Quantization approach of driving enablers helping transition from Traditional to Flexible Manufacturing System

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Abstract - *The highly unstable condition of today's world market is forcing the managers in manufacturing sector to use Flexible Manufacturing Systems to withstand ever changing customer demand. There are some push forward factors known as "Enablers" (Driving/Driven***)** *which help in transition from Conventional Manufacturing System to Flexible Manufacturing System. In this project, our main focus is on Driving Enablers due to the fact that they are Primary ones and thereby more influencing variables. To express these Enablers as a number, that is, Quantization, we are using ISM (INTERPRETIVE STRUCTURE MODELLING) approach.*

Key Words**: Flexible manufacturing system; Enablers; Interpretive structural modelling; Traditional Manufacturing System.**

1.INTRODUCTION

Competitive international environment is forcing the companies to establish departments in different areas in order to maximize their profits such as Research and Development departments are situated in places where skilled human resources are easily available, production and manufacturing departments are established in areas close to the availability of lower material and labor costs(SOUTH EAST ASIA and CHINA).The tech giants such as Apple, HP and Nokia procure some or all of the items from other companies with highly specialized design/production skills or precise equipment. These are the so-called original equipment manufacturers or original design manufacturers, such as many of the electrical companies in Taiwan, and the outsource strategy can fit well within the firm's core competencies and assist in the manufacture of successful products. In order to integrate effectively such separated enterprise functions or outsourced operations into a single entity, enterprises need agile management, which must be flexible and able to respond rapidly, and have virtual operation capabilities [1].

The capricious condition of today's market is forcing the manufacturing managers to adapt the flexible manufacturing systems (FMS) to meet the challenges imposed by international competition, dynamic customer demands, lower lead time and advancement in technology There are certain enablers, which help in the implementation of FMS or in the transition process from traditional manufacturing systems to FMS. The need of hour is to analyze the behavior of these enablers for their effective utilization in the implementation of FMS. The main objective of this paper is to understand the mutual interaction of these enablers and identify the 'driving enablers' (i.e. which influence the other enablers) and the 'dependent enablers' (i.e. which are influenced by others). In the present work, these enablers have been identified through the literature, their ranking is done by a questionnaire-based survey and interpretive structural modelling (ISM) approach has been utilized in analyzing their mutual interaction. An ISM model has been prepared to identify some key enablers and their managerial effects in the implementation of FMS.

An FMS is an interconnected, computer-controlled complex system involving automated material handling devices and numerically controlled (NC) machine tools. It can simultaneously process medium-sized volumes of a variety of part types [1,2]. An FMS consists of not only computer numerical control (CNC) machine tools but it is integrated with material handling devices like robots and automatic guided vehicles (AGVs) and automatic storage and retrieval system (AS/RS). This new production technology has been designed to attain the efficiency of well-balanced machine paced transfer lines, while utilizing the flexibility that job shops have to simultaneously machine multiple parts. Consequently, the adoption of flexible automation is growing fast and millions of dollars are being invested by companies worldwide in FMS [2]. FMS ensures quality products at lower costs while maintaining a short lead-time. Usually, the system is designed in such a way that manual intervention and changeover time are kept to a minimum [4,5]. Firms adopt FMS as a means for meeting the mounting requirements of customized production [2]. A unique characteristic that distinguishes FMS from other factory automation technologies is the ability to achieve flexible automation, i.e. the capacity to efficiently produce a great variety of part types in variable quantities [3].

The main objectives of this paper are as follows:

- To identify the enablers in transition from conventional manufacturing system to flexible manufacturing system.
- To establish relationship among these enablers using ISM.
- To understand the quantization approach.

2. Identification of enablers for FMS

Transition to FMS on one hand seems to be difficult due to the presence of certain obstacles but industries are adopting it widely as some of the enablers simplify this process. The characteristics of FMS taking organization as the core target such as cultural strategy , size and structure & management experience co-ordinate among themselves to determine the tendency of the organization to adopt FMS [7]. Top management commitment is one of the important enablers of FMS. It is reflected through the 100% commitment by top management for the complete success of FMS. The development of capabilities to be flexible rests on the mandate of top management. Strategies adopted by top management reflect the tendency of the organization to adopt or not adopt the FMS.

Narain et al. (2004) have also suggested that availability of trained personnel, education, skill and motivation of employees and management, management's attitude towards technical changes and perceived risk are the key factors which facilitate the adoption of FMS. Management should have a clear vision about implementation of FMS and should prepare a long term plan for it, i.e. it should accept the real fact that the benefits of FMS do not start flowing immediately but can take some time. Noble (1990) suggests that the time horizon considered for cost justification should be at least eight to 10 years. Similarly, on the basis of their investigation carried out in Japanese industry, Huang and Sakurai (1990) have reported that the payback period ranges from two to seven years depending upon the type of specific project. FMS is a highly beneficial production technique which is well tested, so management should come forward to support its adoption.

It is true that heavy investment is needed for the implementation of FMS in any organization and not every firm can afford this type of investment. In developed countries this is not considered as a big problem but in developing countries like India, lack of funds is still considered as one of the major hurdles in the process of adaptation of FMS. No doubt, heavy funds may not be readily available with the firms but there are certain agencies and resources which can be proved as good financial enablers for such firms. FMS requires significant investment but the current policy of the government allows large amounts of capital to be raised through the open capital market. These enablers include:

- funds for FMS,
- loans from private agencies,
- financial help from government,
- land from Government at a reduced price,
- power facility from government at reduced price and low taxes

FMS comprises high end software and hardware and other equipment used in FMS is highly complicated, e.g. CNC machine tools, robots, AGVs and CMMs, etc. Similarly software used in the FMS environment is very complex. But these problems are solved without much difficulty if the people using FMS are well conversant with some modern manufacturing and control techniques such as:

- computer aided design (CAD),
- computer aided manufacturing (CAM),
- computer aided process planning (CAPP),
- computer aided quality control (CAQC),
- CNC machine tools, direct numerical control system (DNC),
- expert system local area networking (LAN),
- advance sensor technology,
- multi-tasking cutting tools,
- web-based tools and
- machine selection systems, etc.

Ethnographic attitude and physical work environment of the organization should also be changed side by side as the industries are moving forward rapidly to adopt FMS.

Table -1: Key enablers

S.NO.	Enablers for transition to FMS	Reference/Source
1	Top management commitment	Evans 1991, Belassi and Fadlalla 1998
2	Clear vision	Expert opinion
3	Effective long term planning	Huang and Sakurai 1990, Noble 1990
4	Team spirit and motivation	Narain et al. 2004
5	Availability of resources	Expert opinion
6	Availability of good vendors	Expert opinion
7	Drive out fear	Expert opinion
8	Work culture in the organization	Belassi and Fadlalla 1998
9	Effective methodologies like MRP, MAP, TOP, etc.	Theodorou and Florou 2008
10	Funds for FMS	Narain et al. 2004
11	Operational and control techniques	Bennett et al. 1992,Ethers and Lieb 1989 , Grieco et al. 2001, Bruccoleri et al. 2003
12	Availability of trained personnel	Ebers and Lieb 1989, Maffei and Meredith 1994, Cordero 1997, Narain et al. 2004
13	Automated production with robots	Kost and Zdanowicz 2005
14	Willingness of human resources to adopt FMS	Cardy and Krzystofiak 1991, Cordero 1997, Grieco et al. 2001
15	Automated production with AGVs	Rajotia et al. 1998, Shankar and Vrat 1999
16	Effective use of IT standards	Theodorou and Florou 2008
17	Availability of adequate space	Expert opinion
18	Availability of support from Government	Narain et al. 2004

3. Methodology

We generally used following methods:

1. **ISM**

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 This approach starts with the identification of key variables which are related to the issue. After finding out the relations among variables we develop a Structural Self Interaction Matrix (SSIM). After this SSIM is converted into Reachability Matrix (RM) and after applying the transitivity concept in Initial Reachability Matrix(IRM), we obtain Final Reachability Matrix(FRM). Then, the partitioning of the elements and an extraction of the structural model called ISM is derived. In this paper, key concept of ISM approach is discussed in detail. The important characteristics of ISM are as follows:

(a) This methodology is interpretive as the judgment of the group decides whether and how the different elements are related.
(b) It is structural on the basis of mutual relationship, an overall structure is extracted from the complex set of elements.
(c) It is a modelling technique, as the specific relationships and overall structure are portrayed in a digraph model.

(d) It helps to impose order and direction on the complexity of relationships among various elements of a system (Sage 1977).

It is primarily intended as a group learning process, but individuals can also use it.

In addition, there are two basic concepts which are essential to understand the ISM methodology. One is the concept of transitivity and the other is that of reachability. Transitivity can be explained with the following example. As shown in figure 1, if element i relates to element j (i.e. iRj) and element j relates to element k (jRk), then transitivity implies element i relates to element k (iRk). In the same fashion, it implies element i relates to element m (iRm) and element j relates to element m (jRm). Transitivity is the basic assumption in ISM and is always used in this modelling approach [7]. It also helps in maintaining the conceptual consistency. For example, in figure 1, if the relationship between element i and element k is missing due to conceptual inconsistency, with the help of transitivity rule just defined, one can modify the diagraph to incorporate this linkage. Similarly, in case of a situation as illustrated in figure 2, one can identify the conceptual inconsistency as element j leads to element k and element k leads to element i. In that case, element i leading to element j would be a conceptual inconsistency. The modeler can re-consult the expert if a situation of conceptual inconsistency is detected. 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.

The reachability concept is the building block of ISM methodology. Different identified elements are compared on a pair-wise basis with respect to their inter-relation. This information is represented in the form of binary matrix. If an element i reaches another element j, then entry in the cell (i, j) of the reachability matrix is 1 and if element i does not reach j, then entry in the cell (i, j) of the reachability matrix is 0. The property of transitivity also allows some of the cells of reachability matrix to be filled by inference (Watson, 1978). In terms of matrix entries (i, j) ¼ 1 and (j, k) ¼ 1 imply (i, k) ¼ 1. There is no need to make the specific comparison.

Between i and k since transitivity answers this comparison. However one must consider i and k and make the inferred entry (i, k). The reachability matrix will then consist of some entries from the pair-wise comparisons and some inferred entries, and one does not need to make all comparisons. The ISM process becomes more efficient because the use of transitive inference may reduce the number of the required relational queries by 50–80% [8].

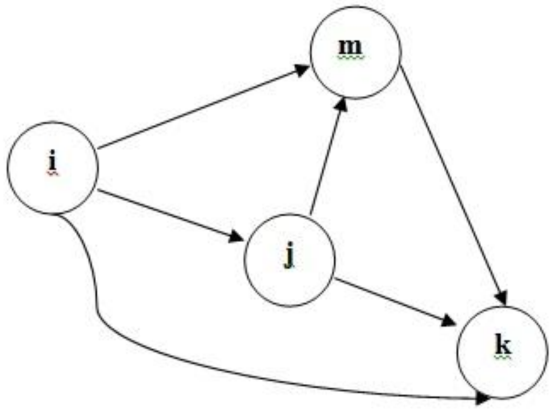


Fig -1: Transitive Graph

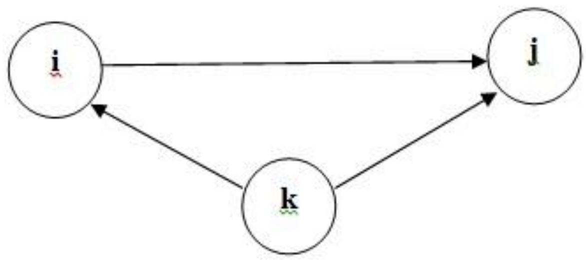


Fig -2: Intransitive Graph

The various steps involved in ISM technique are illustrated below:

Step 1: Key enablers are identified by a survey or group problem solving technique and then contextual relationship is established between these enablers.

After identifying and enlisting the 18 enablers through literature review and expert opinion, the next step is to analyze these enablers. The following four symbols have been used to denote the direction of the relationship between two enablers (i and j):

- V is used for the relation from enabler i to enabler j (i.e. if enabler I reaches enabler j).
- A is used for the relation from enabler j to enabler i (i.e. if enabler j reaches to enabler i).
- X is used for both direction relations (i.e. if enablers i and j reach to each other).
- O is used for no relation between two enablers (i.e. if enablers i and j are unrelated).

Step 2: A structural self-interaction matrix (SSIM) is developed for enablers as shown in Table 2. This matrix indicates the pair-wise relationship among enablers of the system. This matrix is checked for transitivity.

Table -2: Structural self-interactive matrix

ENABLERS	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	X
2	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
3	A	A	V	V	A	V	V	V	A	V	V	O	V	V	V		
4	O	O	O	O	A	O	O	O	O	O	A	O	O	O			
5	A	A	V	V	A	V	A	V	A	A	O	O	A				
6	O	O	A	V	O	V	O	V	A	X	O	O					
7	A	O	A	O	A	O	A	O	A	A	O						
8	O	O	V	A	V	A	V	A	O	A							
9	A	A	X	V	O	V	O	X	A								
10	A	V	V	V	O	V	V	V									
11	A	A	X	V	A	V	A										
12	O	O	V	O	O	O											
13	A	A	A	X	O												
14	O	O	V	V													
15	A	A	A														
16	A	V															
17	A																

Step 3: Development of the Initial reachability matrix (IRM)

This transformation has been done with the following rules:

1. If the cell (i, j) is assigned with symbol V in the SSIM, then, this 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, then, this 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, then, this 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, then, this cell (i, j) entry becomes 0 and the cell (j, i) entry also becomes 0 in the initial reachability matrix.

Table -3: IRM

ENABLERS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	1	1	1	1	0	1	1	0	1	1	1	0	1	1	0	0
4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	0	0	0	0	0	1	0	1	0	1	1	0	0
6	0	0	0	0	1	1	0	0	1	0	1	0	1	0	1	0	0	0
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0	1	0	0
9	0	0	0	0	1	1	1	1	1	0	1	0	1	0	1	1	0	0
10	0	0	1	0	1	1	1	0	1	1	1	1	1	0	1	1	1	0
11	0	0	0	0	0	0	0	1	1	0	1	0	1	0	1	1	0	0
12	0	0	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0	0
13	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0
14	0	0	1	1	1	0	1	0	0	0	1	0	0	1	1	1	0	0
15	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0
16	0	0	0	0	0	1	1	0	1	0	1	0	1	0	1	1	1	0
17	0	0	1	0	1	0	0	0	1	0	1	0	1	0	1	0	1	0
18	0	0	1	0	1	0	1	0	1	1	1	0	1	0	1	1	1	1

Step 4: Partitioning the reachability matrix

Once the reachability matrix has been created, it must be processed to extract the structural model.

Step 5: Development of Final Reachability Matrix (FRM)

After applying the transitivity approach in IRM, we develop FRM as shown in Table 4.

Table -4: FRM

ENABLERS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	1	1	1	0	1	0	1	0	1	1	1	0
6	0	0	0	0	1	1	1	1	1	0	1	0	1	0	1	1	0	0
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
8	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
9	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
10	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0

11	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
12	0	0	0	0	1	1	1	1	1	0	1	1	1	0	1	1	1	0
13	0	0	0	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0
14	0	0	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	0
15	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	0
16	0	0	1	0	1	1	1	1	1	0	1	0	1	0	1	1	1	0
17	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
18	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Step 6: Development of conical matrix

In the next step, a conical matrix is developed by clubbing together enablers in the same level, across rows and columns of the final reachability matrix, as shown in Table 5.

Step 7: Development of ISM model

An ISM model is developed as shown in the Figure 3.

Step 8 : Finally, the ISM model is checked for conceptual inconsistency and necessary modifications are incorporated.

Some Indian industries have already started using FMS. Though the numbers of such industries are very low at present, it is certain to grow in the near future. It has been found that most of the Indian industries which claim to use FMS are using only partial FMS. They are using CNC machines with partial manual and partial automatic material handling systems [8].

Table -5: Conical Matrix

ENABLERS	4	7	8	12	13	14	15	16	5	6	9	11	17	3	10	18	2	1	DRIVE POWER
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	**14**
12	0	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	**11**
13	1	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	**5**
14	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	**13**
15	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	**7**
16	0	1	1	0	1	0	1	1	1	1	1	1	1	1	0	0	0	0	**11**
5	0	1	1	0	1	0	1	1	1	1	1	1	1	0	0	0	0	0	**10**
6	0	1	1	0	1	0	1	1	1	1	1	1	0	0	0	0	0	0	**9**
9	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	**13**
11	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	**13**
17	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	**13**
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	**14**
10	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	**14**
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	**16**
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	**17**

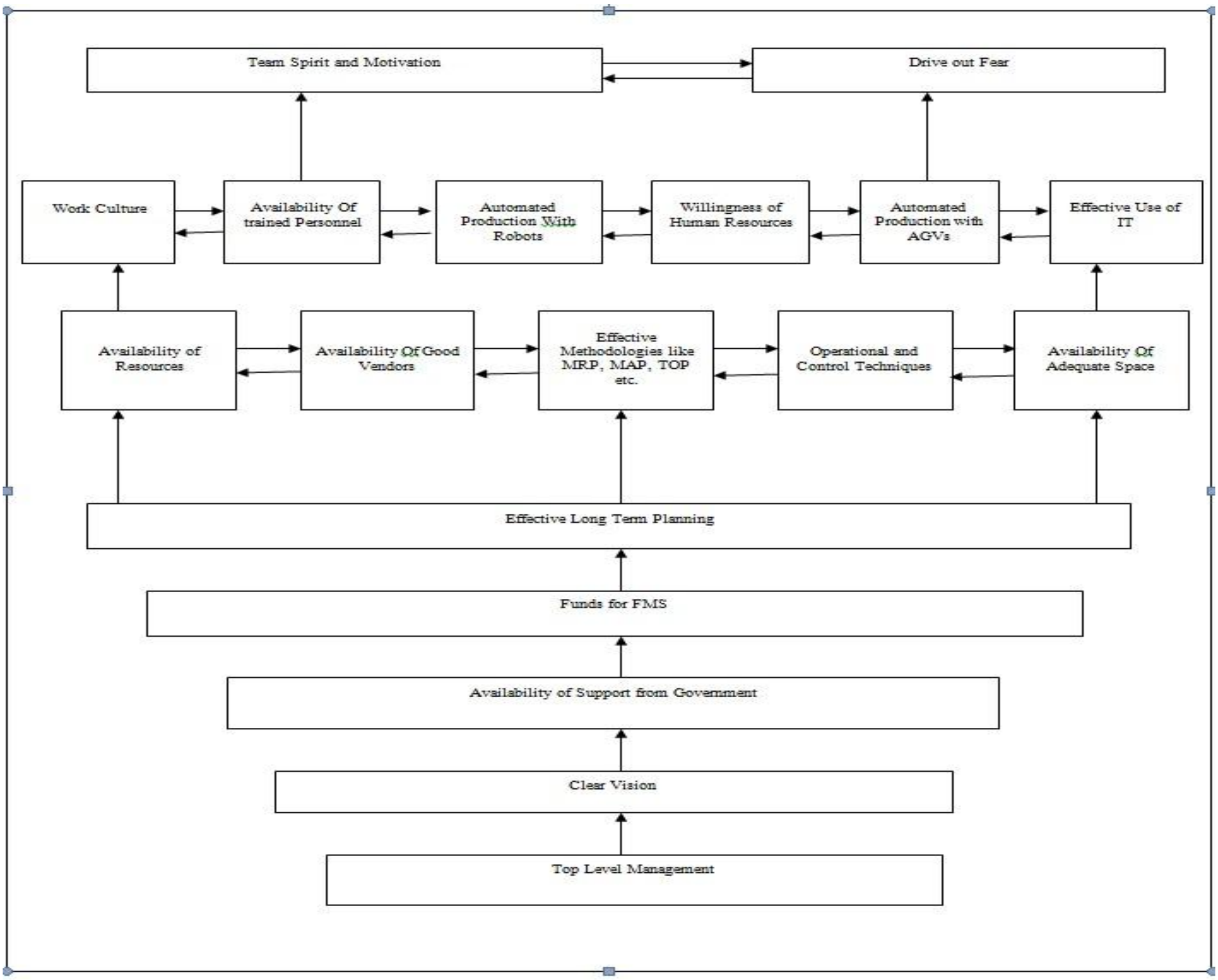
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**18**
DEPENDENCE POWER	**13**	**15**	**15**	**13**	**16**	**9**	**16**	**15**	**14**	**14**	**14**	**14**	**13**	**9**	**4**	**3**	**2**	**1**	

2. MICMAC ANALYSIS

Matrice d'Impacts croises-multipication applique´an classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The MICMAC principle is based on multiplication properties of matrices [7, 8]. The purpose of MICMAC analysis is to analyze the drive power and dependence power of enablers. This is done to identify the key enablers that drive the system in various categories. Based on their drive power and dependence power, the enablers, in the present case, have been classified into four categories as follows:

- Autonomous
- Linkage
- Independent
- Dependent

Fig -1: ISM model



4. Quantization Approach

In order to quantize the relationship between the enablers, Structural Equation Modelling (SEM) technique is used. Based on the past experiences three driving enablers are selected and SEM is applied on them. From the past research work , factors relating to these three enablers are found out which are shown in Table 8.

Table -6: Factors

ENABLERS	FACTORS	REFERENCES
CLEAR VISION	Employee Support	Expert Opinion
	Long Term Planning	Suhaib,M.,2008
	Proper Schedule	Zhang,D.Z.,2011
	Core Competency	Bernardo,1997
TOP LEVEL MANAGEMENT	Committee Credentials	Shankar,R.,2007
	Conceptual Skills	Zhou&Fan,2001
	Strategic Planning	Expert Opinion
	Organisational Goals	Expert Opinion
SUPPORT FROM GOVERNMENT	Good Governance	Narain et al. 2004
	Funding	Narain et al. 2004
	Trading Feasibility	Expert Opinion
	Energy Resources	Devadasan,2007

A theoretical framework is established between these factors using IBM AMOS. Figure 4 demonstrate the hypothesised relationship between clear vision, top level management and support from govenent. A questionnaire on these factors is developed on a 5 point Likert Scale , whose format is given below :

1 Strongly Disagree

2 Disagree

3 Neither agree nor disagree

4 Agree

5 Strongly agree

Developing questions that respondents can and will answer and that will yield the desired information is difficult. Two apparently similar ways of posing a question may be a challenge. Hence, this objective is a challenge. Second, a questionnaire must uplift, motivate and encourage the respondent to become involved in the interview, to cooperate and to complete the interview. In designing a questionnaire, the researcher should strive to minimize respondent fatigue, boredom, incompleteness and non-response. Third, a questionnaire should minimize response error which is defined as the error that arises when respondents give inaccurate answers or their answers are miss recorded or miss analyzed.

This questionnaire is then sent to different manufacturing industries who have successfully adopted the flexible manufacturing system. The number of questionnaires to be sent is calculated by the Cochran (1963) formula :

$$n_0 = \frac{Z^2 \times p \times q}{c^2}$$

where

Z value of confidence level at 95% (1.96) in normal distribution

c confidence interval (5% or 0.05)

p It is the probability that a particular observation will be selected in the sample, in the worst case it is 0.5 (50%), meaning every observation has an equal chance being selected in sample.

q $(1 - p)$.

By using this formula, the sample size comes out to be 384.16.

Now, for calculating the sample size according to a finite population, the formula used is:

$$n = \frac{n_0}{1 + \left(\frac{n_0 - 1}{N}\right)}$$

Where N is the number of manufacturing industries under study. After obtaining N, we can calculate the sample size, n (no of questionnaires to be sent).

After obtaining the response, following steps should be carried out:

- Step1 : SPSS analysis
- Step2 : AMOS analysis

5. SPSS Analysis

Responses to the questionnaire are then entered in SPSS software and the following analysis is then carried out :

1. Desciptive Statistics
   1.1. Mean
   1.2. Standard deviation
   1.3. Variance

2. Scale Reliability

3. Factor Loadings

4. Exploratory factor analysis
   4.1. KMO
   4.2. Eigen values
   4.3. Percentage of variance explained

5. Correlation

6. AMOS Analysis

In AMOS, hypothesised research model is constructed and the data file from SPSS is imported into AMOS. The path diagram is shown in Figure 5 resulting from the SEM analysis using AMOS. In order to establish the validity of the constructs, CFA is carried out using AMOS.

The model is then evaluated using various common goodness of fit measures, i.e., the ratio of chi-square (χ^2) statistics to the degree of freedom (df), normal fit index (NFI), comparative fit index(CFI), goodness of fit index (GFI), adjusted goodness-of-fit index (AGFI), and root mean square error of approximation (RMSEA).

AMOS determines the values of H1, H2 and H3.

The values of these unknown variables will suggest whether the model has a good fit or not.

7. Summary

By following the above mentioned approach, relation between top level management commitment, clear vision and availability of support from government can be quantized.

And this quantization in turn will provide information to the managers of industries that upon which enablers and to what extent they should emphasize in order to have an efficient and hassle free transition. The results of this study can help in the strategic and tactical decisions for a firm to move from a traditional manufacturing system to FMS. The main strategic decision relies on the commitment of top management for the adaptation of FMS. Once the top management commits itself it will help the company to implement the FMS and the firm can sample some strategic and tactical benefits such as: better competitive edge, development of engineering and management expertise, ability to introduce new products faster to the market, reduced set-up time, reduced work-in-process inventory, improved quality, improved response to demand variation, improved working conditions and improved ability to design or process change-over.

Sometimes manufacturing companies take quick decisions regarding the adaptation of new technologies just by following the production system reports of the competitors without taking into account their own capabilities or limitations. In such cases, new technologies, especially FMS, prove to be suicidal decisions. It is essential that the interested companies must do the introspection before jumping into the FMS environment. They must find out key enablers for the adoption of FMS.

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