"Modeling and Analysis of Lean Manufacturing Strategies using ISM-Fuzzy MICMAC Approach"

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By

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CERTIFICATE

This is to certify that the project entitled "**Modeling and Analysis of Lean Manufacturing Strategies using ISM-Fuzzy MICMAC Approach**" being submitted by me, is a bonafide record of my own work carried by me under the guidance and supervision of Dr. Mohit Tyagi (Assistant Professor) & Dr. R.S. Walia (Associate Professor) in partial fulfilment of requirements for the award of the Degree of Master of Technology in Production Engineering from Department of Mechanical Engineering, Delhi Technological University, Delhi.

The matter embodied in this project either full or in part have not been submitted to any other institution or University for the award of any other Diploma or Degree or any other purpose what so ever.

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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Abstract

In this competitive market, working with great efficiency is the major concern for the organization. Lean manufacturing is a Japanese philosophy, which aims at continuous improvement by elimination of waste created through unevenness in workloads and overburden. This research work shows that how lean manufacturing strategies can help the organization to enhance the efficiency of the organization with great effectiveness. In this study, thirty six lean strategies have been identified and out of which thirteen lean strategies were extracted by factor analysis using software SPSS 21. Interpretive Structural Modeling (ISM) is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. Interrelationship among various strategies related to lean manufacturing could be established and represented effectively using ISM. Matriced' Impacts croises-multipication applique' and classment (MICMAC) is a modern approach based on the properties of matrix multiplication. To make the convectional MICMAC analysis more robust, fuzzy set theory has been introduced. Fuzzy MICMAC helps to understand the dependence and driving power of the lean strategies. ISM model has been taken as initial start for analysis in fuzzy MICMAC. The present research deals with identification of different lean strategies and extraction of relevant strategies after discussion with experts. The extracted strategies have been visualized using ISM model and finally the relationship of each strategy with each of the other strategies is derived using the Fuzzy MICMAC analysis.

Keywords: lean manufacturing system (LMS); lean strategies; factor analysis; Structural self-interaction matrix; ISM methodology; fuzzy MICMAC

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1.1 Introduction

In the present scenario, it has been observed that the manufacturing firms are facing many challenges worldwide like quality, productivity, time management etc. To overcome these challenges, it is required to force the world's manufacturing firms to develop new manufacturing methods and concepts in the competitive market. Among them, one of the main concepts is implementation of lean manufacturing strategies in the production system. The concept of lean manufacturing system (LMS) was initiated by a Japanese automobile industry Toyota during 1950's was well known as Toyota Production system (TPS). The aim of Toyota Production system was to enhance and rise the productivity with cost-reduction of the product by eliminating waste or non-value added ventures (Womack et al., 1990; Srinivasaraghavan and Allada, 2006). It defines the production process and procedures to improve the working environment of the shop floor consequently it also helps in increasing the overall productivity of company (Narasimhan et al. 2006). It can provide the essential extended term performance to automobile companies by refining the organization of cost effectiveness, elimination of wastage and also environmental risks over the improvement of experiences for endless organizational progress.

Lean manufacturing can implement the various set of activities for better performance of a company. There are different techniques generally accessing in the industry for effective outcomes. Application of lean manufacturing strategies can lead to continuous improvement in industrial field. The concept of lean can be implemented in any business organization along with the industries. Different types of tool are being used from past several decades in order to get error free production from production unit. It is a tool that provides effective results to withstand the competition in prevailing different segments in the market aiming to remove all others unnecessary parameters from production unit. It uses very small inventory for manufacturing of product at high productivity. That’s why, it can be seen as a very popular tool or technique used by most of big industries and firms.

Lean management is meant for respect of humanity, it does not under estimate the capacity of people working in the company. Moreover, it will help people to be more effective and appreciate their work. Lean management maintains the production and levelise all stages of production in the company. Many errors occur during production like breakdown, lot reject etc. it can provide the framework to remove all these errors during the production. It can analyze the production procedure to find out the causes occur during production. Lean can help in maintaining the documentation of work process or procedure of production and establish the standards of the manufacturing for the company for present and future production.

Many articles have focused on lean manufacturing strategies and lean integrated production system (Hackman and Wageman, 1995; Samson and Terziovski, 1999; McKone et al., 2001).This research aims to identify various lean strategies and features through extensive literature review and analyze them by interpretive structural modeling. To visualize the direct relationship among the considered strategies ISM based model has been developed. Then the fuzzy MICMAC analysis is done to find the driving power and dependence power of different enablers This present study will help the managers to improve the efficiency of their firm in this competitive market.

1.2 Need for the Study

The major concern in competitive market is to maximize the performance as well as growth of organization. The concept of lean manufacturing has emerged as one of the best concept through which manufacturing firms can achieve higher outputs per unit of capital. Organizations which have integrated lean strategies in their manufacturing process enjoy benefits of reduction in time product takes to reach the market and lower rejection rates. But successful integration of lean strategies is always a problem for the firms. There is always confusion for managers to decide the strategies which they need to pay more attention with respect to others.

In present research, an assessment of important lean manufacturing strategies is done with an objective to reduce waste and promote the continuous improvement. This study deals with the identification and analysis various lean strategies and development of the ISM model which will help the organizations to enhance their growth as well performance. ISM is a popular technique which can be used to develop the contextual relationship among various lean manufacturing strategies. The model is developed based on driving and dependence power of the extracted strategies with respect to every other strategy. This study would help managers in the organizations to segregate lean strategies which have more driving power and dependence power or both. They would then be able to focus more on the strategies on the lower levels which push other strategies and act as crucial components of a successful lean manufacturing system. With the help to this study, managers can easily select the appropriate lean strategies depending on their driving and dependence power and could help in making the effective decision for the growth of the organization.

1.3 Research Direction

The flow chart of the work plan is shown in figure 1.1. This flow chart shows how this work is carried out in solitary view.

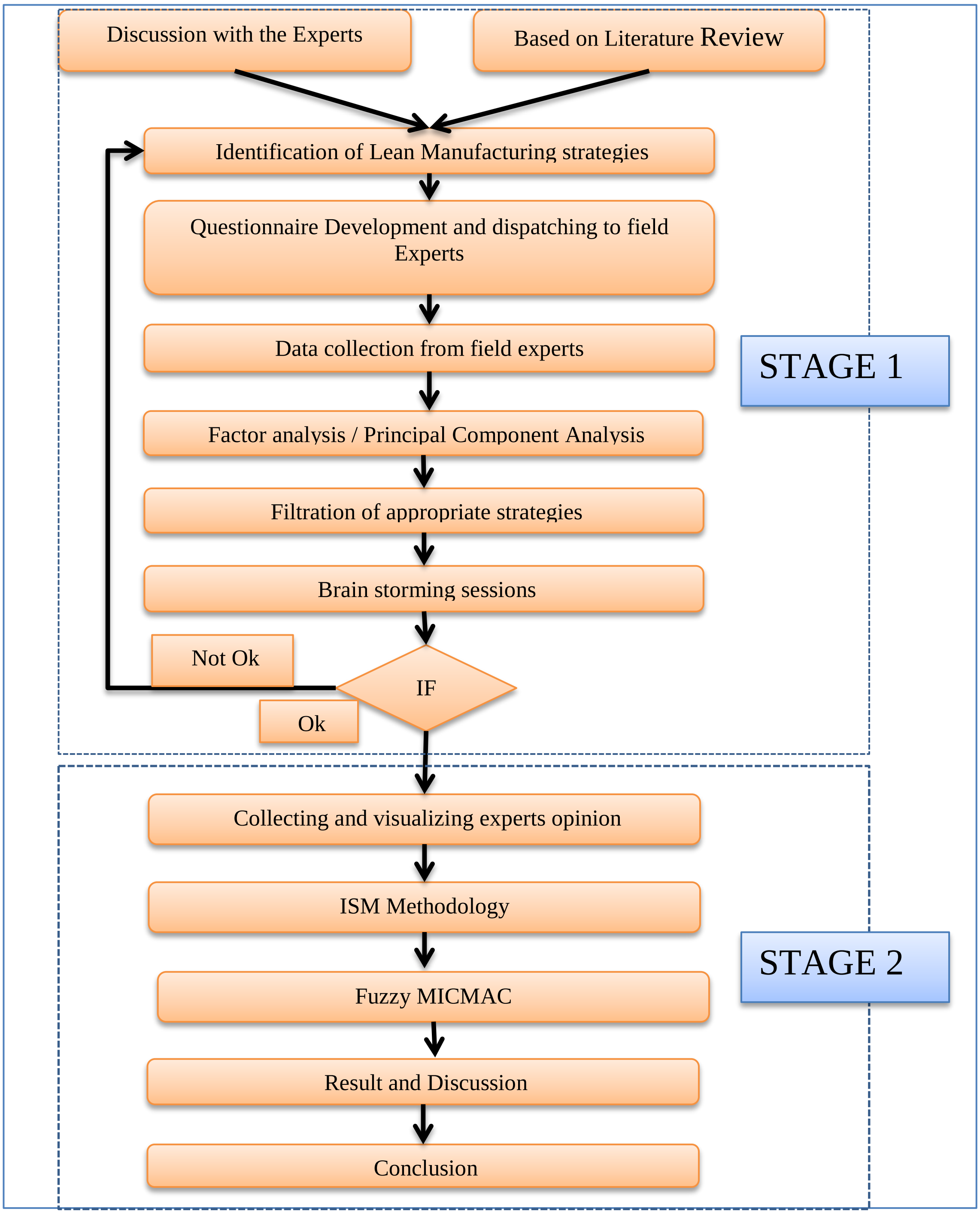

Figure 1.1 Research Direction

1.4 Identification of Lean Strategies and Data Collection from Experts

On the basis of literature review and discussion with the field experts, thirty six lean manufacturing strategies were identified. Then, a questionnaire was designed using Google form and posted on Google doc. Opinions of field experts were gathered. Also during the study, specialists from Indian automobiles companies situated near Delhi NCR and academicians from various institutes were communicated for the opinion of lean manufacturing strategies.

1.5 Research Tool

1.5.1 Factor Analysis

Factor analysis is vital tool for data reduction and provides the close measures of different variable by determining the common factors based on the account of observed correlations. (Fabrigar et al., 1999; Hayton et al., 2004). This is one of the most popular systematic and theoretical approaches in decisions making for researchers to retain the factors.

1.5.2 Interpretive Structural Modeling

Interpretive structural modeling (ISM) is an interactive learning process in which a set of dissimilar and directly linked elements are structured into a comprehensive systematic model. The model so formed, portrays the structure of complex issue or problem, a system or a field of study, in a carefully designed pattern inferring graphics as well as words. The elementary notion of ISM is to use experts' practical experience and knowledge to molder a complicated system into several sub-systems (elements) and develop a multilevel structural model. ISM methodology helps impose order and direction on the complexity of relationships among elements of a system (Warfield, 1974; Sage, 1977).

1.5.3 Fuzzy MICMAC Analysis

Inspections of direct interactions may disclose that indicators having strong direct impact can be suppressing hidden indicators, which at times may significantly affect the system under consideration (Saxena and Sushil, 1990; Abbasi and Arya, 2000). Such indirect inter-relationship between indicators may have an influence on the system through influence chains and reaction loops, or feedback. The number of such chains and loops could be so large that it may be difficult to interpret them without the help of computers.

To analyze these inter-relationships and to study their role and behaviour, MICMAC method was introduced by Duperrin and Godet (1973) and Kanungo et al. (1999). MICMAC (a French term: Matriced Impacts croises-multipication applique i.e., cross-impact matrix–multiplication applied to classification) is used for the examination of the indirect and hidden relationships among the components of the structure obtained using ISM technique (which only captures the direct relationships among these elements). The method enables study of the diffusion of impacts through reaction paths and loops for developing hierarchy of the indicators

1 in order of their driver power, by taking into account the number of paths and loops of length 1, 2, ..., n. ... arising from each indicator

2 in order of dependence by taking into account the number of paths and loops of length 1, 2,…, n .... accruing to each indicator

1.6 CONCLUSION

This chapter gives the brief introduction of the lean manufacturing system and also introduces the research tools used in the study.

2. 1 Introduction

This chapter presents previous research and theories concerning the concept of lean manufacturing system, starting with review of LMS, review of ISM and fuzzy MICMAC, finally describing the critical lean manufacturing strategies that affecting the LMS.

2.2 Literature Review

The objective of lean manufacturing system is to reduce inventory and increase human efficiency , catering the right market at right time, and handling industrial stocks that are highly responsive to consumer demand while manufacturing quality industrial products in the most effective and economical manner (Bhim et al., 2010). The increase of resource effectiveness by excluding unnecessary consumption represents the logical extension from lean manufacturing to lean and green manufacturing. Sebastian et al. (2015) studied a simulation based methodology for monetary assessment of lean and green manufacturing systems as non-monetary green parameters. Thus, economical efficiency remains the key decision criterion for the application of lean and green manufacturing strategies.

Wahab et al. (2013) defined in their research paper an introductory study to make a conceptual model to evaluate leanness in manufacturing unit. Most of the mutual tools or methods and their effectiveness have been investigated. In this research, a concept based model for leanness measurement in the manufacturing unit has been made and designed in two main levels i.e. dimensions and factors. Additionally, the model also demonstrates how lean parameters in the manufacturing system co- relate to different types of wastes. Hartini and Ciptomulyono (2015) examine the effect of lean and sustainable production system to improve organization performance. Many of the suggestions recommended that lean production system is favorable for Sustainable production system; most influentially it would help in perspective environment and cost-effective aspects. Arslankaya and Atay (2015) observed and apply the maintenance management and lean manufacturing methods at the maintenance workshop in order to remove the losses caused by breakdowns and to improve productivity and motivate the employees.

Lean manufacturing with ergonomic working environment in the automobile sector is another very effective concept to enhance the working condition, improve productivity, improving production processes, and main is to eliminate waste (Dos Santos et al.,2015). The key area of ergonomics is to improve and apply the man adaptation methods to their work and efficient and safe ways in order to enhance the welfare, safety, health, prosperity and thus to accumulate efficiency and productivity of the organization (Dul and Neumann, 2009). In this study they applied some methods of analysis process by the common relation with application of Lean Manufacturing and working conditions in ergonomics manner. Study of ergonomics determines a result of analysis of aims achieved by continuous enhancement among the eliminating of waste and improved productivity subsequently the results achieved in enhancing the industrial productivity and welfare of its staffs (Das, 1987).

Rohani and Zahraee (2015) studied one of the most important lean manufacturing techniques called Value Stream Mapping (VSM) to enhance the production line of a color industry as a case study. Morlocka and Meiera (2015) also worked on VSM and gave an overview on process improvement how product and service can be improved to increase the performance of the management. To attain this goal, lean principles was applied to construct VSM for identification, elimination of wastages and improved performance of the organization.

Lean manufacturing is very popular technique in the field of production system from past several decades. Kanban system among them is the most important lean manufacturing strategies for lean production system with reduced cost and minimal inventories. The objectives of this study are i) to define how does the Kanban system works successfully in international organization; and ii) to categorize factors hindering small and medium enterprises (SME) from executing Kanban in lean manufacturing system (Rahman et al., 2013). Shah and Ward (2003) observed the outcomes of three dependent issues, plant size, plant age and unionization position, on the chance of applying different manufacturing industrial practices that are main facets of LMS.

Table 2.1 Brief review ISM and fuzzy MICMAC

S.No.	Authors	Theme of the problem
1	Mandal and Deshmukh (1994)	They explored the vendor selection process of the firm based on various attributes using ISM
2	Kannan and Haq (2007)	They analyze the interaction in the supplier selection between the supply chain criteria and sub-criteria.
3	Kannan et al. (2008)	Integration of analytic hierarchy process and interpretative structural modelling to select the green supplier
4	Wang et al. (2008)	They analyse the interactions among the barriers to energy saving in a Chinese context.
5	Faisal (2010)	This study analysed the barriers of CSR in supply chain
6	Singh et al. (2010)	The tool gets used in the selection of the best supply chain practices.
7	Charen et al. (2008)	They explore the barriers of supply chain performance measurement system implementation in Indian context
8	Diabat and Govindan (2011)	Analyse the drivers of green supply chain management
9	Lee et al. (2011)	Analyse the benefits, costs, and risks for selecting technologies using the integrated IMS and fuzzy Analytic Hierarchy Process.
10	Talib et al. (2011)	They analyse the barriers for implementing the total quality management in firm.
11	Lal and Haleem, A. (2009)	They used ISM technique for structural modeling for e-governance service delivery in rural India.
12	U. Khan and A. Haleem (2012)	They used ISM and Fuzzy Micmac Approach for Modeling of the Enablers of Smart organization

2.3 Strategies Affecting the Lean Manufacturing System

Lean manufacturing strategies that affecting the LMS are shown in table 2.2. These lean strategies were identified from various literature reviews as well as discuss with the field experts, academicians and industrialist.

Table 2.2 Lean Strategies

S.No.	Lean Strategies	Sources
S1	Line improvement activity	Salleh et al. (2012) and Cha et al. (2012)
S2	Minimizing Work in progress	Onyeocha et al.(2015); Riezebos et al (2009)
S3	Proper machine utilization	Nordin et al.(2010)
S4	Just-in-time replenishment	Turner and lane (2013); Lee(2004); Johnson and Momyer (1998)
S5	Increasing environmental awareness of customers	Greinacher et al. (2015); Bunse et al. (2011)
S6	Time availability	Tu et al. (2001) and Keskinocak et al. (2001)
S7	More frequent changeovers in one-piece-flow manufacturing	King and Lenox (2001)
S8	short delivery cycles	Skinner (1974); Amoako-Gyampah and Acquaah (2008)
S9	flexibility in quality and volume at low cost	Skinner (1974) and Wheelwright (1978)
S10	Design for performance	Krajewski (1987)
S11	Handling of appropriate variations in customer orders	Anand and Ward (2004)
S12	Modification in product design as per customers requirement	Pan and Nguyen (2015)
S13	Monitoring the implementation schedules step by step	Ballard and Howell (1998) ; Guo et al. (2015)
S14	Recycling of raw materials and defective parts	Thierry et al. (1995) ; Wang et al. (2015)
S15	Idle time consideration	Teichgräber and de Bucourt (2012); Sugimori (1977)
S16	Physical proximity with respect to raw materials	Rebolledo and Jobin (2013)
S17	Share inventory level information	Hayes (1994); Howard et al. (2015)
S18	Physical integration within the same plant	Gebauer (2008) ; Xu et al. (2014)
S19	Development programs or past performance record	Brown and Cousins (2004)
S20	value stream mapping	Teichgräber and de Bucourt (2012)

Table 2.2 Lean Strategies

S.No.	Lean Strategies	Sources
S21	proper maintenance	Olivier (2009) ; Ebrahimipour (2015)
S22	Ability to adjust capacity rapidly within a short time period	Stecke and Kim (1988); Ward and Duray (2008)
S23	Adherence to labor laws	Bresnahan et al. (1999)
S24	Computer based buffering of machines documentation.	Williams et al. (1994) ; Johnson and McElroy Jr (1998) ; Fischer and Perner (2001)
S25	Improvement and organization of personal	Sanchez and Mahoney (1996) ; Fisher and Torbert (1995)
S26	Proper sequencings of parts	Youssouf et al. (2014) ; Boysen et al. (2015)
S27	Higher collaboration for better production planning	Kenné et al. (2007) ; Seifert (2003)
S28	availability of instrumentation and tools at appropriate time	Drees and Young (2004)
S29	Alternative supply chain networks	Harland (1996); Hugo and Pistikopoulos (2005) ; Mohammaddust et al. (2015)
S30	improve operational performance along the triple bottom line	Ashby et al (2012); De Medeiros et al. (2014); Taisch et al. (2015)
S31	Bottleneck removal	Sakakibara et al. (1997); White et al. (1999)
S32	Focus on Market orientation	Venkatraman and Ramanujam (1987)
S33	Execution of safety improvement programs	Seng Chan et al. (1990)
S34	Focus towards Technology improvement	GRI (2006) ; Lozano and Huisingh (2011)
S35	Training of employees to develop multi skills	Heimerl and Kolisch (2010); Wang et al. (2015)
S36	Ability to provide innovation design	Zhao et al (2006) ; Le Dain (2011)

2.4 Conclusion

This chapter gives a detailed description of lean manufacturing system, which helps to conceptualize the critical lean strategies which influence lean manufacturing system.

3.1 Introduction

Factor analysis is vital tool for data reduction and provides the close measures of different variable by determining the common factors based on the account of observed correlations. (Fabrigar et al., 1999; Hayton et al., 2004). This is one of the most popular systematic and theoretical approaches in decisions making for researchers to retain the factors.

3.2 Reliability Analysis

At the initial level, a questionnaire has been structured using a 5-point Likert scale for thirty six lean strategies and was send to the one hundred and fifty field experts to collect their opinion regarding the importance of lean strategies. Out of one hundred and fifty, fifty seven responses were received, which shows the 38% response rate. According to Malhotra and Groover (1998), if response rate is thirty percent then it is sufficient to drive the reliability analysis.

For the collected data to be considered reliable, the value of Cronbach's alpha coefficient (α) should lie between 0.7 to 1. [George and Mallery, (2003); Gliem and Gliem, (2003)] provide the following rules of thumb, if the value Cα is > 0.9 means Excellent, > 0.8 means Good, > 0 .7 means Acceptable, >0 .6 means Questionable, >0 .5 means Poor, and < 0 .5 means Unacceptable". As the value of Cronbach's alpha coefficient is 0.794, hence the collected data can be considered reliable.

3.3 Filtration of Lean Strategies

Factor analysis is done for the filtration of appropriate lean strategies by SPSS21 software and extracted the listed lean strategies in table 3.2.

Table 3.1 shows the cumulative variances of different lean strategies and thirteen lean strategies contributed to about 77.648%of the total variance and have eigenvalues greater than threshold value of 1. The component matrix was observed to extract thirteen lean strategies based on the variable loaded in the software.

Scree plot graph in figure 2 approves the dominance of the thirteen lean strategies over the total. The scree plot makes an elbow after the thirteenth component, which means that each succeeding factor accounts for smaller and smaller accounts of the total variance.

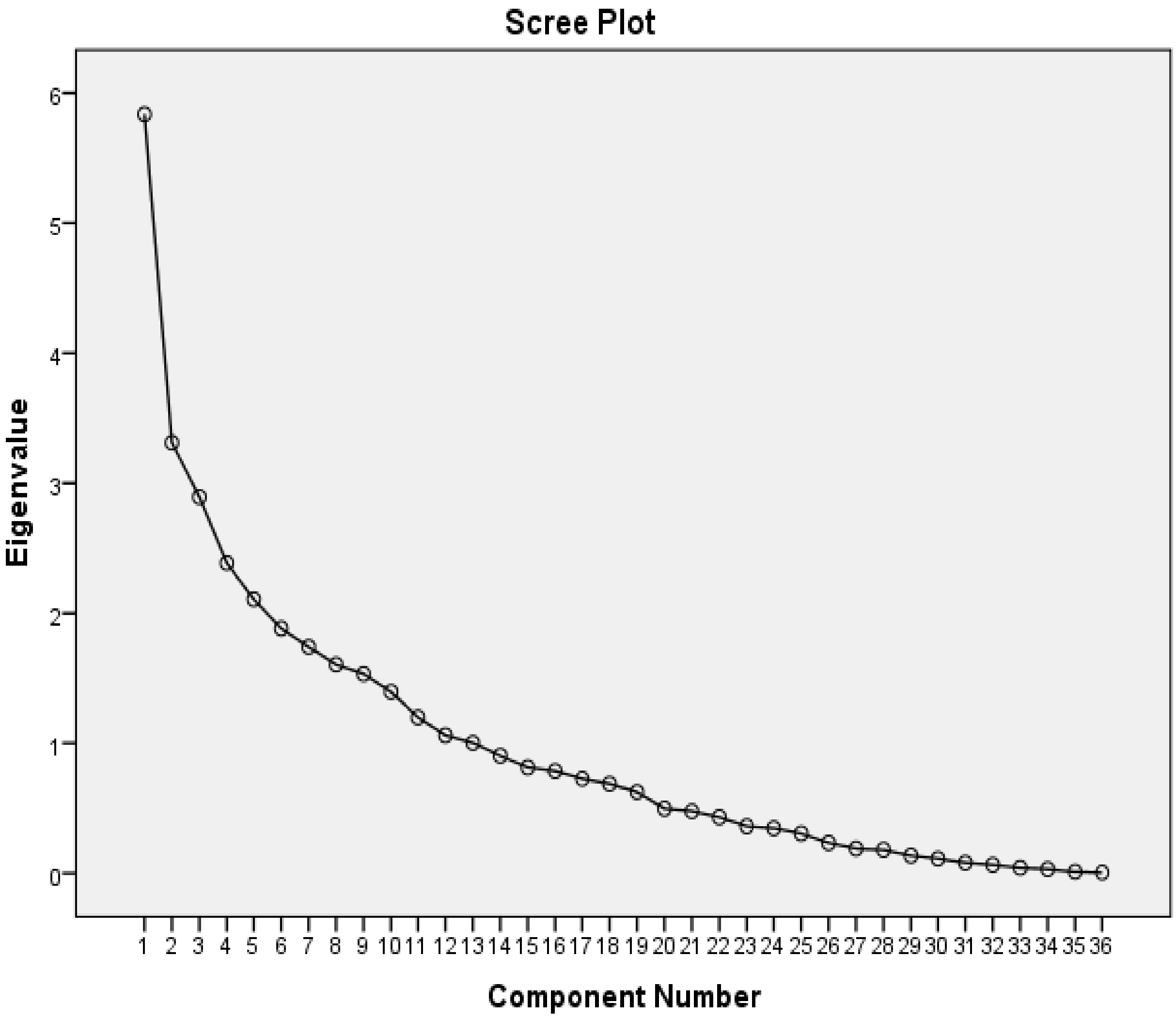

Figure 3.1 Scree plot graph for different components

Table 3.1 Total Variance Explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.838	16.216	16.216	5.838	16.216	16.216	2.764
2	3.311	9.196	25.412	3.311	9.196	25.412	2.745
3	2.894	8.038	33.450	2.894	8.038	33.450	2.608
4	2.386	6.628	40.078	2.386	6.628	40.078	2.557
5	2.107	5.854	45.932	2.107	5.854	45.932	2.547
6	1.882	5.229	51.161	1.882	5.229	51.161	2.420
7	1.741	4.836	55.997	1.741	4.836	55.997	2.220
8	1.604	4.456	60.453	1.604	4.456	60.453	1.971
9	1.533	4.258	64.712	1.533	4.258	64.712	1.750
10	1.396	3.878	68.590	1.396	3.878	68.590	1.742
11	1.198	3.329	71.919	1.198	3.329	71.919	1.595
12	1.060	2.946	74.865	1.060	2.946	74.865	1.578
13	1.002	2.784	77.648	1.002	2.784	77.648	1.458
14	.903	2.510	80.158				
15	.814	2.261	82.419				
16	.786	2.184	84.603				
17	.727	2.019	86.622				
18	.688	1.911	88.533				
19	.625	1.735	90.268				
20	.497	1.380	91.648				
21	.476	1.323	92.971				
22	.431	1.197	94.168				
23	.361	1.002	95.170				
24	.346	.962	96.131				
25	.305	.848	96.980				
26	.233	.649	97.628				
27	.190	.529	98.157				
28	.180	.501	98.658				
29	.135	.375	99.034				
30	.112	.312	99.346				
31	.081	.225	99.571				
32	.065	.180	99.751				
33	.041	.115	99.866				
34	.032	.089	99.955				
35	.011	.031	99.986				
36	.005	.014	100.000				

Table 3.2 Extracted lean strategies

S.No.	Lean Strategies	Sources
S1.	Line improvement activity	Salleh et al. (2012) and Cha et al. (2012)
S2.	Ability to adjust capacity rapidly within a short time period	Stecke and Kim (1988); Ward and Duray (2008)
S3.	Alternative supply chain networks	Harland (1996); Hugo and Pistikopoulos (2005); Mohammaddust et al. (2015)
S4.	Focus on Market orientation	Venkatraman and Ramanujam (1987)
S5.	Development programs or past performance record	Brown and Cousins (2004)
S6.	Proper machine utilization	Nordin et al.(2010)
S7.	Minimizing Work in progress	Onyeocha et al.(2015); Riezebos et al (2009)
S8.	Ability to provide innovation design	Zhao et al (2006) ; Le Dain (2011)
S9.	Recycling of raw materials and defective parts	Thierry et al. (1995) ; Wang et al. (2015)
S10	Higher collaboration for better production planning	Kenne et al. (2007) ; Seifert (2003)
S11.	Monitoring the implementation schedules step by step	Ballard and Howell (1998) ; Guo et al. (2015)
S12.	Training of employees to develop multi skills	Heimerl and Kolisch (2010); Wang et al. (2015)
S13.	Handling of appropriate variations in customer orders	Anand and Ward (2004)

3.4 Conclusion

This chapter gives the detail explanation of the factor analysis of lean manufacturing strategies and interpreted the results of filtration of lean strategies.

4.1 Introduction

This chapter gives the overview of interpretive structural modeling methodology in continuation with the different lean manufacturing strategies identified in previous chapter is modeled using interpretive structural modeling methodology.

4.2 ISM Methodology

Interpretive structural modeling (ISM) used to create a complex system into an envisioned ordered structure. It is used for studying and solving complex problems to help in decision-making (Warfield, 1973; Warfield, 1974; Tyagi et al., 2015; Jain and Raj, 2016). It is based on computer-assisted method that usually used to conclude the multiplex situations by providing a sensible and reasonable path of action (Kannan et al., 2009; Tyagi et al., 2015).
ISM approach starts with an identification of strategies or drivers or any variables, which are related to the problem. Then a contextually appropriate subservient relation is chosen (Attri et al., 2013).

ISM methodology involve various steps as follows (Kannan and Haq, 2007; Tyagi et al., 2015)

1. Identify and enlist the different strategies of lean manufacturing system.
2. Creating a contextual relationship between different lean manufacturing strategies.
3. Develop a structural self-interaction matrix (SSIM) for lean manufacturing strategies which show interactions among lean manufacturing strategies under concern.
4. Developing the reachability matrix from the SSIM and transitivity is checked.
5. Based on the reachability matrix, a flow chart is drawn without representing transitive links.

6. Translate the resultant relationship digraph into an ISM by replacing lean strategies with statements
7. Check for conceptual variation and necessary amendments made and contextual correlation was developed among different lean manufacturing strategies.

4.3 Structural self-interaction matrix (SSIM)

SSIM is used for finding the contextual relationship among the different extracted lean strategies as given in table 4.1 using expert's opinion. The matrix provides the pair-wise relationship of each lean strategy. The symbols (V, A, X and O) are used for relationship of lean strategies (i and j).

V - Strategy i will assist to enhance strategy j

A -Strategy j will assist to enhance strategy i

X -Strategy i and j will assist to enhance each other

O - Strategy i and j are isolated

Table 4.1 SSIM lean strategies

S.no.	Lean Strategies	13	12	11	10	9	8	7	6	5	4	3	2	1
S1.	Line improvement activity	V	A	A	A	O	V	V	V	A	V	A	A	-
S2.	Ability to adjust capacity rapidly within a short time period	V	A	A	A	O	A	V	X	O	A	A	-	
S3.	Alternative supply chain networks	V	O	A	O	X	A	V	V	O	A	-		
S4.	Focus on Market orientation	V	V	V	A	V	V	O	V	V	-			
S5.	Development programs or past performance record	V	A	V	X	V	V	V	V	-				
S6.	Proper machine utilization	A	A	A	A	O	O	V	-					
S7.	Minimizing Work in progress	O	A	A	A	V	A	-						
S8.	Ability to provide innovation design	X	A	A	A	O	-							
S9.	Recycling of raw materials and defective parts	A	A	O	O	-								
S10	10. Higher collaboration for better production planning	V	A	V	-									
S11.	Monitoring the implementation schedules step by step	X	A	-										
S12.	Training of employees to develop multi skills	V	-											
S13.	Handling of appropriate variations in customer orders	-												

4.4 Reachability matrix

The successive phase in ISM methodology is to prepare the initial reachability matrix. Based on the above pair-wise relationship of the lean strategies in SSIM (table 4.1) is converted into initial reachability matrix as shown in table 6 in a binary system i.e. 0 and 1. This conversion is done with the help of following rules:

If the (i, j) result in the SSIM is V, then set the (i, j) result in the reachability matrix to 1 and the (j, i) result to 0.

If the (i, j) result in the SSIM is A, then set the (i, j) result in the reachability matrix to 0 and the (j, i) result to 1.

If the (i, j) result in the SSIM is X, then set the (i, j) result in the reachability matrix to 1 and the (j, i) result to 1.

If the (i, j) result in the SSIM is O, then set the (i, j) result in the reachability matrix to 0 and the (j, i) result to 0.

Final reachability matrix as shown in table 7 was constructed with the aid of initial reachability matrix by means of the transitivity rule, which states that if the strategy 'X' is linked to 'Y' and 'Y' is linked to 'Z', then it is necessary that X will be linked with Z. The transitivity is marked as *

Table 4.2 Initial reachability matrix

S.no.	Lean Strategies	1	2	3	4	5	6	7	8	9	10	11	12	13
S1.	Line improvement activity	1	0	0	1	0	1	1	1	0	0	0	0	1
S2.	Ability to adjust capacity rapidly within a short time period	1	1	0	0	0	1	1	0	0	0	0	0	1
S3.	Alternative supply chain networks	1	1	1	0	0	1	1	0	1	0	0	0	1
S4.	Focus on Market orientation	0	1	1	1	1	1	0	1	1	0	1	1	1
S5.	Development programs or past performance record	1	0	0	0	1	1	1	1	1	1	1	0	1
S6.	Proper machine utilization	0	1	0	0	0	1	1	0	0	0	0	0	0
S7.	Minimizing Work in progress	0	0	0	0	0	0	1	0	1	0	0	0	0
S8.	Ability to provide innovation design	0	1	1	0	0	0	1	1	0	0	0	0	1
S9.	Recycling of raw materials and defective parts	0	0	1	0	0	0	0	0	1	0	0	0	0
S10	Higher collaboration for better production planning	1	1	0	1	1	1	1	1	0	1	1	0	1
S11.	Monitoring the implementation schedules step by step	1	1	1	0	0	1	1	1	0	0	1	0	1
S12.	Training of employees to develop multi skills	1	1	0	0	1	1	1	1	1	1	1	1	1
S13.	Handling of appropriate variations in customer orders	0	0	0	0	0	1	0	1	1	0	1	0	1

Table 4.3 Final reachability matrix

S.No.	**Lean Strategies**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Strategy power**
S1.	Line improvement activity	1	1*	1*	1	1*	1	1	1	1*	0	1*	1*	1	**12**
S2.	Ability to adjust capacity rapidly within a short time period	1	1	0	1*	0	1	1	1*	1*	0	1*	0	1	**9**
S3.	Alternative supply chain networks	1	1	1	1*	0	1	1	1*	1	0	1*	0	1	**10**
S4.	Focus on Market orientation	1*	1	1	1	1	1	1*	1	1	1*	1	1	1	**13**
S5.	Development programs or past performance record	1	1*	1*	1*	1	1	1	1	1	1	1	0	1	**12**
S6.	Proper machine utilization	1*	1	0	0	0	1	1	0	1*	0	0	0	1*	**6**
S7.	Minimizing Work in progress	0	0	1*	0	0	0	1	0	1	0	0	0	0	**3**
S8.	Ability to provide innovation design	1*	1	1	0	0	1*	1	1	1*	0	1*	0	1	**9**
S9.	Recycling of raw materials and defective parts	1*	1*	1	0	0	1*	1*	0	1	0	0	0	1*	**7**
S10	Higher collaboration for better production planning	1	1	1*	1	1	1	1	1	1*	1	1	1*	1	**13**
S11.	Monitoring the implementation schedules step by step	1	1	1	1*	0	1	1	1	1*	0	1	0	1	**10**
S12.	Training of employees to develop multi skills	1	1	1*	1*	1	1	1	1	1	1	1	1	1	**13**
S13.	Handling of appropriate variations in customer orders	1*	1*	1*	1*	1*	1	1*	1	1	1*	1	0	1	**12**
		12	**12**	**11**	**9**	**5**	**12**	**10**	**10**	**13**	**5**	**10**	**4**	**12**	

4.5 Level Partition

From final reachability matrix, different levels of sets are partitioned for each strategy to find the reachability set and antecedent set (Sage, 1977; Warfield, 1974). The reachability set of a definite strategy include itself and the other strategy, which may help to accomplish. The antecedent set includes the strategies themselves and the other, which may provide contribution in achieving it, and then resulting the intersection of these sets for all considered strategies. The reachability and antecedent set for each driver were found from the final reachability matrix as given in tables 4.3 and 4.4. The strategy having same reachability set and intersection subsists at level 'I' and acquire topmost place in ISM model (Kannan and Haq, 2007; Tyagi et al., 2015).

This procedure is completed in different level of iteration .The strategies founding at level 'I' are deleted in next iteration. The next iteration was completed with the remaining strategies and by repeating in same manner as above and continuously performing these iterations up to the levels of each strategy have been obtained.

Table 4.4 Level Partition (Iteration I)

Lean Strategies	Reachability set	Antecedent set	Interaction	Level
S1.	1,2,3,4,5,6,7,8,9,11,12,13	1,2,3,4,5,6,8,9,10,11,12,13	1,2,3,4,5,6,8,9,11,12,13	
S2.	1,2,4,6,7,8,9,11,13	1,2,3,4,5,6,8,9,10,11,12,13	1,2,4,6,8,9,11,13	
S3.	1,2,3,4,6,7,8,9,11,13	1,3,4,5,7,8,9,10,11,12,13	1,3,4,7,8,9,11,13	
S4.	1,2,3,4,5,6,7,8,9,10,11,12,13	1,2,3,4,5,10,11,12,13	1,2,3,4,5,10,11,12,13	
S5.	1,2,3,4,5,6,7,8,9,10,11,13	1,4,5,10,13	1,4,5,10,13	
S6.	1,2,6,7,9,13	1,2,3,4,5,6,8,9,10,11,12,13	1,2,6,9,13	
S7.	3,7,9	1,2,3,4,5,6,7,8,9,10,11,12,13	3,7,9	I
S8.	1,2,3,6,7,8,9,11,13	1,2,3,4,5,8,10,11,12,13	1,2,3,8,11,13	
S9.	1,2,3,6,7,9,13	1,2,3,4,5,6,7,8,9,10,11,12,13	1,2,3,6,7,9,13	I
S10	1,2,3,4,5,6,7,8,9,10,11,12,13	4,5,10,12,13	4,5,10,12,13	
S11.	1,2,3,4,6,7,8,9,11,13	1,2,3,4,5,8,10,11,12,13	1,2,3,4,8,11,13	
S12.	1,2,3,4,5,6,7,8,9,10,11,12,13	1,4,10,12	1,4,10,12	
S13.	1,2,3,4,5,6,7,8,9,10,11,13	1,2,3,4,5,6,8,9,10,11,12,13	1,2,3,4,5,6,8,9,10,11,13	

Table 4.5 Level Partition Iteration II

Lean Strategies	Reachability set	Antecedent set	Interaction	Level
1	1,2,3,4,5,6,8,11,12,13	1,2,3,4,5,6,8,10,11,12,13	1,2,3,4,5,6,8,11,12,13	II
2	1,2,4,6,8,11,13	1,2,3,4,5,6,8,10,11,12,13	1,2,4,6,8,11,13	II
3	1,2,3,4,6,8,11,13	1,3,4,5,8,10,11,12,13	1,3,4,8,11,13	
4	1,2,3,4,5,6,8,10,11,12,13	1,2,3,4,5,10,11,12,13	1,2,3,4,5,10,11,12,13	
5	1,2,3,4,5,6,8,10,11,13	1,4,5,10,13	1,4,5,10,13	
6	1,2,6,13	1,2,3,4,5,6,8,10,11,12,13	1,2,6,13	II
8	1,2,3,6,8,11,13	1,2,3,4,5,8,10,11,12,13	1,2,3,8,11,13	
10	1,2,3,4,5,6,8,10,11,12,13	4,5,10,12,13	4,5,10,12,13	
11	1,2,3,4,6,8,11,13	1,2,3,4,5,8,10,11,12,13	1,2,3,4,8,11,13	
12	1,2,3,4,5,6,8,10,11,12,13	1,4,10,12	1,4,10,12	
13	1,2,3,4,5,6,8,10,11,13	1,2,3,4,5,6,8,10,11,12,13	1,2,3,4,5,6,8,10,11,13	II

Table 4.6 Level Partition Iteration III

Lean Strategies	Reachability set	Antecedent set	Interaction	Level
3	3,4,8,11,	3,4,5,8,10,11,12	3,4,8,11,	III
4	3,4,5,8,10,11,12	3,4,5,10,11,12	3,4,5,10,11,12	
5	3,4,5,8,10,11,	4,5,10	4,5,10	
8	8,11	3,4,5,8,10,11,12	8,11	III
10	3,4,5,8,10,11,12	4,5,10,12	4,5,10,12	
11	3,4,8,11	3,4,5,8,10,11,12	3,4,8,11	III
12	3,4,5,8,10,11,12	4,10,12	4,10,12	

Table 4.7 Level Partition Iteration IV

Lean Strategies	Reachability set	Antecedent set	Interaction	Level
4	4,5,10,12	4,5,10,12	4,5,10,12	IV
5	4,5,10,	4,5,10	4,5,10	IV
10	4,5,10,12	4,5,10,12	4,5,10,12	IV
12	4,5,10,12	4,10,12	4,10,12	

Table 4.8 Level Partition Iteration V

Lean Strategies	Reachability set	Antecedent set	Interaction	Level
12	12	12	12	V

Table 4.9 Level Partition (Final Iteration)

Lean Strategies	Reachability set	Antecedent set	Interaction	Level
S1.	1,2,3,4,5,6,8,11,12,13	1,2,3,4,5,6,8,10,11,12,13	1,2,3,4,5,6,8,11,12,13	II
S2.	1,2,4,6,8,11,13	1,2,3,4,5,6,8,10,11,12,13	1,2,4,6,8,11,13	II
S3.	3,4,8,11,	3,4,5,8,10,11,12	3,4,8,11,	III
S4.	4,5,10,12	4,5,10,12	4,5,10,12	IV
S5.	4,5,10,	4,5,10	4,5,10	IV
S6.	1,2,6,13	1,2,3,4,5,6,8,10,11,12,13	1,2,6,13	II
S7.	3,7,9	1,2,3,4,5,6,7,8,9,10,11,12,13	3,7,9	I
S8.	8,11	3,4,5,8,10,11,12	8,11	III
S9.	1,2,3,6,7,9,13	1,2,3,4,5,6,7,8,9,10,11,12,13	1,2,3,6,7,9,13	I
S10	4,5,10,12	4,5,10,12	4,5,10,12	IV
S11.	3,4,8,11	3,4,5,8,10,11,12	3,4,8,11	III
S12.	12	12	12	V
S13.	1,2,3,4,5,6,8,10,11,13	1,2,3,4,5,6,8,10,11,12,13	1,2,3,4,5,6,8,10,11,13	II

4.6 Formation of the ISM model

The interpretive structural model is generated from final reachability matrix (Table 7). If there is a relationship between the barriers i and j, this is presented by an arrow which points from i to j. Figure shows the ISM model for the given problem. The factors which are at a lower level in the hierarchy have a very high driving power and the factors which are at the top of the hierarchy have a high dependence power. The driving power for each factor is the total number of factors (including itself), which it may help achieve. Dependence power is the total number of factors (including itself), which may help achieve it.

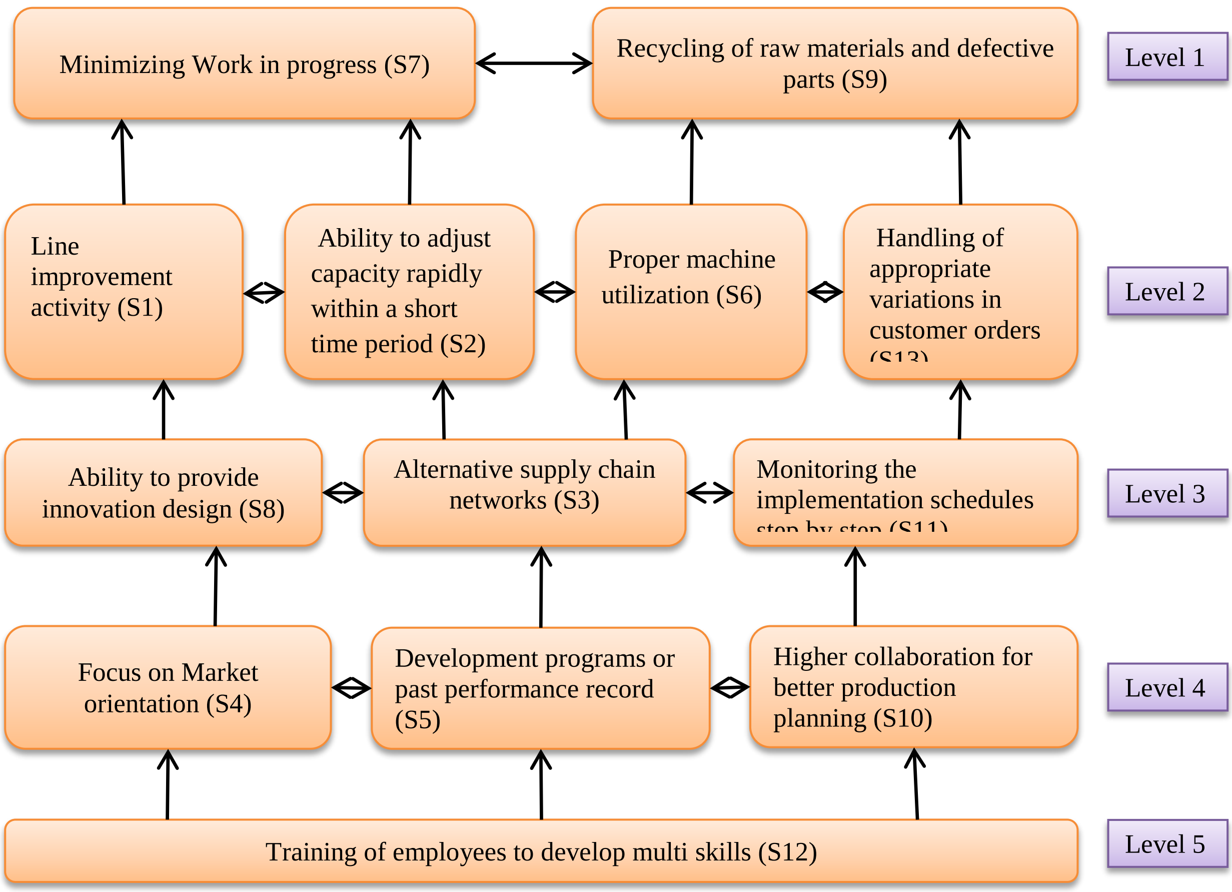

Figure 4.1 Model based on ISM

The above bus diagram as shown in figure 3 represents the different strategies and their corresponding inter-relation. From the above inter-relationships, the selected manipulative steps have been divided into 5 levels for the growth of the organization. Training of employees to develop multi skills (S35) is most important strategy which drives all the other strategies which result in successful integration of lean and every organization need to focus on this strategy. With regular and interactive training, employees learn new techniques that help to develop multiple skills which further lead the organization to superior level. Strategy (S12) at level 5 builds the base of this ISM model.

Training of employees to develop multi skills (S12) escorts the three strategies at level 4 i.e. focus on market orientation (S4), development programs or past performance record (S5) and higher collaboration for better production planning (S10). These three strategies have strong relation among them. Depending on past performance record or development programs helps to find out drawbacks of final products or new demands of the customers based by focusing on the market orientation. It will help the production unit to collaborate with others employees and create better production planning.

At level 3 strategies, alternative supply chain networks (S3), ability to provide innovation design (S8) and monitoring the implementation schedules step by step (S11) ushered by level 4. Regular training and Focusing on market orientation helps the employees to create the ability of innovative designing according to the demand .that further come out to give alternative sully chain networks. This is also helps in monitoring the implementing schedules steps by steps. Level 2 drive the further four strategies i.e. line improvement activity (S1), ability to adjust capacity rapidly within a short time period (S2), proper machine utilization (S6) and handling of appropriate variations in customer orders (S13).

Strategies at level 2 have very strong connectivity with each other. If there is proper machine utilization and improved line activity, it can create ability to adjust the capacity rapidly within short period of time that helps to handle the variations in customers' orders.

Minimizing work in progress (S7) and recycling of raw materials and defective parts (S9) at level 1 guided by level 2 and are the desired outcomes of the figures. These two strategies achieve the topmost position of this hierarchical representation. With help of proper machine utilization and improved line activity helps in minimizing work in progress with less defective parts that give desired best quality products and increases the productivity of the organization.

4.7 Conclusion

ISM can only act as a tool for imposing order and directions on the complexity of relationships among the variables. ISM technique has been found appropriate to model the different lean manufacturing strategies. "Training of employees to develop multi skills (S12)" has been identified as bottom level independent lean strategy driving which successfully implement the LMS towards “minimizing work in progress (S7) and recycling of raw materials and defective parts (S9)” that have been identified as top dependence lean strategy in the model.

It does not suggest any relative weights associated with the variable. Even so, this model can be applied with other approaches such as the Fuzzy MICMAC, which requires a decision structure to help determine the weights of factors.

5.1 Introduction

This chapter gives the insight of fuzzy-MICMAC methodology and its level of importance after applying ISM methodology

5.2 Fuzzy-MICMAC Methodology

Examinations of direct relationships may reveal that indicators having strong direct impact can be suppressing hidden indicators, which at times may substantially influence the system under consideration (Saxena and Sushil, 1990; Abbasi and Arya, 2000). Such indirect inter-relationship between indicators may have an impact on the system through influence chains and reaction loops, or feedback. The number of such chains and loops could be so large that it may be difficult to interpret them without the help of computers.

To analyse these inter-relationships and to study their role and behaviour, MICMAC method was introduced by Duperrin and Godet (1973) and Kanungo et al. (1999). MICMAC (a French term: Matrice d'Impacts Croisés Multiplication Appliquée á un Classement, i.e., cross-impact matrix – multiplication applied to classification) is used for the analysis of the indirect and hidden relationships among the elements of the structure obtained using ISM technique (which only captures the direct relationships among these elements). The method enables study of the diffusion of impacts through reaction paths and loops for developing hierarchy of the indicators

1.in order of their driver power, by taking into account the number of paths and

loops of length 1, 2, ..., n. ... arising from each indicator

2.in order of dependence by taking into account the number of paths and loops of length 1, 2, ..., n .... accruing to each indicator.

5.2.1 MICMAC Principle

The MICMAC principle is based on the multiplication properties of matrices. If indicator i directly influences indicator k and if k directly influences indicator j, any change affecting indicator i can have repercussions on indicator j. There is an indirect connection between i and j.

Numerous indirect relationships of i → j type which exists in the structural matrix cannot be taken into account in a direct relationship approach. When the matrix is squared, second order relationships are revealed, such as i → j. Similarly, when the matrix is multiplied, 3, 4, 5 or n times, the number of influence paths (for influence loops) of the 3rd, 4th, 5th order interconnecting the indicators can be found. Each time this process is repeated, a new hierarchy of indicators can be deduced. Their classification is based on the number of indirect actions (influences) they have on other indicators. When raised to a certain power, this hierarchy repeats in the next stage of multiplication (both in the hierarchy of column as well as in the row) and such a stage is considered as a stable stage and such matrix is called *stabilised indirect matrix*.

Fuzzy MICMAC considers binary type of relationships, with an additional input of possibility of interaction between the elements. Fuzzy-MICMAC is more sensitive than ordinary MlCMAC analysis, the former continues to be useful in cases where enormous resources would be required to decide the possibility of interaction (Saxena and Sushil, 1990).

In Fuzzy MICMAC analysis, direct relationship matrix (DRM) deduced from digraph –

basic input to MICMAC – is enriched by incorporating in it the possibility of interactions. It is then called fuzzy direct relationship matrix (FDRM) and because an input to Fuzzy MICMAC analysis; instead of using Boolean multiplication of matrices to stabilise the ranks, fuzzy matrix multiplication is used (Saxena and Sushil, 1990). Fuzzy matrix multiplication is basically a generalisation of boolean matrix multiplication (Vasantha Kandasamy, 2007). According to fuzzy sets theory (FST), two fuzzy matrices are being multiplied the product matrix will also be a fuzzy matrix. Multiplication follows the given rule:

AB = Max {min (aij, bij)}

Where A = [aij] and B = [bij] are two fuzzy matrices.

For example:

$$\mathbf{A} = \begin{matrix} a11 & a12 & a13 & a14 \\ a21 & a22 & a23 & a24 \\ a31 & a32 & a33 & a34 \\ a41 & a42 & a43 & a44 \end{matrix} \qquad \mathbf{B} = \begin{matrix} b11 & b12 & b13 & b14 \\ b21 & b22 & b23 & b24 \\ b31 & b32 & b33 & b34 \\ b41 & b42 & b43 & b44 \end{matrix}$$

C = AB

$$\mathbf{C} = \begin{matrix} c11 & c12 & c13 & c14 \\ c21 & c22 & c23 & c24 \\ c31 & c32 & c33 & c34 \\ c41 & c42 & c43 & c44 \end{matrix}$$

c11= max {min (a11, b11), min (a12, b21), min (a13, b31), min (a14, b41)} c12= max {min (a11, b12), min (a12, b22), min(a13, b32), min(a14, b42)} c13= max {min (a11, b13), min (a12, b23), min (a13, b33), min (a14, b43)}

:

:

c44= max min {(a41, b14), min(a42, b24), min(a43, b34), min(a44, b44)}

5.2.2 Stabilization of Fuzzy Matrix

The FDRM is taken as the base to start the stabilization process. The matrix is multiplied repeatedly until the hierarchies of the driver power and dependence stabilize. The multiplication process follows the principle of fuzzy matrix multiplications as described earlier.

5.2.3 Key Indicators

The indicators with the greatest driver power in the stabilized matrix are the key indicators. The key indicator that is nearest to the origin in the graph represents the highest driver power.

5.3 Advantages of Integrating Fuzzy-MICMAC

Duperrin and Godet (1973) used structural analysis for research on the key variables which bear on the future dimensions and developed the MICMAC method where the importance of a variable is measured less by its direct inter-relationships but rather by many indirect inter relationships. The indirect relationship (MICMAC) approach of structural analysis is much superior approach compared to direct relationship analysis. It is an important tool for the management for an in-depth analysis of the programme/system (Saxena and Sushil, 1990).

Identification and classification of the key criteria is essential to develop the system under study. Comparing the hierarchy of variables in the various classifications (direct, indirect and potential) leads to rich source of information (Qureshi et al., 2008). As per Watson (1973), MICMAC enables one not only to confirm the importance of certain variables, but also effect to uncover certain variables, which because of their indirect actions play an important role (yet were not identifiable through direct classification). Examination of direct relationships may reveal that criteria having strong direct impact can be suppressing hidden criteria, which at times may substantially influence the system under consideration (Saxena and Sushil, 1990). Fuzzy theory is applied to the traditional MICMAC for possible reachability based on driving power and dependence of each criterion. FMICMAC helps in critical investigation of each criterion (Qureshi et al., 2008). The application of soft computing techniques allows us a more robust modelling of the information given by experts as well as providing a closer and easier way to understand the resultant information.

This method for structural analysis permits to experts to evaluate the influence among system's variables by linguistic terms. In this way, the process of reaching consensus on opinions is facilitated since the linguistic labels can be defined according to experts' preferences (Nieves et al., 2011).

"Another problem of ISM is the difficulty of valuating the results from an absolute point of view. A system with a high percentage of strong influences cannot be analyzed in the same way that another system where almost all the influences defined are low. All the advantages that we have enumerated lead to richer and interpretable results which make easier, faster and more robust the identification of the key variables (Nieves et al., 2011)."

5.4 Fuzzy-MICMAC Analysis of Lean Strategies

It involves the following steps in Fuzzy Micmac analysis (Gorane and Kant, 2013; Dubey and Singh, 2015):

I: Development of binary direct relationship matrix (Gorane and Kant, 2013)

II: Fuzzy direct reachability matrix

III: Creating stabilized fuzzy MICMAC matrix

5.4.1 Binary direct relationship matrix

To make the binary direct relationship matrix, it is required to convert the convectional MICMAC analysis into fuzzy MICMAC analysis using binary system (0 & 1). To make an analysis more strong, fuzzy set theory may be used (Dewangan et al., 2015; Khan and Haleem, 2012). The binary direct relationship matrix is shown below in table 5.1.

Table 5.1 Binary direct relationship matrix

S.no.	Lean Strategies	1	2	3	4	5	6	7	8	9	10	11	12	13	Driving power
S1.	Line improvement activity	0	0	0	1	0	1	1	1	0	0	0	0	1	**5**
S2.	Ability to adjust capacity rapidly within a short time period	1	0	0	0	0	1	1	0	0	0	0	0	1	**3**
S3.	Alternative supply chain networks	1	1	0	0	0	1	1	0	1	0	0	0	1	**6**
S4.	Focus on Market orientation	0	1	1	0	1	1	0	1	1	0	1	1	1	**9**
S5.	Development programs or past performance record	1	0	0	0	0	1	1	1	1	1	1	0	1	**8**
S6.	Proper machine utilization	0	1	0	0	0	0	1	0	0	0	0	0	0	**2**
S7.	Minimizing Work in progress	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
S8.	Ability to provide innovation design	0	1	1	0	0	0	1	0	0	0	0	0	1	**4**
S9.	Recycling of raw materials and defective parts	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**
S10	Higher collaboration for better production planning	1	1	0	1	1	1	1	1	0	0	1	0	1	**9**
S11.	Monitoring the implementation schedules step by step	1	1	1	0	0	1	1	1	0	0	0	0	1	**7**
S12.	Training of employees to develop multi skills	1	1	0	0	1	1	1	1	1	1	1	0	1	**10**
S13.	Handling of appropriate variations in customer orders	0	0	0	0	0	1	0	1	1	0	1	0	0	**4**
Dependence power		**6**	**7**	**4**	**2**	**3**	**9**	**9**	**7**	**7**	**2**	**5**	**1**	**9**	

Table 5.2 Possibility of numerical values of the reachability

Possibility of reachability	No	Very low	Low	Medium	High	Very high	Complete
Value	0	0.1	0.3	0.5	0.7	0.9	1

5.4.2 Fuzzy direct reachability matrix

For the development of Fuzzy direct reachability matrix, possibilities of numerical values shown in table 5.2 are used in the binary direct relationship matrix. The sensitivity of MICMAC analysis increases by using fuzzy set theory that's why possibility of interaction is introduced which state the direct relationship between strategies .i.e. whether lean strategies have " very low , low, medium high, very high and complete relationship or not depending on driving power". Based on this Fuzzy direct reachability is stabilized and shown in table 5.3.

5.4.3 Creating stabilized fuzzy MICMAC matrix:

For Creating stabilized fuzzy MICMAC matrix, Fuzzy direct reachability matrix in table 10 is used as the base for the formation of the same. In this matrix is multiplied again and again until the hierarchies of dependence and driving power will become constant and according to set of fuzzy theory , the product would be fuzzy matrix if two fuzzy matrix were multiplied (Dewangan et al., 2015; khan and Haleem, 2012; Diabat and Govindan, 2011; Kannan et al., 2009; Kandasamy et al., 2007). For multiplication of two fuzzy matrixes, following method is used to obtain the desired result.

$MN = Max \{min (m_{ij}, n_{ij})\}$

Where, $M = [m_{ij}]$ and $N = [n_{ij}]$ are two fuzzy matrices.

This program is written in the 'C' language to accurate and desired result is obtained. The stabilized fuzzy MICMAC matrix is shown in table 13.

Table 5.3 Fuzzy direct reachability matrix

S.no.	**Lean Strategies**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
S1.	Line improvement activity	0	0	0	0	0	0.9	0.5	0.3	0	0	0	0	0.1
S2.	Ability to adjust capacity rapidly within a short time period	0	0	0	0	0	0.5	0.7	0	0	0	0	0	0.3
S3.	Alternative supply chain networks	0.3	0	0	0	0	0.7	0.9	0	0.9	0	0	0	0.3
S4.	Focus on Market orientation	0	0.9	0.7	0	0.5	0.9	0	0.7	0.9	0	0.3	0	0.5
S5.	Development programs or past performance record	0	0	0	0	0	0	0	0.3	0	0	0	0	0.1
S6.	Proper machine utilization	0	0	0	0	0	0	0.1	0	0	0	0	0	0
S7.	Minimizing Work in progress	0	0	0	0	0	0	0	0	0	0	0	0	0
S8.	Ability to provide innovation design	0	0	0	0	0	0	0	0	0	0	0	0	0
S9.	Recycling of raw materials and defective parts	0	0	0	0	0	0	0	0	0	0	0	0	0
S10	Higher collaboration for better production planning	0.5	0.5	0	0	0.5	0.7	0.9	0.7	0	0	0.5	0	0.9
S11.	Monitoring the implementation schedules step by step	0.1	0.1	0	0	0	0.5	0.7	0.5	0	0	0	0	0
S12.	Training of employees to develop multi skills	0.5	0.5	0	0	0.5	0.9	0.9	0.7	0	0	0.5	0	0.7
S13.	Handling of appropriate variations in customer orders	0	0	0	0	0	0.1	0	0.1	0.3	0	0	0	0

Table 5.4 Stabilized fuzzy MICMAC matrix

S.no.	Lean Strategies	1	2	3	4	5	6	7	8	9	10	11	12	13	Driving power
S1.	Line improvement activity	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0.5	**6.1**
S2.	Ability to adjust capacity rapidly within a short time period	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0.5	**6.1**
S3.	Alternative supply chain networks	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0.5	**6.1**
S4.	Focus on Market orientation	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0.9	**6.9**
S5.	Development programs or past performance record	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0.5	**6.3**
S6.	Proper machine utilization	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0.5	**6.1**
S7.	Minimizing Work in progress	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**1.3**
S8.	Ability to provide innovation design	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0.9	**6.5**
S9.	Recycling of raw materials and defective parts	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**1.3**
S10	Higher collaboration for better production planning	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0.7	**6.3**
S11.	Monitoring the implementation schedules step by step	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0.5	**6.1**
S12.	Training of employees to develop multi skills	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.5	0.3	0.3	0.5	0.7	**6.5**
S13.	Handling of appropriate variations in customer orders	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.5	0.3	0.3	0.5	0.5	**6.5**
Dependence power		**5.7**	**5.7**	**5.7**	**5.7**	**5.7**	**5.7**	**5.7**	**6.9**	**5.7**	**3.5**	**3.5**	**5.7**	**6.9**	

```
Level-5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.9  0.5  0.3  0.3  0.5  0.9
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.7  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.9
  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.7
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.7  0.5  0.3  0.3  0.5  0.7
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.9  0.5  0.3  0.3  0.5  0.5

Matrix Stabalised !!!
press ANY key to exit..._
```

Figure 5.1 Stabilized fuzzy MICMAC matrix in C Program

The stabilized matrix as shown in table 13, is classified into four cluster based on driving power and dependence power. The summing up values of rows in the stabilized fuzzy Micmac matrix is driving power and summing up values columns in the stabilized fuzzy Micmac matrix is dependence power. The cluster representation is shown in figure 5

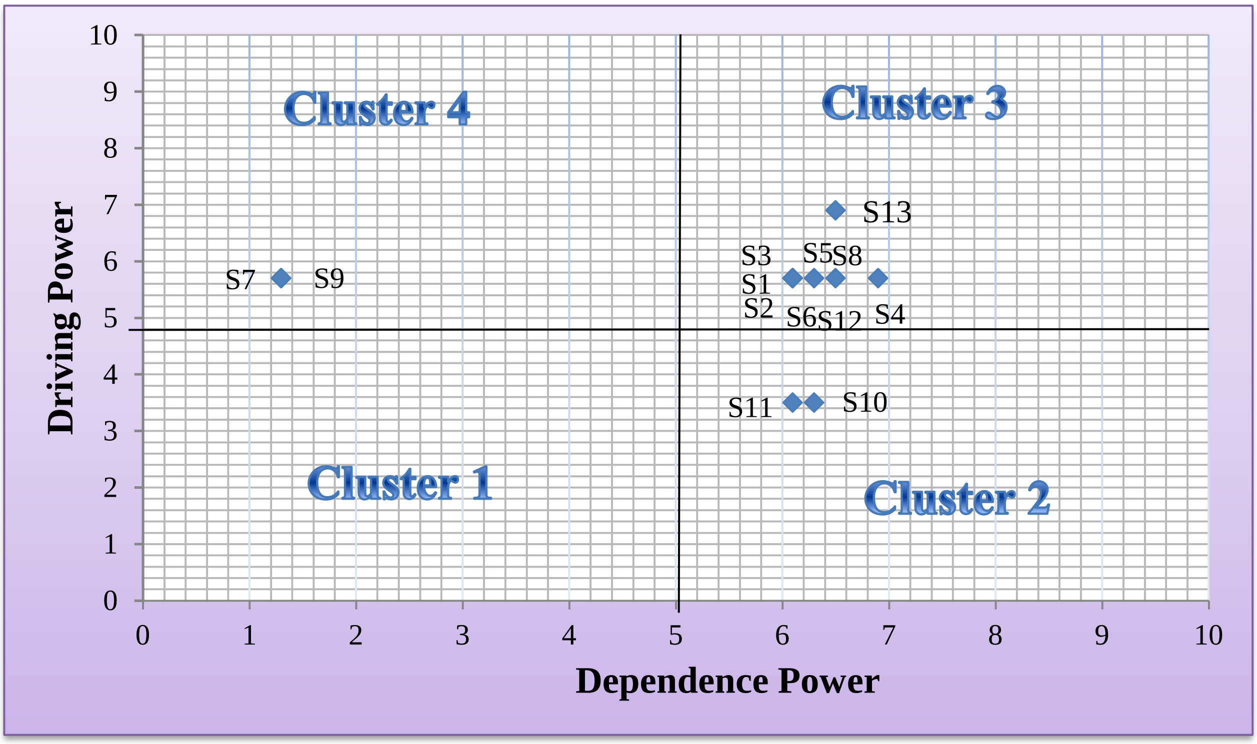

Figure 5.2 Driving And Dependence Graph

Cluster 1 (Autonomous Cluster): Lean strategies in this cluster have very low driving and dependence power. Strategies in this cluster have no relation with others. They are neither influence nor influenced by any others strategies. There is no lean strategy in our study that fall into this cluster.

Cluster 2 (Dependence Cluster): In this cluster, lean strategies that have low driving power but high dependence power is known as dependence cluster. It represents lean strategies which are dependent on others. The dependency of these lean strategies shows that they need all other lean strategies to implementation of lean strategies into the system. Lean strategy (S7) minimizing work in progress and lean strategy (S9) recycling of raw materials and defective parts and are categorized in this cluster.

Cluster 3 (Linkages Cluster): Lean strategies in this cluster have very high driving power and dependence power as well. This cluster shows lean strategies have very strong relation among them. Most of lean strategies in this present study fall in this cluster. If there is a change in any lean strategy it will immediately affect the other lean strategy. Most of the lean strategies of present study fall in this cluster. Total eight strategy are categorized that are Line improvement activity(S1), ability to adjust capacity rapidly within a short time period(S2), alternative supply chain networks(S3), focus on Market orientation(S4), development programs or past performance record(S5), proper machine utilization(S6), ability to provide innovation design(S8) , training of employees to develop multi skills(S12) and handling of appropriate variations in customer orders(S13).

Cluster 4 (Independent Cluster): Lean strategies in this cluster have very high driving power and low dependence power. Lean strategies which are fall in this cluster are also known as driving cluster. Lean strategy which fall in this category are higher collaboration for better production planning (S10) and monitoring the implementation schedules step by step (S11).

5.5 CONCLUSION

In this chapter fuzzy-MICMAC analysis has been done to analyze the lean strategies. The driver power and dependence graph has been plotted (as shown in Figure 5). The lean manufacturing strategies have been classified into four categories which are: autonomous, linkage, dependent and independent according to their driver power and dependence.

6.1 Introduction

This chapter concludes the overview of the project with the results obtained by applying ISM and fuzzy MICMAC on the factors of knowledge sharing. The scope of the future research has also been analyzed in this chapter.

6.2 Conclusion

It is understood that no single strategy is enough for implementation of lean manufacturing for enhancement of the efficiency organization. After factor analysis out of thirty six lean strategies thirteen were extracted using software SPSS 21 and analyzed by structural modeling and then used to develop the ISM based model which helps to understand the direct relationship among various lean strategies. “Training of employees to develop multi skills (S12)” has been identified as the most crucial strategy which drives all the other strategies for the success of lean. Minimizing Work in progress (S7) and recycling of raw material and defective parts (S9) were level one, strategies whose success is dependent on other factors. Apart from the relationship among various lean strategies, there it was also essential to express the role of individual strategy also.

It was observed that most of the selected strategies have very high driving power and dependence power as well. No lean strategy was identified which fall in the autonomous cluster. Higher collaboration for better production planning (S10) and monitoring the implementation schedules step by step (S11) have been identified as the independent strategies which have high driving power and low dependence power. Also, minimizing work in progress (S7) and recycling of raw materials and defective parts (S9) were categorized in dependence cluster as they have low driving power and high dependence power.

6.3 Research Contribution

This analysis would help managers of the organization to understand the direct and indirect relationship among various lean strategies and help them improve the efficiency of their enterprise in this competitive market.

6.4 Managerial Implementations

To overcome the various challenges that arise at the time of production and to improve the efficiency of their organization, managers need versatile approaches to make the effective decision for the growth of organization. This study shows that manager needs to focus on various strategies depending on the situation at different level. Training of employees is the primary need of the organization of the organization which accelerates the others strategies effectively in every field. Apart from this strategy, managers need to focus on secondary strategies at different level also as shown in figure 2. Driving and dependence graph shown in figure 3 would help the managers to decide whether the applied strategies are driving in nature or dependent on others. Most of strategies fall in cluster 3 managers have to focus more on this category. Strategies in this category are very crucial for implementation of lean manufacturing in the organization. Also, each and every strategy serves its role in the performance of the organization at its level. Therefore this study helps the managers for implementation of various lean strategies into the organization.

6.5 Limitation and Future scope

In this study, initially thirty six lean strategies were identified on the basis of literature review; however thirteen lean strategies have been extracted by using factor analysis. In ISM approach, there is no restriction in consideration on numbers of lean strategies, therefore more numbers of lean strategies can also be considered. Moreover, as the numbers of lean strategies increases, ISM model will become more complex. To drive the analysis, data has been collected only from the automobiles industries located at Delhi NCR. In future, data can also be collected from the automobile industries located at different locations of India and comprehensive analysis can also be performed. To compare the results of present study, the other multi-criteria decision making techniques like SEM, DEMATEL, and Fuzzy DEMATEL can be considered.

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