Journal of Advances and Scholarly Researches in Allied Education
Vol. 17, Issue No. 1, April-2020, ISSN 2230-7540

Design and Development of Sustainable Lean Manufacturing Using Interpretive Structural Model (ISM) Approach

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Abstract – In the recent time many industries are implementing lean manufacturing to reduce/eliminating wastes. But, while implementing LM in the industries the faces many issues. In this research workers involvements, communication and improved material handling and housekeeping are the three factors which have high driving power and low dependent power. So work on these issues can lean to successful implementation of the lean manufacturing for the sustainable development.

Waste minimization and improving efficiency have been identified as key objectives of lean manufacturing system implementation. Literature review and subsequent discussions with experts have helped to sort the factor relevant to lean manufacturing system implementation based upon their importance. Questionnaire based survey has been carried out to rank these identified factor followed by structural modeling. Top management commitment has been ranked the most important factor as a result of survey analysis and also has been identified as the most important bottom level factor in ISM hierarchy. MICMAC analysis has been utilized to classify the factors.

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INTRODUCTION

Lean Manufacturing Principles

Traditional manufacturing systems are built on the principle of economies of scale. Here, the large fixed costs of production are depreciation- intensive because of huge capital investments made in high-volume operations.

These fixed costs are spread over large production batch sizes in an effort to minimize the total unit costs of owning and operating the manufacturing system. Large work-in-process inventories are also characteristic of traditional manufacturing. The resultant ‘‘batch and queue’’ operation produces large numbers of a particular product and then shifts sequentially to other mass-produced products.

Economic benefits attributable to lean manufacturing include reduced lead-time and higher throughput, smaller floor space requirements, and lower work-in process. Lean manufacturing can be understood at different contexts. Lean, as a philosophy drives the goals and culture, as foundational aspects of quality control on which it is built, as a business strategy to handle the customer needs and as skills which are utilized in the control to become Lean. Figure 1.3 is the house of Lean, a descriptive metaphor in graphic format that will assist in understanding how all these aspects work together to describe the mature Lean Manufacturing system.

Lean as philosophy, which focuses on growth by generating value for the customer, society, and the economy with the objectives of reducing costs, improving delivery times, and improving quality through the total elimination of waste. Wastes could occur in the management, clerical, sales, administration, and factory workers. The most common wastes are: Overproduction, Inventory, Transportation, Defects, Processing Waste, Operating Waste, and Idle Time Waste. Reduction of any wastes will increase productivity, reduce costs and make the company more competitive in the global markets. It will increase the desirability of the company's products; the customer base will grow and require more workers to meet the demand.

Lean Implementation

Applying the philosophy of lean requires a fundamental shift in the way one thinks about business processes. Lean philosophy is all about eliminating waste. Any action or process that does not add value in the eyes of the customer is waste and should be prevented or eliminated. For example: View the activities in the processes from the perspective of the customer. Which activities in the process add value for the customer? Think from the perspective of the part, product, or service as it goes through the process. Walk the path that a part travels. Look for ways to reduce the distance travelled and reduce the number of times the part is handled. View the process as end-to-end, not just as individual steps. Don't optimize individual areas while sub-optimizing the whole. Look for ways to standardize processes across products. When the operations are lean, each remaining activity adds value from the customer's perspective. Activities that do not add value represent wastes. Each type of waste adds cost and delay to the product or service but doesn't add value for the customer. To stay ahead in today's highly competitive global economy; waste in the enterprise must be identified and eliminated.

ARC ELECTRODE MANUFACTURING

Preparation of Core Wire

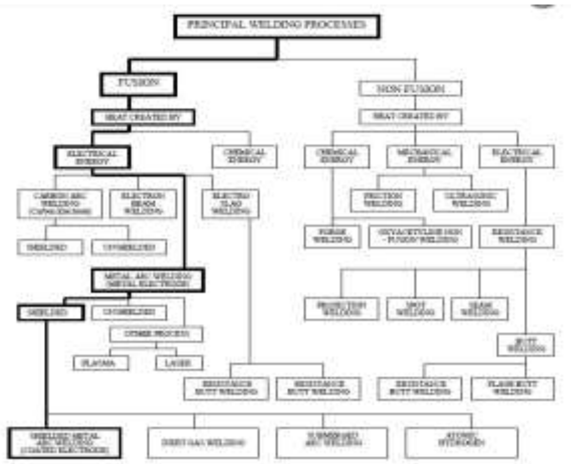
Electrode quality rimming wire confirming JIS 3503 SWRY 11 with low carbon and low silicon is available in the open market. The wire rod coils are converted to the drawn wire coils of sizes such as 2.5mm, 3.15mm, 4mm and 5mm at the wire drawing plants in house or on job-work basis. It is then straightened and cut in to required lengths by 'Straightening and Cutting Machine'.

Preparation of Dry Mix

Rutile, Low carbon Ferro Manganese, Cellulose, Titanium Di-Oxide, Mica, Feldspar, quartz, etc., are some of the chemical powders used as the raw materials for the preparation of flux. These chemicals are available worldwide and they are weighed accurately as per the technology for each type of electrodes and they are mixed in a dry mixer to get homogeneous mix or can be sourced from Eureka as a readymade flux.

Preparation of the Wet Mix

Potassium Silicate is used as the Binding agent. The flux is mixed with Silicate in a correct proportion to obtain a wet mix in a mixer. The Wet mix is then pressed to form briquettes in a hydraulically operated press in order to load the flux in the flux cylinder of the extruder.



Baking of Coated Electrode

After air drying of the coated electrodes they are baked in oven. Depending on the type of electrode the baking cycle will vary. The moisture content in the electrode should not exceed 4 percent

Quality Control

Quality control in electrode making shop calls for, constant checking of the ground ingredients their proportioning and mixing, application procedures, moisture content and drying conditions. In addition, the chemical analysis of the core wire, powders and bonding materials are determined, the coating thickness is measured and the electrodes are tested on trial plates.

Grading and Packing

The finished electrodes are stored and wrapped in polythene or waxed paper and packed in cartons. Cartons are packed in master cartons as per requirement.

LITERATURE REVIEW

(Ankur Chauhan, Amol Singh & Sanjay Jharkharia, 2018) Increasing amount of wastes is posing great difficulties for all countries across the world. The problem of waste management is more severe in developing countries such as India where the rates of economic growth and urbanization are increasing at a fast pace. The governments in these countries are often constrained by limited technical and financial capabilities, which prevent them from effectively addressing these problems. There is a limited participation from the private players too in terms of setting up of waste recycling units. The present study aims at identifying various barriers that challenge the establishment of these units, specific to India. Further, it attempts to identify the most influential barriers by utilizing Multicriteria decision-making tools of interpretive structural modeling (ISM) and decision-making trail and evaluation laboratory (DEMATEL).

(Manuela Ingaldi, Szymon T. Dziuba and Anna Cierniak-Emerych, 2018) The aim of the paper is to collect and analyze information concerning the problems that occur during implementation of the Lean Manufacturing in Polish enterprises. The data were collected by means of a direct questionnaire survey. The results can be a suggestion for the enterprises which are planning to implement the Lean Manufacturing and indicate the problems they should be prepared for in the process.

(Arvind Kumar Shrimali, Vimlesh Kumar Soni, and Shashank Singh Pawar, 2018) Lean practices are implemented in manufacturing companies and services to find hidden waste and attain continuous improvement. Various enterprises have experienced difficulties in the Lean implementation. Following the use of appropriate lean instruments and techniques, there are many other factors that affect success lean implementation process. Researchers have identified a huge number of barriers to the implementation of Lean. Understanding the barriers and the interactions between them can be crucial to the success of lean implementation. Interpretive Structural Modeling (ISM) is one of the established methodologies to bring forward the interrelationships among parameters of an issue or a problem. Purpose- The purpose of this paper is to create the hierarchy of the various barriers to Lean Implementation according to their importance using the approach of ISM to facilitate Small and Medium Enterprises (SMEs) across India. The study is specific to the Small and Medium Enterprises (SMEs) from India.

(Abdillah Arif Nasution, Ikhsan Siregar, Anizar, Tigor Hamonangan Nasution, Khalida Syahputri Indah Rizkya, 2018) This research was conducted in manufacturing industry, so this research is based on case study application. This research serves to reduce waste in the industry when making a product. This study categorizes value-added work and which work has no added value. And it is measurable and has value, so it can be evaluated in the future. Later this will be poured or depicted on a map called Value stream mapping. This is a tool from Lean Manufacturing. Lean manufacturing is useful for analyzing and reducing non value-added activities, value stream mapping analysis tools, 5L1H process mapping activities, and 5 why tools. From the results of this study obtained the efficiency of the process cycle and total estimation of the improvement of the lead time. This calculation can be an evaluation material for the company.

(Rajender Kumara, Vikas Kumar and Singh, 2017) Existing literature on lean principles reveals the impact of lean principles on the organizational performance. During the past few years, the Indian manufacturing context has been competing with the global competitors directly to sustain their presence. One of the big motivations behind this is the steps taken in favor of replacing the policies and regulations for the manufacturing context by the government of India. In present, the manufacturing context is still far away to get the sustainable market because of customer perception variation i.e. cost, delivery and quality related issues. To overcome the uncertainties based on the attributes i.e. quality, productivity, de-livery etc., almost all the manufacturing units use the basic of lean principle i.e. apply the 5'S. Whereas the heavy industries used the VSM approach especially the automotive product manufacturers. The work presented in this paper gives an insight on the application of lean principles in the manufacturing context and analyzes the impacts using ISM approach

(Marcos José Alves Pinto Junior, Juliana Veiga Mendes, 2017)A literature review was conducted to analyse the relationship between operational practices of Lean and reduction of environmental impact in organizational contexts. Verified theoretically, this relationship was observed in a company of the electronics industry, through an exploratory research which contemplated a mixed approach. The adopted research method consisted of a single case study, by providing greater depth and detail of the study. Utilized a research protocol, validated test pilot. The instruments for data collection were semi-structured interviews, direct observation and document analysis. The information was examined qualitatively considering the technique for content analysis. As a result of the study, it was found that there is evidence for the existence of relationship between the practices of Lean, for example, Kaizen, PDCA (plan, do, check, act), Ishikawa Diagram, Poka-Yoke, Standardized Work and Value Stream Mapping, with the reduction of environmental impacts of an organization.

(Rajesh Attri, Nikhil Dev and Vivek Sharma, 2013) Interpretive structural modelling (ISM) is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. This approach has been increasingly used by various researchers to represent the interrelationships among various elements related to the issue. ISM approach starts with an identification of variables, which are relevant to the problem or issue. Then a contextually relevant subordinate relation is chosen.

(Lathin, 2009) insist that quality improvements are only possible if companies implement comprehensive change management programs addressing "both the organizational and technological aspects of quality management".

(Ohno, 2008) In part, as a result of these innovations, key objectives of Toyota's early management practice have been characterized as "production efficiency by consistently and thoroughly laminating waste", and "the equally important respect for humanity"

(Imai, 2007) Eight distinct types of waste are recognized in the Lean manufacturing system cause effective implementation of Lean management results in the establishment of intra and inter organizational capability building routines and improve time – based competitiveness depends on the use of this principles, structured processes and supporting tools.

PROCEDURE AND METHODOLOGY

Interpretive Structural Modeling(ISM)

Interpretive Structural Modeling(ISM) is an emerging modeling methodology which is useful as an aid to individual or small groups in developing and understanding of complex situation this modeling tool was introduced by [349], with the objective of understanding of complex relationships among the research variables related to the subject. ISM is a cumulative learning process. In this process, a set of different directly and indirectly related elements are structured into a comprehensive systematic mode. The model formed after the process predicts the structure of a complex issue in a carefully designed pattern implying graphics as well as words. The ISM methodology is an interactive learning process in which a systematic application of some elementary notions of graph theory is used in such a way that theoretical, conceptual and computational leverage are exploited to explain the complex pattern of contextual relationship among a set of variables.

ISM methodology is used to investigate the IT/IS adoption in the Indian SMEs and its adoption in various sectors of SMEs for the enhancement of capability of manufacturing and to maintain the quality, ISM process transforms unclear and raw conceptual models of system into clear and well defined useful models. It helps to impose order and direction on the complexity of relationships among elements of a system. It enables individuals or groups to develop a map of the complex relationships between many elements involved in a complex decision situation ISM is often used to provide fundamental understanding of complex situations, as well as to put together a course of action for solving a problem .The method is interpretive, based on group's judgments; structural means on the basis of the relationship and it is modeling on the ground that the specific relationships are portrayed in a structured digraph model

ISM is a technique that can be placed upon a system – for example group or an environment – to scientifically grasp both the direct and indirect relationships among the list of system's components .Its fundamental rationale ought to utilize experts' practical experience and knowledge to break down a challenging structure into several sub-systems (elements) and generate a multilevel structural model. ISM is most often applied to supply quintessential grasping of challenging circumstances, along with impart collectively a course of action for solving a problem. The primary outcomes of ISM are driver power-dependence matrix, recognition of levels of criteria and digraph (relationship among variables). ISM quantifies the associations between buyer-supplier relationship variables and also provides comprehensive visualization of it in the form of digraph. The method is interpretive, based upon group's judgments; structural mans based on this relationship which is modeling on the basis that that the certain relationships are portrayed in a structured digraph model. Hence, ISM is currently being used as it gives you relational hierarchy amongst most of the complex variables of any network or system like SMEs.

RESEARCH VARIABLES

In this research study variables are identified by literature review and are related to the IT/IS adoption in Indian SMEs and its effectiveness in SMEs that will lead to the realization of need of the technology in small organization to increase the efficiency and to gain the numerous advantages of information technology that will be helpful in expanding the business in future and to increase the profit as well as to increase the level of customer satisfaction. List of all variables used in this study are shown in the table:

Structural Self-Interaction Matrix (SSIM)

ISM methodology suggest the use of expert opinions based on various management techniques such as brain storming, nominal group technique etc. in developing contextual relationship among the variables, the opinion of experts from different sectors of SMEs from across the India have been taken along with the academia people, experts were asked to identify the extent to which one variable lead to another. Based on this contextual relationship and associated direction between any two parameters (i and j) all relationship between the two parameters in associated direction are questioned from the experts, following four symbols are used to denote the direction of the relationship between the research variables.

V: Variable i will help to achieve variable j

A: Variable j will help to achieve variable i

X: Variable i and j will lead to achieve each other

O: variable I and j are unrelated

Initial Reachability Matrix (IRM)

SSIM is now transformed into binary matrix called the initial reachability matrix by substituting V, A, X and O by 1 and 0 according to the following rules

1. If (i, j) entry in the SSIM is V, then the (i, j) entry in the Initial Reachability Matrix (IRM) becomes 1 and (j, i) entry becomes 0.

2. If the (i, j) entry in the SSIM is A, then the (i, j) entry in the Initial Reachability Matrix (IRM) become 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 Initial Reachability Matrix (IRM) becomes 1 and the (j, i) also becomes 1.

4. If the (i, j) entry in the SSIM is O, then the (i, j) entry in the Initial Reachability Matrix (IRM) becomes 0 and the (j, i) also becomes 0.

The final reachability matrix (FRM) is obtained after checking for transitivity and removing transitivity if there is any, transitivity effects in IRM should be considered and it is to be removed. To remove the transitivity in table 2, we need to follow these steps

1. Look for the entry 0 in IRM.

2. Check for the transitivity e.g., if A leads to B is 1 and B leads to C is 1 this Implies A leads to C is 1

3. If there is any transitivity replace the 0 with 1*.

Level Partition

From the final reachability matrix reachability and antecedent set for each factor are found. The reachability set contains the element itself and other elements which it can have impact on other elements the antecedent set consist of the element itself and other factors that may impact it, therefore intersection of the set obtained in reachability set and antecedent set are derived. The factors for which the reachability set and intersection set are same occupy the top level of hierarchy in ISM model The top level factors in the hierarchy will not lead to any other parameter above its own level, once a level is identified its parameters are removed from the further consideration of other levels. Same process is repeated till the level of each and every parameter is identified, these levels help in building the diagraph and the ISM model

Conical Matrix

A conical matrix is been developed by clustering the factors of the same level across the rows and columns of the final reachability matrix. Conical matrix obtained shown in table 12 below

Development of Digraph

ISM is one of the important tool for the modeling and it need to be interpreted correctly and hence the successful implementation can be done by relevant authority. A binary digraph is obtained by examining the direct relationship among the factors affecting the IT/IS adoption in Indian SMEs. The relationships among the factors are shown with the help of arrow at their respective levels and hence the digraph or initial model is developed as per the hierarchy of different factors.

Development of ISM Based Model

Relationships among various factors were identified from the conical matrix which is obtained as per the levels of factors, the model will show how the required objective is achieved at various levels and the arrow at various factors indicating relevance at different levels, the levels that were identified were used in building the diagraph and later to build the final model of ISM.

ISM supplies a wide variety of added advantages like the procedure is systematic; the computer is programmed to take into consideration all attainable pair wise connections of system factors, either straight from the actions of the members or by transitive inference. The method is efficient; dependent upon the framework, the usage of transitive inference may decrease the multitude of the expected relational enquiries by certain extent, no familiarity with the primary procedure information about given participant in basic terms it must made sufficient knowledge of the entity structure to have the ability to improve with the sequence of relational inquires produced by the computer. It guides and reports the consequences group deliberations on challenging situations in a highly effective and taxonomical approach. It results in a planned model or graphical illustration of the chronology predicament circumstances that can be communicated more effectively to others. It is beneficial to the quality of multidisciplinary and interpersonal interactions throughout the framework of the predicament situation by concentrating response of the members on one specific question at a time. It promotes issue interpretation by allowing contributors to review the adequacy of a suggested list of structures factors or concern remark for lighting precise circumstances. It acts as a gaining knowledge of tool by compelling contributors to produce a more profound knowledge of what it actually means and sophistication associated with a selected variable list and interaction. It permits performance or policy interpretation by helping the members in figuring out specific areas for policy action that give many benefits or capitalize upon in seeking precise targets.

Micmac Analysis

Matriced' Impactscroises-multiplication applique and classment (cross impact matrix multiplication applied to classification) is abbreviated as MICMAC. The purpose of the MICMAC analysis is to assess the driving power and the dependence of the variables

Driving power and dependence of each benefit is shown in the final reachability matrix

It is carried out to obtain the key attributes that drive the system in a number of categories. In accordance to their drive power and dependence power, the variables, have been classified right into four categories i.e. autonomous measures, linkage measures, dependent and independent measures.

Autonomous Measures

These factors do have weak drive power and weak dependence power. They are relatively disconnected from the system, with which they have actually few links, which might be very strong.

Linkage Measures

These factors have strong drive power that is likely to be strong dependence power. These variables are unstable within the indisputable fact that any impact on these variables can have an impact on others as well as are sponsor result on their own.

Dependent Measures

These factors have weak drive power but strong dependence power.

Driver's Measures

These variables do have compelling drive power but weaker dependence power. A factor by using a very strong drive power, referred to as 'key factor' is categorized as class of independent or linkage factors.

However if policymakers tend to effectively influence majority of these supporting enhancements into modernization as well as swifter advancement, they ought to enhance the actual procedure to pay attention to, put into practice, and check endeavors'.

The procedure will certainly be a great deal much more useful, revolutionary, and extremely versatile if a lot more endeavors can incorporate unique models of public-private alliances and regional links. For in the India policy will almost certainly play a bigger task than technology in setting up the stride for a way technology advances. For the reason that the ability to access technological innovation is certainly not the bottleneck in many parts of the India, however generating the whole environmental circumstances for technology to do well continues to be a continuous mission, even in the greater amount of improved economies of the region. A top policy preference really should be to for techniques to promote SMEs to invest in technology and progressive business strategies, due to the reason that the bigger economical and sociable advantages could possibly be significant. Maintaining and Supporting Technology and Innovation boosting SMEs increase the ways technology may potentially stimulate innovative and a lot more highly effective business activities. The substantial level and number expenditures needed to bring up Indian SMEs technology and innovation overall performance implies decision makers will need to now explore new financing assistance methods to build infrastructure and technology opportunities. Each of these approaches, illustrating with highly competitive standards and private-sector involvement, will challenge standard receptions toward the state's role in the economy, but they hold the promise of unlocking much-needed new funding sources. Unique technologies eventually carry change, unsettling at times, as economies and firms adapt. This is especially true for many SMEs. However, all of this conservatism could become an ally to modernization if decision makers eliminate potential risk only by sharing best process supporting important information exchanges, and creating regional innovation ventures.

Observation

Lean manufacturing system implementation variables identification in Indian arc welding electrode manufacturing and establishing mutual relationship had been carried out by conducting brainstorming session with experts after circulating literature of lean manufacturing among the experts. In this session, the experts had identified 18 most important variables for the implementation of lean manufacturing and identification contextual relationship among these identified variables had been carried out. These identified variables have been listed in Table

Sr. No.	Lean Manufacturing System implementation Variables	Researchers
1	Quality of human resources	Yu Lin &Hui Ho (2008); Åhlström (1998); Womack, Jones &Roos (1990).
2	Production Planning & Control	Hayes & Wheelwright (1984); Skinner (1974); Poppendieck (2002); Heizer& Render (2006); Womack et al. (1990).
3	Part standardization to reduce complexity and excessive processing	Kasul & Motwani (1997); Liker (2004).
4	Plant Layout & Ergonomics	Walder, Karlin&Kerk (2007).
5	Collaborative decision making	Kasul&Motwani (1997); Ahuja (1996)
6	Proper utilization of floor space	Heragu (1997).
7	Minimization of defects	LEI (2003).
8	Customer involvement	Panizzolo (1998).
9	Improved quality of raw material	Nakamura, Sakakibara & Schroeder (1998); Forza (1996); Shah & Ward (2003); Taj (2008).
10	Reduction in unnecessary inventory	Liker (2004).
11	Top management commitment	Hamel &Prahald (1989)
12	Optimization of transportation and material handling cost	LEI (2003); Karlsson & Åhlström (1996); Womack et al. (1990).

A questionnaire based study had been carried out and respondents were asked to rank above variables on Likert scale of 1-5 (where 1 means "not important" and 5 means "most -important"). Fifty Six questionnaires were sent to respondents, out of them forty Eight questionnaires were received back and forty two questionnaires were considered for research work, whereas six questionnaires were discarded due to incompletion.

The mean, variance and rank on the basis of mean value have been shown in Table. Variable number eleven named as Top management commitment has been reported as "rank I" by the respondents. It is evident from Table that the variable number one (Quality of human resources) and variable number seven (Minimization of defects) have the maximum variance of the responses.

Variable	Mean	Standard Error Mean	Trimmed Mean	Standard Deviation	Variance	Rank Based on Mean
1	3.650	0.132	3.611	0.834	0.695	IX
2	3.950	0.113	3.994	0.714	0.510	III
3	3.775	0.098	3.750	0.619	0.384	VI
4	3.750	0.099	3.722	0.630	0.397	VII
5	3.625	0.106	3.583	0.667	0.446	XI
6	3.975	0.116	3.972	0.733	0.538	II
7	3.875	0.130	3.861	0.822	0.676	V
8	3.525	0.113	3.472	0.716	0.512	X
9	3.600	0.112	3.556	0.709	0.503	XII
10	3.950	0.129	3.944	0.815	0.614	IV
11	4.175	0.129	4.194	0.813	0.661	I
12	3.750	0.112	3.722	0.707	0.500	VIII

Structural Self-Interaction Matrix (SSIM) and Reachability Matrix

In the present research for identifying the contextual relationship among the variables of the lean manufacturing system implementation, three experts from academia and four experts from manufacturing industry, were consulted. These experts from the academia and from the industry were well conversant with lean manufacturing system implementation variables in Indian arc welding electrode manufacturing industry. Based on contextual relationship among the variables SSIM has been developed. Four symbols have been used to denote the direction of the relationship between the variables (i and j):

V- variable i will help to achieve variable j;

A- variable j will help to achieve variable i;

X- variable i and j will help to achieve each other; and

O- variable i and j are unrelated.

SSIM

variable	12	11	10	9	8	7	6	5	4	3	2	
1	V	A	V	V	X	V	V	X	V	V	V	
2	V	A	X	A	O	A	V	A	V	X		
3	V	A	V	A	A	A	V	A	V			
4	A	A	A	A	A	A	A	A				
5	V	A	V	V	X	V	V					
6	V	A	A	A	O	A						
7	V	A	V	A	A							
8	O	A	V	V								
9	V	A	V									
10	V	A										
11	V											
12												

Final IRM

variable	1	2	3	4	5	6	7	8	9	10	11	12	DP
1	1	1	1	1	1	1	1	1	1	1	0	1	11
2	0	1	1	1	0	1	0	1	0	1	0	1	7
3	0	1	1	1	0	1	0	1	0	1	0	1	7
4	0	0	0	1	0	0	0	0	0	0	0	0	1
5	1	1	1	1	1	1	1	1	1	1	0	1	11
6	0	0	0	1	0	1	0	0	0	0	0	1	3
7	0	1	1	1	0	1	1	0	0	1	0	1	7
8	1	1*	1	1	1	1*	1	1	1	1	0	1*	11
9	0	1	1	1	0	1	1	0	1	1	0	1	8
10	0	1	1*	1	0	1	0	0	0	1	0	1	6
11	1	1	1	1	1	1	1	1	1	1	1	1	12
12	0	0	0	1	0	0	0	0	0	0	0	1	2
DEP	4	9	9	12	4	10	6	6	5	9	1	11	

Level Partition

Variables	Reachability Set	Antecedent Cell	Intersection Cell	Level
1	1,2,3,4,5,6,7,8,9,10,12	1,5,8,11	1,5,8	
2	2,3,4,6,8,10,12	1,2,3,5,7,8,9,10,11	2,3,8,10	
3	2,3,4,5,8,10,12	1,2,3,5,7,8,9,10,11	2,3,5,8,10	
4	4	1,2,3,4,5,6,7,8,9,10,11,12	4	1
5	1,2,3,4,5,6,7,8,9,10,12	1,5,8,11	1,5,8	
6	4,6,12	1,2,3,5,6,7,8,9,10,11	6	
7	2,3,4,6,7,10,12	1,5,7,8,9,11	7	
8	1,2,3,4,5,6,7,8,9,10,12	1,2,3,5,8,11	1,2,3,5,8	
9	2,3,4,6,7,9,10,12	1,5,8,9,11	9	
10	2,3,4,6,10,12	1,2,3,4,5,7,8,9,10,11	2,3,4,10	
11	1,2,3,4,5,6,7,8,9,10,11,12	11	11	
12	4,12	1,2,3,5,6,7,8,9,10,11,12	4	

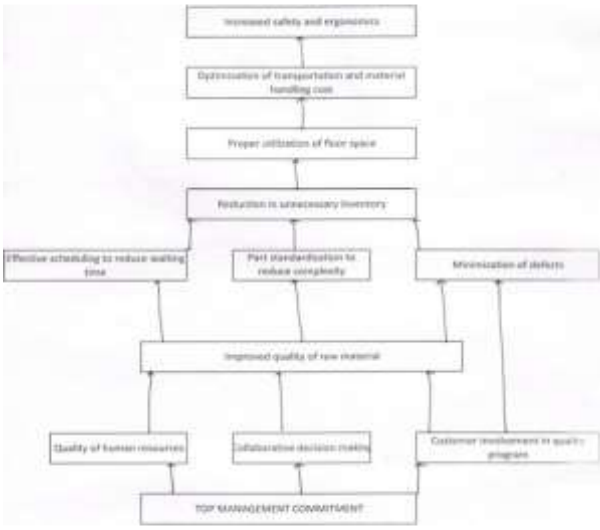
Partition of Variables Iteration -1

The reachability set and antecedent set (Warfield, 1974) for each variable have been found out from final reachability matrix. Subsequently, the intersection set of these sets have been derived for all variables. The variable for which the reachability set and the intersection set are the same has been given the top level variable in the ISM hierarchy. From Table, it has been seen that Relative cost benefits has been found at Level 1. The iteration has been continued till the level of each variable has been found out as shown in Table

VARIABLES	Reachability Set	Antecedent Cell	Intersection Cell	Level
1	1,2,3,4,5,6,7,8,9,10,12	1,5,8,11	1,5,8	VII
2	2,3,4,6,8,10,12	1,2,3,5,7,8,9,10,11	2,3,8,10	IV
3	2,3,4,5,8,10,12	1,2,3,5,7,8,9,10,11	2,3,5,8,10	IV
4	4	1,2,3,4,5,6,7,8,9,10,11,12	4	I
5	1,2,3,4,5,6,7,8,9,10,12	1,5,8,11	1,5,8	VII
6	4,6,12	1,2,3,5,6,7,8,9,10,11	6	III
7	2,3,4,6,7,10,12	1,5,7,8,9,11	7	V
8	1,2,3,4,5,6,7,8,9,10,12	1,2,3,5,8,11	1,2,3,5,8	V
9	2,3,4,6,7,9,10,12	1,5,8,9,11	9	VI
10	2,3,4,6,10,12	1,2,3,4,5,7,8,9,10,11	2,3,4,10	IV
11	1,2,3,4,5,6,7,8,9,10,11,12	11	11	VIII
12	4,12	1,2,3,5,6,7,8,9,10,11,12	4	II

Formation of ISM-Based Model

From the final reachability matrix, the structural model is generated known as diagraph. After removing the transitivity links and replacing the node numbers by statements, the ISM model is generated which has been shown in Figure No. 20. It has been observed from Figure that 'Top management commitment' has been very significant variable for lean manufacturing system implementation in the Indian arc welding electrode manufacturing industry as it comes at the base of the ISM hierarchy. 'Plant Layout and ergonomics has been identified as the top level variable in the model.



MICMAC Analysis

Matriced' Impact scroises - Multipication Applique´ Anlassment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC (Rajm Shankar &Suhaib, 2008). MIC MAC analysis is done with the help of driving power and dependence power. In table 6 the driving power and dependence of each variable have been also shown. These driving power and dependence calculations have been used in the MIC MAC analysis to classify these variables into four groups of autonomous, dependent, linkage, and independent (driver) variables. The driver power-dependence diagram has been constructed . The first cluster consists of the autonomous variables that have weak driver power and weak dependence. No variable has been identified as autonomous variable. Second cluster consists of the dependent variables that have weak driver power but strong. Dependence. Effective scheduling to reduce waiting time, Part standardization to reduce complexity and excessive processing, Reduction in unnecessary inventory, Proper utilization of floor space, Minimization of defects, Reduction in transportation and material handling cost, Increased safety and ergonomics, Value addition and Relative cost benefits have been identified as dependent variables. Third cluster has the linkage variables that have strong driver power and also strong dependence. No variable has been found out as linkage variable in our study. Fourth cluster includes the independent variables having strong driving power but weak dependence. Top management commitment, Quality of human resources, Collaborative decision making, Customer involvement in quality program, Capability and competence of sales network, Effective use of newer more efficient technology, Improved quality of raw material, Effective visual control and Appropriate quality of manufacturing facilities have been identified as the driver variables.

DISCUSSIONS

Lean Manufacturing System has been identified as an approach for improving performance of the processes and products. Eighteen factors to implement lean manufacturing in Indian automobile industry have been identified. Interpretive Structural Modeling (ISM) methodology has been used for finding contextual relationships among various variables to implement lean manufacturing in Indian automobile industry. A Model has been developed from ISM methodology. Nine variables have been identified as driver variables and nine as dependent variable. No variable has been identified as linkage variable and autonomous variable. Relative ost benefits has been identified as top level variables whereas Top management commitment as most important bottom level variable.

5.2 Conclusions

In the recent time many industries are implementing lean manufacturing to reduce/eliminating wastes. But, while implementing LM in the industries the faces many issues. In this research workers involvements, communication and improved material handling and housekeeping are the three factors which have high driving power and low dependent power. So work on these issues can lean to successful implementation of the lean manufacturing for the sustainable development.

Waste minimization and improving efficiency have been identified as key objectives of lean manufacturing system implementation. Literature review and subsequent discussions with experts have helped to sort the factor relevant to lean manufacturing system implementation based upon their importance. Questionnaire based survey has been carried out to rank these identified factor followed by structural modeling. Top management commitment has been ranked the most important factor as a result of survey analysis and also has been identified as the most important bottom level factor in ISM hierarchy. MICMAC analysis has been utilized to classify the factors.

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