Implementation of Agile Manufacturing Technique in the Indian Engineering Industries using Interpretive Structural Modeling Approach

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Abstract **In the global manufacturing environment, Agile Manufacturing (AM) technique becomes the key source of advanced and flexible manufacturing systems. AM is a concept to improve competitiveness of the industries. AM can permit cost effective responses against unplanned products tailored to meet sudden change of customer desire. The principal objective of this paper is to identify and recognize the several Agile Manufacturing Implementation Techniques (AMITs) which may be the key enablers of its successful implementation in the Indian engineering industries. In this research, Interpretive Structural Modeling (ISM) technique has been applied to develop the hierarchy of identified AMITs according to their driving and dependence power. Once the AMITs are isolated by evaluating their effects with respect to driving powers, they can be implemented by framing suitable strategies in the industry one by one. In the present research work, Top management commitment, Employee participation and Forming virtual partnerships have been suggested as most driving enablers for the successful implementation of AM system in the Indian Engineering Industries.**

Keywords: **Agile manufacturing, Interpretive Structural Modeling, Driving power, Dependence Power.**

I. INTRODUCTION

In the Indian engineering industries, it is believed that agile manufacturing systems can permit maximum cost-effective responses against unpredictable and ever-changing product demand. Also, it can support rapid product launches for previously unplanned products tailored to meet sudden changing customer desires during production process [1]. In this paper AMITs have been explored as organizational key enablers to enhance successful implementation of AM systems in the production line of Indian engineering sectors. This research describes a decision model to implement AM system in different sectors in Indian scenario using an ISM approach. In this research, ISM model has been developed to obtain a hierarchy of the identified AMITs according to their driving power. Once managers get the hierarchy of the identified AMITs, they can make some strategies to overcome them according to their effectiveness. This paper is organized into five sections, including the introduction and literature to identify the AMITs. The third section presents the ISM model development. Fourth section explores the conclusions and result, while the fifth section presents managerial implications and scope for future research.

II. LITERATURE REVIEW OF AMITS

In the present competitive scenario of the business world, Indian engineering sectors are compelled to adopt unique strategies and technologies to enhance their product quality with respect to cost effectiveness as well as productivity by reducing product lead time. AM is primarily a business concept to make the presence of industries alive in the market competition. Its aim is to put the enterprises way out in front of our primary competitors. In AM system, primary aim is to combine organizational, individual and technological perspectives into an integrated and coordinated whole. AM can be defined as the capability of the industries to survive and thrive in a competitive environment against unpredictable change by reacting quickly and effectively to changing demands, driven by forecasting of customer-desire for the products and services [2].

In traditional manufacturing systems, the extended lead time causes delay in the goods delivery due to several wastages such as bottleneck time, waiting time, inventory, lack of strategy, financial secrecy and record inaccuracy etc. In Contrast to the traditional manufacturing strategy, the Am system concentrates on the customer enrichment, competitiveness through co-operation and this could be achieved by integration of the people, information and technology at a single platform. Enhancing the competitiveness among the competitors and built the cooperation from all the enterprises can influence the knowledge sharing and sharing of technological innovations and thus enhance the smooth and effective implementation of AM systems in the industry. AM system is dedicated to use of modern information and communication technology to form virtual enterprises, which commendably respond to the changing market demands. A virtual enterprise, different from a traditional enterprise, is constructed by different companies, who collaborate with each other to design and manufacture high quality and customized products [1,2].

Based on literature reviewed, fourteen AMITs have been identified as critical enablers of AM implementation in the Indian engineering industries listed in the table 1.

Table 1. Agile Manufacturing Implementation Strategies/Techniques

AMITs No.	Agile Manufacturing Implementation	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[2]
1.	Top Management	√	√	√	√	√	√		√
2.	Employee	√	√		√	√		√	√
3.	Forming virtual				√	√			√
4.	Product service life	√	√	√			√	√	√
5.	Value based pricing	√	√	√	√	√	√	√	
6.	Organizational	√	√	√	√	√	√	√	√
7.	Suitable organizational		√			√			√
8.	Regular feedback					√	√	√	
9.	Enriching the	√	√	√	√	√	√	√	√
10.	Use of latest IT	√		√			√	√	
11.	Reduced Non-Value	√	√			√			√
12.	Reconfigurable				√	√	√	√	√
13.	Cooperation that	√	√	√					√
14.	Valuing human				√	√	√		

Identification and recognition of the AMITs play an important role to enhance the productivity of engineering industries. To adopt AM environment, a significant change requires with respect to organizational polices, business processes, culture and employee participation. Therefore, top management commitment is essential to incorporate such changes [10]. The modification of enterprise is impossible without interest and involvement of employees. Therefore employee participation is the critical enabler for the successful implementation of AM systems in any industry [11]. Organizational and vendor co-operation are the imperative strategies of choice to bring agile products to market in minimum time by leveraging resources through virtual partnerships [3]. Lack of training of employees regarding use of IT system and processes obstruct the successful knowledge sharing in the engineering industries. [12] Has explained about unrealistic expectations of employees regarding the role of technology on which they are working. Generally, employees of the industries are not fully aware of the various applications of the technology because they confuse that what technology should do, can do, or cannot do [13]. Due to the lack of training, such unrealistic expectations occur in the engineering industries among the employees [14]. These also create reluctance to use the technology. Similarly other enablers of AM systems are explored by several authors with respect to different engineering sectors.

III. ISM METHODOLOGY AND MODEL DEVELOPMENT

Interpretive Structural Modeling was introduced by J. Warfield in 1974 to analyze the hierarchy of complex socioeconomic systems. The ISM methodology transforms unclear, poorly articulated models into visible, well-defined models useful for many purposes. It is a method for developing hierarchy of system variables to represent the model. ISM is an interpretive in that the judgment of the group decides whether and how the variables are related. It is structural because an overall structure is extracted from the complex set of variables on the basis of relationship. It is a modeling technique in that the specific relationships and overall structure are portrayed in a graphical model [15].

Many researchers have used the ISM methodology to impose order and direction on the complexity of relationships among variables of a system as shown in table 2.

Table 2. ISM as reported in the literature

Sl.	Researchers	Area in which ISM has been
1	Bolanos and	Strategic decision-making groups
2	Sahney et al. (2006) [17]	Interrelationships of design characteristics of a high-quality
3	Hasan et al. (2007)	Barriers to agile manufacturing
4	Kant and Singh	Knowledge Management
5	Lee et al. (2010)	Structural approach to design
6	Sharma et al. (2012) [20]	Knowledge Sharing Barriers : An integrated approach of ISM and
7	Sharma and Singh (2015) [12]	Modeling the knowledge sharing barriers: An ISM approach

Structural self-interaction matrix (SSIM)

ISM methodology suggests the use of expert opinions based on management techniques such as brainstorming or nominal group discussion in developing the contextual relationships among the AMITs. Groups of experts from industry as well as from academics have been consulted for identifying the nature of contextual relationships among the AMITs. These experts were well-acquainted with AM systems and its various implementation issues. A contextual relationship is selected for analyzing the AMITs. Keeping the contextual relationship for each AMIT in mind, the existence of a relationship between any two AMIT (*i* and *j*) and associated direction of the relationship is questioned; where 'i' is shown on the vertical axis and 'j' on horizontal axis. SSIM is developed as shown in table 3. Following four symbols have been used to denote the direction of relationship between AMIT (*i* and *j*) for the development of SSIM:

- V is used for the relation from AMIT i to AMIT j (i.e. if AMIT i supports to AMIT j).
- A is used for the relation from AMIT j to AMIT i (i.e. if AMIT j supports to AMIT i).
- X is used for the relation in both directions (i.e. if AMIT i and j support to each other).
- O is used for no relation between two AMIT (i.e. if AMIT i and j are unrelated).

Taking opinion of experts SSIM has been developed in which relationship between $AMIT_{i=1}$ and $AMIT_{j=4}$ is assigned as 'V' which indicates that the "Top management commitment" supports or drives to "Product service life assurance" [11]. Similarly, other relationships have been incorporated on the basis of brain storming sessions, industry feedback as well as literature reviewed. [10] Has explained the interdependencies of few enablers in the context of AM implementation. Therefore, relationships have been assigned by taking opinion of experts as well as from literature reviewed.

Table 3. Structural Self-Interaction Matrix (SSIM):

AMITs No.	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	V	V	V	V	V	V	V	V	V	V	V	X	X	X
2	V	V	V	V	V	V	V	V	V	V	V	X	X	
3	V	V	V	V	V	V	V	V	V	V	V	X		
4	O	O	V	A	A	O	X	V	O	O	X			
5	A	O	V	V	V	O	O	V	A	X				
6	X	V	V	V	V	V	V	V	X					
7	O	O	X	A	A	O	O	X						
8	O	A	V	O	O	A	X							
9	O	V	V	V	V	X								
10	A	V	V	X	X									
11	A	V	V	X										
12	A	A	X											
13	A	X												
14	X													

Development of the reachability matrix

In this step SSIM is converted into the initial reachability matrix by transforming the information of each cell of SSIM into binary digits (i.e. ones or zeros). This transformation as shown in (table 4) has been done with the following rules:

1. If the cell (i, j) is assigned with symbol 'V' in the SSIM, cell (i, j) entry becomes 1 and the cell (j, i) entry becomes 0 in the initial reachability matrix.
2. If the cell (i, j) is assigned with symbol 'A' in the SSIM, cell (i, j) entry becomes 0 and the cell (j, i) entry becomes 1 in the initial reachability matrix.
3. If the cell (i, j) is assigned with symbol 'X' in the SSIM, cell (i, j) entry becomes 1 and the cell (j, i) entry also becomes 1 in the initial reachability matrix.
4. If the cell (i, j) is assigned with symbol 'O' in the SSIM, cell (i, j) entry becomes 0 and the cell (j, i) entry also becomes 0 in the initial reachability matrix.

Table 4. Initial reachability matrix:

AMI	1	2	3	4	5	6	7	8	9	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	0	0	0	1	0	0	1	1	0	0	0	1	0	0
5	0	0	0	0	1	0	1	0	0	1	1	1	0	0
6	0	0	0	0	1	1	1	1	1	1	1	1	1	1
7	0	0	0	0	0	0	1	0	0	0	0	1	0	0
8	0	0	0	1	0	0	0	1	0	0	0	1	0	0
9	0	0	0	0	0	0	0	1	1	1	1	1	1	0
10	0	0	0	1	0	0	1	0	0	1	1	1	1	0
11	0	0	0	1	0	0	1	0	0	1	1	1	1	0
12	0	0	0	0	0	0	1	0	0	0	0	1	0	0
13	0	0	0	0	0	0	0	1	0	0	0	1	1	0
14	0	0	0	0	1	1	0	0	0	1	1	1	1	1

Table 5. Final reachability matrix:

AMITs No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Dri
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
4	0	0	0	1	0	0	1	1	0	0	0	1	0	0	
5	0	0	0	1*	1	0	1	0	0	1	1	1	1*	0	
6	0	0	0	1*	1	1	1	1	1	1	1	1	1	1	
7	0	0	0	0	0	0	1	0	0	0	0	1	0	0	
8	0	0	0	1	0	0	1*	1	0	0	0	1	0	0	
9	0	0	0	1*	0	0	1*	1	1	1	1	1	1	0	
10	0	0	0	1	0	0	1	1*	0	1	1	1	1	0	
11	0	0	0	1	0	0	1	1*	0	1	1	1	1	0	
12	0	0	0	0	0	0	1	0	0	0	0	1	0	0	
13	0	0	0	1*	0	0	1*	1	0	0	0	1	1	0	
14	0	0	0	1*	1	1	1*	1*	1*	1	1	1	1	1	
Dependence Power	**3**	**3**	**3**	**12**	**6**	**5**	**14**	**11**	**6**	**9**	**9**	**14**	**10**	**5**	

In addition, there is one basic concept which is essential to understand the ISM methodology termed as the concept of transitivity. Transitivity can be explained with the following example. As shown in figure 1, if element 'x' relates to element 'y' (i.e. xRy) and element 'y' relates to element 'z' (yRz), then transitivity implies element 'x' relates to element 'z' (xRz). Similarly, element 'x' relates to element 'w' (xRw) then element 'y' shall relate to element 'w' (yRw).

Transitivity is the basic assumption in ISM and is always used in this modeling approach [21]. Since, the ISM approach is based on expert opinion about these complex relationships, the literature only deals with the qualitative way to detect conceptual inconsistency. Thus, after imposing the transitivity relationships by 1* final reachability matrix has been developed as shown in table 5.

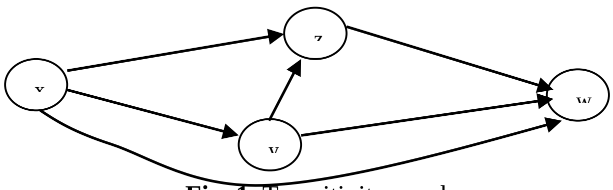

Fig. 1. Transitivity graph

Partitioning of the reachability matrix

Warfield (1974) has presented a series of partitions which are induced by the final reachability matrix on the relationships among different elements. From these partitions, one can identify many properties of the structural model [22]. Based on literature reviewed the reachability sets and antecedent sets for each AMIT have been obtained from the final reachability matrix. Reachability set consists of AMIT numbers with '1' and '1*' in the row of final reachability matrix and antecedent set consists of AMIT numbers with '1' and '1*' in the column of final reachability matrix for each AMIT. After finding the reachability set and antecedent set for each AMIT, the intersection for these sets is derived for all the AMITs and levels of different AMITs are determined. Intersection set consist of AMIT numbers common to both reachability and antecedent set. If reachability set and intersection set is common for any one or more AMIT, these AMITs will be allotted at the level of hierarchy. Once the top level is identified, it is removed from consideration and other level AMITs are obtained by the same process in the further iterations. This procedure is continued till all levels of the AMITs are identified. These identified levels and relationships in the final reachability matrix help in the development of digraph and the final ISM model. Top level AMIT is positioned at the top of digraph and so on.

In the present work, the fourteen AMITs have been identified. Reachability set, antecedent set, intersection set and levels have been tabulated with the help of final reachability matrix for all AMITs. Level identification process of these AMITs has been completed in twelve iterations for the partitioning of the final reachability matrix, which can be summarized as shown in table 6.

Table 6. Partitioning of the reachability matrix showing all iterations and levels of the AMITs:

AM	Reacha	Antecedent set	Interse	lev
1	1.2.3.6	1.2.3	1.2.3	**VI**
2	1,2,3,6	1,2,3	1,2,3	**VI**
3	1,2,3,6	1,2,3	1,2,3	**VI**
4	4,8	1,2,3,4,5,6,8,9,10,1	4,8	**II**
5	5	1,2,3,5,6,14	5	**V**
6	6,14	1,2,3,6,14	6,14	**VI**
7	7,12	1,2,3,4,5,6,7,8,9,10,	7,12	**I**
8	4,8	1,2,3,4,6,8,9,10,11,	4,8	**II**
9	9	1,2,3,6,9,14	9	**V**
10	10,11	1,2,3,5,6,9,10,11,14	10,11	**IV**
11	10,11	1,2,3,5,6,9,10,11,14	10,11	**IV**
12	7,12	1,2,3,4,5,6,7,8,9,10,	7,12	**I**
13	13	1,2,3,5,6,9,10,11,13	13	**III**
14	6,14	1,2,3,6,14	6,14	**VI**

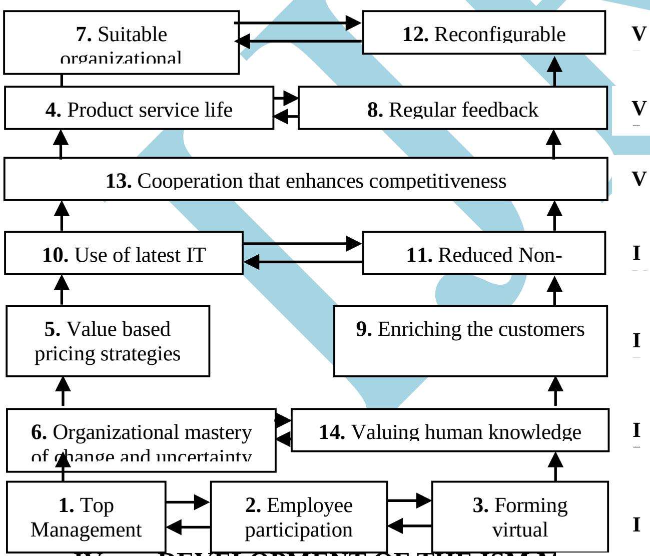

Fig.2. ISM model showing the levels of AMITs

IV. DEVELOPMENT OF THE ISM M

een AMITs. Considering these levels, an initial digraph including transitivity links can be obtained. In the initial diagraph, number of indirect and direct links depends on the relationships assigned by '1' or '1*' in the final reachability matrix which can be shown by large number of arrows. In the development of initial diagraph, the top level AMIT is positioned at the top of the digraph and second level AMIT is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph. Next, the digraph is converted into an ISM model by replacing nodes of the elements with relationship statements shown in final reachability matrix. After removing the indirect links, a final digraph (ISM model) has been developed as shown in figure 2. Rigid arrows indicate the direct relationships and dotted arrows indicate the indirect relationships imposed due to transitivity.

V. CONCLUSION AND RESULT

In this research, an attempt has been made to identify and recognize the AMITs for effective implementation of AM systems in the Indian engineering industries. In the globalization of business, AM system helps to the engineering industries for their survival and growth. The key finding of this research is that, Top management commitment, Employee participation and forming virtual partnerships may be suggested as significant enablers to implementation of AM systems at an organizational level in the engineering industries due to their maximum driving power evaluated by ISM model. Engineering industries should conduct seminars, work-shops, conferences, meets, to make their employees aware of Am system benefits. It is essential for the top management to formulate a better technology and knowledge sharing environment in the industry to maximize the effect of identified AMITs to make their employees more productive. Those AMITs possessing higher driving power in the ISM model and maximum effectiveness in ranking need to be addressed on a priority basis followed by others. This result provides assistance to the managers to take care of identified AMITs according to their effectiveness during implementation of AM systems in their industries.

VI. PRACTICAL IMPLICATIONS

This research has strong practical implications for both practitioners as well as academicians. The practitioners need to concentrate on identified AMIs carefully during AM practices in the engineering industries. On the other hand, researchers may be encouraged to identify and categorize more issues which are important in addressing AMITs. ISM model (Figure 2) identifies the hierarchy of actions to be taken by practitioners in order to maximize the effect of AMITs to enhance AM systems successfully in the engineering industries. Practitioners should concentrate on those AMITs which have higher driving power as well as maximum effectiveness because they are the root cause for other AMITs. Once managers identify AMITs, they will be able to formulate strategies for evolving their effects during AM practices in the engineering industries.

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