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IDENTIFICATION OF THE KEYELEMENTS IMPACTING THE DESIGN AND EXECUTION OF LEAN MANUFACTURING SYSTEM BY ISM APPROACH

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ABSTRACT

Lean manufacturing is reflected as a quick developing manufacturing culture. The companies are facing cut throat competition and are accumulated to perform better than their competitors. Hence the organizations are growing at a faster pace, and change their position in this competitive world, which can be accomplished by adopting the new methodologies like lean. Management strategies and philosophies are always difficult and undefined because change is inevitable and the companies should adopt it as per the customer's requirement.

The lean manufacturing as the combination of instructions and a culture which managers through the guidelines in executions can achieve the profits. Implicitly, the two basic line of lean manufacturing, 'respect to the workforce' and 'waste elimination' is introduced and how these factors can cause an effective guidance during executions. In continue, it is described that how every companies use the benefits of lean tools in their conception with lean implementations, and what factors the managers include with culture and leaderships issues.

This is also helpful to understand mutual influences of barriers and to identify those barriers which hold up other barriers(driving barriers) and also those barriers which are most affected by other barriers(dependent barriers).The Interpretive Structural Modeling (ISM) methodology is used to develop mutual relationship among these barriers

I.   INTRODUCTION
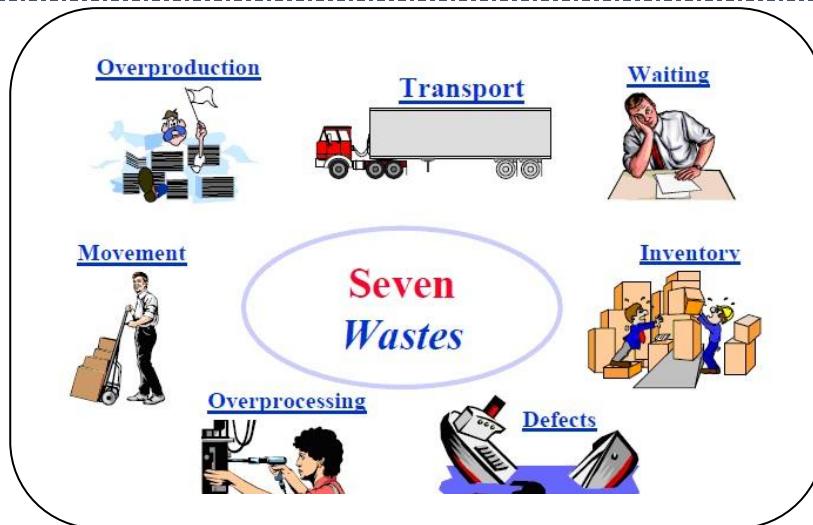
Definition of Lean Manufacturing
Lean Manufacturing, also called Lean Production, is a set of tools and methodologies that aims on the continuous removal of all waste in the production process. The main advantages of this are lower production costs, greater output and shorter production lead time. Lean Manufacturing Concepts

Research at the Lean Enterprise Research Centre (LERC) in the United Kingdom indicated that for a distinctive manufacturing company the ratio of activities could be broken down as follows:

Value-added activity   30%
Non value-added activity   40%
Necessary non value-added activity   30%
Total activities   100%
This implies that up to 40% of the activities at a distinctive manufacturing company could be eliminated.

Main Types of Wastes

The Barriers to effective implementation of Lean Manufacturing

- Management Support
- Finance
- Proper Information System
- Lack of Skilled Employees
- Product Variety
- Training
- Supplier Collaboration
- Customer feedback
- Handling the change process
- Just In Time Purchase
- Resistance to change
- Collaboration among function
- JIT Delivery
- Reducing WIP
- Lack of Time for changing
- No. of Suppliers
- Creating Multi-functional Team
- Cultural Problem

II. METHODOLOGY & MODEL DEVELOPMENT

ISM Methodology And Model Development

ISM methodology helps to execute order and direction on the complexity of relationships among elements of a system. It is interpretive as the judgement of the group decides whether and how the variables are related. It is structural as on the basis of relationship, an overall structure is extracted from the complex set of variables.It is a modeling technique as the specific relationships and overall structure are portrayed in a graphical model[34].

The various steps involved in the ISM technique are:

1. Identifying elements which are relevant to the problem or issues-this could be done by survey.
2. Establishing a contextual relationship between elements with respect to which pairs of elements would be examined.
3. Developing a structural self-interaction matrix (SSIM) of elements which indicates pair-wise relationship between elements of the system.
4. Developing a reachability matrix from the SSIM, and checking the matrix for transitivity – transitivity of the contextual relation is a basic assumption in ISM which states that if element A is related to B and B is related to C, then A is related to C.

5. Partitioning of the reachability matrix into different levels.
6. Based on the relationships given above in the reachability matrix, drawing a directed graph (digraph), and removing the transitive links.
7. Converting the resultant digraph into an ISM-based model by replacing element nodes with theStatements.
8. Reviewing the model to check for conceptual inconsistency and making the necessary modifications.

The various steps, which lead to the development of ISM model, are illustrated below.

Structural self-interaction matrix (SSIM)

No.	Barrier description	Barrier Number																
		18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	Management Support	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
2	Finance	V	V	V	V	V	X	V	X	V	V	V	V	V	V	V	V	
3	Proper Information System	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V		
4	Lack of skilled Employees	V	V	V	V	V	V	V	V	V	V	V	V	V	V			
5	Product Variety	X	X	V	V	V	V	V	X	X	V	A	V	V				
6	Training	V	V	X	V	V	X	V	V	X	V	V	X					
7	Supplier Collaboration	A	X	V	X	X	A	A	A	X	X	A						
8	Customer Feedback	X	V	V	X	X	A	X	V	X	X							
9	Handling the change process	A	A	V	A	V	V	A	A	X								
10	Just in time purchase	X	X	V	X	V	V	X	X									
11	Collaboration among functions	A	V	V	A	V	V	V										
12	Resistance to change	A	X	V	A	V	V											
13	JIT Delivery	A	V	V	A	O												
14	Reducing WIP	A	V	X	A													
15	Lack of Time for changing	X	V	X														
16	No. Of Suppliers	X	X															
17	Creating multifunctional team	X																
18	Cultural Problem	X																

Group of experts, from industries and the academics were consulted in identifying the nature of contextualrelationships among the barriers. For analyzing the barriers in developing

SSIM, the followingfour symbols have been used to denote the direction of relationship between barriers (i and j),

V - Barrier i will help to achieve barrier j.

A - Barrier j will help to achieve barrier i.

X - Barriers i and j will help to achieve each other.

O - Barriers i and j are unrelated.

Reachability matrix

The SSIM has been converted into a binary matrix, called the initial reachability matrix (see Tab. 3) by substituting V , A, X and O by 1 and 0 as per given case. The substitution of 1s and 0s are as per the following rules:

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

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

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

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

Since, there is no transitivity in this case; hence initial reachability matrix will be used for further calculations. The driving power and the dependence of each barrier are shown in. The driving power for each barrier is the total number of barriers (including itself), which it may help achieve. Dependence is the total number of barriers (including itself), which may help achieve it.[30]

No.	Barrier description	Barrier Number																		Driving
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	Management Support	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
2	Finance	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
3	Proper Information System	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
4	Lack of skilled Employees	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
5	Product Variety	0	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	13
6	Training	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	13
7	Supplier Collaboration	0	0	0	0	0	1	1	0	1	1	0	0	0	1	1	1	1	0	8
8	Customer Feedback	0	0	0	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	12
9	Handling the change process	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	1	0	0	7
10	Just in time purchase	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
11	Collaboration among functions	0	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	0	10
12	Resistance to change	0	0	0	0	0	0	1	1	1	1	0	1	1	1	0	1	1	0	9
13	JIT Delivery	0	1	0	0	0	1	1	1	0	0	0	0	1	0	0	1	1	0	7

14	Reducing WIP	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1	1	0	5
15	Lack of Time for changing	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	12
16	No. Of Suppliers	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	6
17	Creating multifunctional team	0	0	0	0	1	0	1	0	1	1	0	1	0	0	0	1	1	1	8
18	Cultural Problem	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	13
	Dependence Power	1	4	3	4	10	10	17	13	15	15	11	13	13	16	12	18	17	13	

Level partitions

From the final reachability matrix, the reachability and antecedent set for each barrier is found.The reachability set consists of the element itself and the other elements which it may help achieve, whereas the antecedent set consists of the element itself and the other elements which may help in achieving it.

N0.	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1	1	
2	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,11,13	2,11,13	
3	3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3	3	
4	4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4	4	
5	5,6,7,9, 10,11,12,13,14,15,16,17,18	1,2,3,4,5,8,10,11,17,18	5,10,11,17,18	
6	6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,5,6,7,10,13,16	6,7,13,16	
7	6,7,9,10, 14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,17,18	6,7,9,10,14,15,17	
8	5, 7,8,9,10,11,12, 14,15,16,17,18	1,2,3,4,6, 8,9,10, 12,13,14,15,18	8,9,10,12,14,15,18	
9	7,8,9,10,13,14,16	1,2,3,4,5,6,7,8,9,10,11,12,15,17,18	7,8,9,10	
10	5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,5,6,7,8,9,10,11,12,15,17,18	5,6,7,8,9,10,11,12,15,17,18	
11	5,7, 9,10,11,12,13,14,16,17	1,2,3,4,5,6,8,10,11,15,18	5,10,11	
12	7,8,9,10, 12,13,14,16,17	1,2,3,4,5,6,8, 10,11,12,15,17,18	8,10, 12,17	
13	2,6,7,8,13,16,17	1,2,3,4,5,6, 9,10,11,12,15,18	2,6	
14	7,8,14,16,17	1,2,3,4,5,6,7,8,9,10,11,12,14,15,16,18	7,8,14,16	

15	7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,5,6,7,8,10,15,16,18	7,8,10,15,16,18	
16	6, 14,15,16,17,18	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	6, 14,15,16,17,18	I
17	5,7,9,10,12,16,17,18	1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18	5,7,10,12,16,17,18	
18	5, 7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,5,6,8,10, 15,16,17,18	5,8,10, 15,16,17,18	

Artition of reachability matrix: first iteration

N0.	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,3,4,5,7,8,9,10,11,12,13	1	1	
2	2,3,4,5,,7,8,9,10,11,12,13	1,2,11,13	2,11,13	
3	3,4,5,7,8,9,10,11,12,13	1,2,3	3	
4	4,5,7,8,9,10,11,12,13	1,2,3,4	4	
5	5,7,9, 10,11,12,13	1,2,3,4,5,8,10,11	5,10,11	
6	7,8,9,10,11,12,13	1,2,3,4,5,7,10,13	7,13	
7	7,9,10,	1,2,3,4,5,7,8,9,10,11,12,13	7,9,10	II
8	5, 7,8,9,10,11,12	1,2,3,4, 8,9,10, 12,13	8,9,10,12	
9	7,8,9,10,13	1,2,3,4,5,7,8,9,10,11,12	7,8,9,10	
10	5,7,8,9,10,11,12,13	1,2,3,4,5,7,8,9,10,11,12	5,7,8,9,10,11,12	
11	5,7, 9,10,11,12,13	1,2,3,4,5,8,10,11	5,10,11	
12	7,8,9,10, 12,13	1,2,3,4,5,8, 10,11,12	8,10, 12	
13	2,7,8,13	1,2,3,4,5, 9,10,11,12	2	
14	7,8	1,2,3,4,5,7,8,9,10,11,12	7,8	

15	7,8,9,10,11,12,13	1,2,3,4,5,7,8,10	7,8,10	
17	5,7,9,10,12	1,2,3,4,5,7,8,10,11,12,13	5,7,10,12	
18	5, 7,8,9,10,11,12,13	1,2,3,4,5,8,10	5,8,10	

Second iteration

N0.	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,3,4,5,11,12,13	1	1	
2	2,3,4,5,11,12,13	1,2,11,13	2,11,13	
3	3,4,5,11,12,13	1,2,3	3	
4	4,5,11,12,13	1,2,3,4	4	
5	5,11,12,13	1,2,3,4,5,8,11	5,11	
6	11,12,13	1,2,3,4,5,13	13	
8	5,11,12	1,2,3,4, 8, 12,13	8,12	
9	13	1,2,3,4,5,8,11,12	8	
10	5,11,12,13	1,2,3,4,5,8,11,12	5,8,11,12	
11	5,11,12,13	1,2,3,4,5,8,11	5,11	
12	12,13	1,2,3,4,5,8, 11,12	8, 12	
13	2,8,13	1,2,3,4,5,11,12	2,6	
14	8	1,2,3,4,5,8,11,12	8	
15	8,11,12,13	1,2,3,4,5,8	8	
17	5,12	1,2,3,4,5,8,11,12,13	5,12	III
18	5,8,11,12,13	1,2,3,4,5,8	5,8	

Third iteration

N0.	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,3,4,11,13	1	1	
2	2,3,4,11,13	1,2,11,13	2,11,13	
3	3,4,11,13	1,2,3	3	
4	4,11,13	1,2,3,4	4	
5	11,13	1,2,3,4,8,11	11	IV
6	11,13	1,2,3,4,13	13	
8	11	1,2,3,4, 8,13	8	IV
9	13	1,2,3,4,8,11	8	IV
10	11,13	1,2,3,4,8,11	8,11	IV
11	11,13	1,2,3,4,8,11	11	IV
12	13	1,2,3,4,8, 11	8	IV
13	2,8,13	1,2,3,4,11	2,6	
14	8	1,2,3,4,8,11	8	IV
15	8,11,13	1,2,3,4,8	8	
18	8,11,13	1,2,3,4,8	8	

Fourth iteration

N0.	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,3,4,11,13	1	1	
2	2,3,4,11,13	1,2,11,13	2,11,13	
3	3,4,11,13	1,2,3	3	
4	4,11,13	1,2,3,4	4	
6	11,13	1,2,3,4,13	13	V
13	2,8,13	1,2,3,4,11	2	V
15	8,11,13	1,2,3,4,8	8	V
18	8,11,13	1,2,3,4,8	8	V

Fifth iteration

	Reachability Set	Antecedent Set	Intersection	Level
1	1,3,4,11	1	1	VIII
2	3,4,11	1,11	1,11	VII
3	3,4,11	1,3	3	VIII
4	4,11	1,3,4	4	VI

Sixth iteration

III.   RESULTS AND DISCUSSION

Discussion
The levels of barriers are significant in understanding the successful LEAN implementation. Management support and proper information system are the most important barriers due to their high driving power and low dependence among all the identified LEAN barriers. This can be validated by the previous surveys results. These barriers are positioned at the lowest level in the hierarchy of the ISM-based model. The barriers No. of suppliers and Supplier collaboration are at the highest level in the ISM-based model due to their high dependence power and low driving power. Those barriers which are at the fourth and fifth levels in the model with highest driving power are known as 'strategic barriers'. Autonomous barriers are weak drivers and weak dependents. These barriers do not affect the LEAN system. The absence of autonomous barriers in this study refers that all the identified barriers affects the process of successful knowledge management. Therefore, it is suggested that management should pay severe attention to all LEAN barriers.

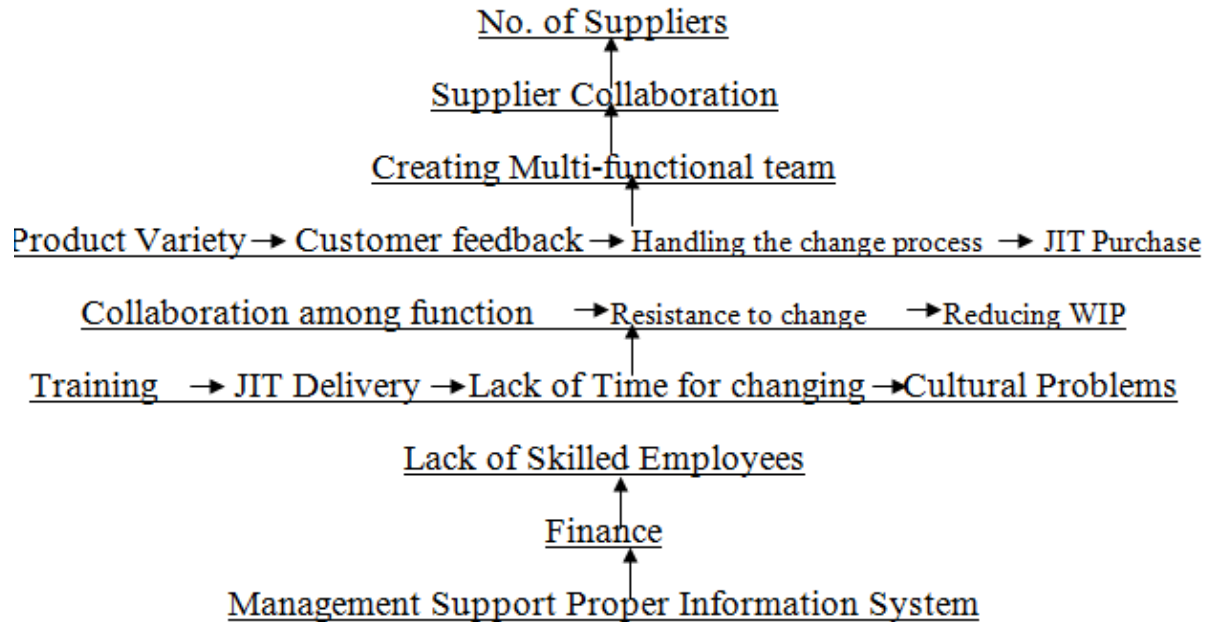**Formation of ISM digraph and model**
The structural model is generated from initial reach ability matrix. If there is a relationship between the barriers i and j, this is presented by an arrow which points from i to j. This graph is called as an initial directed graph, or initial digraph. After removing the transitivities - see step 4 of the ISM methodology the final digraph is formed . This final digraph is converted into the ISM-based model .

IV.   CONCLUSIONS & SUGGESTIONS FOR FUTURE WORK

Conclusion and future directions
The levels of barriers are significant in the Leanimplementation process. It can also be observed from Fig. 1 that four barriers, namely management support (barriers 1), Proper Information System (barriers 3), Finance (barriers 2) and Lack of skilled employees (barrier 4) have high driving power and less dependence power. Therefore, these barriers can be treated as key LEAN barriers. On the basis of above discussion, we can conclude that all the eighteenbarriers are important (although in varying degrees) for the purpose of successful implementation of LEAN system. Structural equation modeling (SEM), also referred to as linear structural relationship approach, has the potential of testing the validity of such hypothetical models. Thus, this approach can be applied in the future research to test the validity of this model. ISM is a tool which can be useful to generate an initial model whereas SEM has the potential of statistically testing an already developed theoretical model. Hence, it has been recommended that future research may be done to develop the initial model through ISM and then testing it using SEM. The manager should think about the different types of barriers and take

required action to remove those ,so that they should be properly executedand company should get profit from implementing lean.

No. of Suppliers

Supplier Collaboration

Creating Multi-functional team

Product Variety → Customer feedback → Handling the change process → JIT Purchase

Collaboration among function → Resistance to change → Reducing WIP

Training → JIT Delivery → Lack of Time for changing → Cultural Problems

Lack of Skilled Employees

Finance

Management Support Proper Information System

ISM based model

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