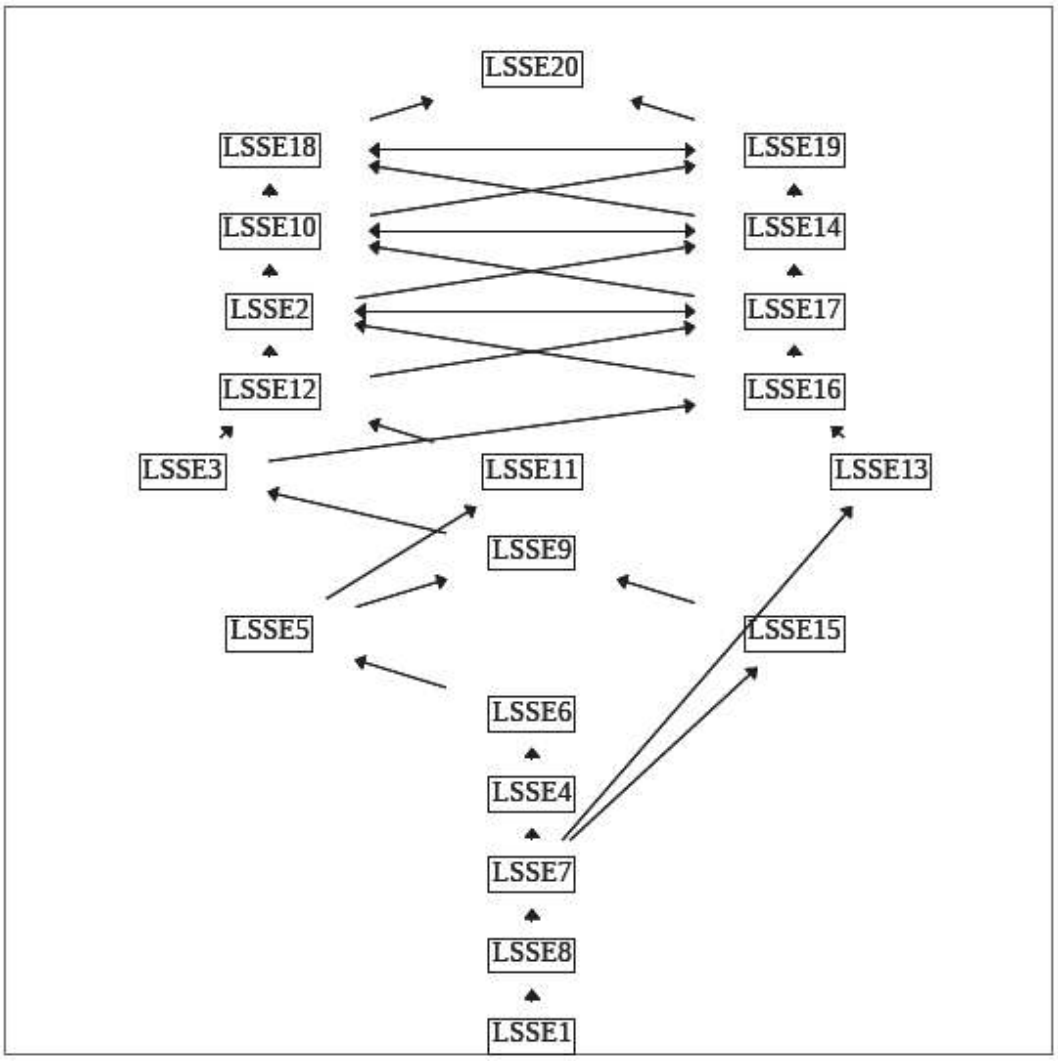

Figure2: Development of ISM Model

4.6 MICMAC Analysis of Obtained Results

MICMAC examination distinguishes the reliance and driving reliance powers of the hindrances to LSS execution. The difficult issues of the reliance and the driving powers are referenced in Table No. 05. A section of 'one' in the segments and columns recognize the reliance and driving power, individually. The driving power and the reliance outline are displayed in Figure. 2. In light of the reliance and driving powers, hindrances were arranged into independent issues, subordinate issues, linkage issues, and autonomous issues.

Cluster I- Autonomous LSSEs:

The enablers subsisting under this cluster are termed as autonomous or excluded enablers. These enablers weak driving as well as weak dependence power and are posted in the bottom-left zone of the graph.

- LSSE11: Reliable data collection and retrieval system.
- LSSE13: Market increase & Stakeholder pressure.

Cluster II- Dependent LSSEs:

The enablers existing under this cluster are termed as dependent or resultant enablers. These enablers contemplate weak driving and strong dependence power and are posted in the bottom right zone of the graph.

- LSSE18: Environmental Management System.
- LSSE19: Benchmarking System
- LSSE20: Organizational culture, change and improvement.
- LSSE16: Improved Customer Satisfaction
- LSSE17: Firm's reputation in the Market

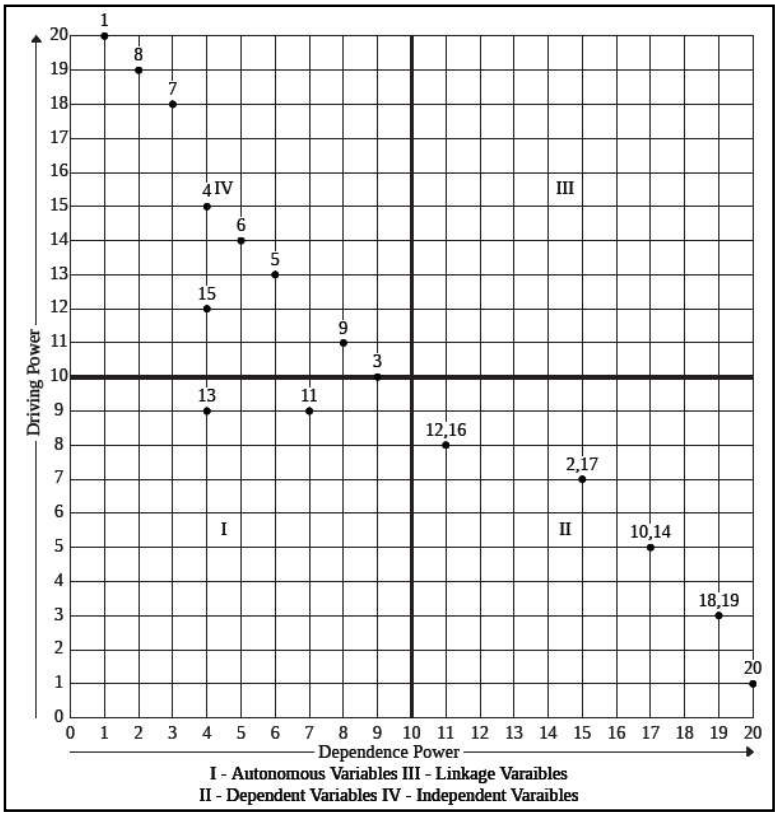

Figure. 3 Driving power and dependence graph for barriers.

Cluster III- Linkage LSSEs:

The enablers subsisting under this cluster depicts the concurrent behavior of highly influent and highly dependent. These enablers exhibit the attributes of strong driving and strong dependence power and are posted in the top-right zone of the graph being unstable. Small modification in these enablers affects other enablers very quickly.

Cluster IV- Driving LSSEs:

The enablers observed in this cluster are a strong driver and very weakly dependent on other enablers. These enablers exhibit the attributes of strong driving and weak dependence power and exist in the top-left zone of the graph, while they act as initiators in the implementing process. These enablers help to achieve other enablers and behave as input for the implementation process.

Result & Conclusion:

- The main objective of the study is to identify the prime Enablers of LSS implementation in Indian Manufacturing Industries.
- In this ISM and MICMAC Hybrid analysis in first Phase 20 Enablers were indentified have been finalized for further analysis.
- In second phase, an ISM model of finalized constructed by using ISM approach.
- In third phase, MICMAC analysis was conducted for grouping the Lean six Sigma Enablers into categories.
- ISM model results recognize the hierarchy of measures considered by technical executives which Increase the effect of Lean six Sigma Enablers in Successful implementation of LSS.
- The MICMAC study shows that the Lean six Sigma Enablers clusters were developed based on driving power and reliance.
- The result of the MICMAC shows Lean six Sigma Enablers have been categorized as 9 dependent, 9 independent, 2 Autonomous.
- Once the Lean six Sigma Enablers with high driving power are keyed out, it becomes the primary responsibility of the management to develop action plans to ameliorate their effects during the journey of LSS implementation.
- The managers in manufacturing concerns must focus on these enablers prior to the LSS implementation as altering the post effects of implementation are more cumbersome.
- In this way the paper giving direction, how An Integrated Modeling Analysis of Enablers can be Successful deployed of Lean Six Sigma in Indian manufacturing Industry.

Findings & Concluding Remarks:

- LSSE18 Environmental Management System
- LSSE19 Benchmarking System
- LSSE20 Organizational culture, change and improvement
- lies on the top of the hierarchy; possessing the property of being highly dependent but portrays weak driving characteristics.
- LSSE1 Support, commitment & Involvement of Top management
- LSSE2 Linking LSS to business strategies
- LSSE4 Quality of Human Resources and Linking to Lean Six Sigma LSSE6 Effective Cross Function Management
- LSSE7 Appropriate Quality of Manufacturing Materials & Facilities
- LSSE8 Strategic Financial Resources & Planning

These Enablers support, facilitate and drive other enablers in the system as they act as a foundation.

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