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MODELLING OF WORLD CLASS MANUFACTURING ENABLERS FOR INDIAN MANUFACTURING ORGANISATIONS –AN ISM APPROACH

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Abstract

The aim of this article is to analyse the enablers that lead to the successful implementation of World Class Manufacturing practices (WCM). For understanding the contextual relationship among the WCM enablersInterpretive Structural Modelling (ISM) approach has been used in this article. Identification of WCM enablers have been through the literature review and expert's opinion from industry.A total 79 WCM enablers have been identified and then divided into nine groups of enablers. ISM has been applied on these nine groups of enablers for development of a hierarchical structure for analyzingthe interactions among the enablers.

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1. Introduction

With the elimination of trade obstructions and increasing competition among firms at the global level has put the manufacturing organisations under heavy pressure to evaluate their old manufacturing practices. Today, these manufacturing organisations are being motivated to adopt the developing world-class manufacturing (WCM) practices that set apart them from, and offer them with asuperiority over, the ordinarymanufacturing organisations. Till now, Indianmanufacturing industry has not performedsatisfactory against the voilent competitive tacticsimplemented by their global competitiors.Today; the task for the Indian manufacturing organisationsis updating their manufacturing activities for being competitive in the global environment. For standing in this competitive global environment, the Indian manufacturing organisations need to understand the enablers that play a vital role in the implementation of WCM practices and their effects on calculatedindustrygoals. This study gives anoutline for understanding the relative importance of enablers that play a vital role in effectiveimplementation of WCM practices. The interactions of enablers for WCM are inspected, and modelling methodology is used for ranking the WCM enablers.Interpretive structural modelling(ISM) has been used for understanding the contextual interactions among the WCM enablers and finding theimportant enablers that expedite the adoption of WCM practices.

2. Literature Review

2.1World Class Manufacturing

Hayes and Wheelwright [1] introduced the word WCM. According to Schonberger [2], the word WCM kindly holds the breadth and the spirit of the major modifications taking place in industrial organisations.This indicates that the manufacturing organisations must observe the effectiveness of their manufacturing approaches for gaining the tag of a world-class manufacturer. Manufacturing organisations involved in WCM practices focus on the improvement of operations, waste elemenation, management of customer relationships and creation of leanorganisations.This leads to higher productivity and profitability. 'Continuous and quick change' is main aim of WCM [2]. WCM is known as collection of thoughts, procedures and theories, which setup benchmarks for construction and production for other firms to watch over [3]. WCM representsvarious systems and innovations proposedfor empowering an organization for competing against its best rivals [4].World Class Manufacturers are those manufacturers who initiallyimprove world class maintenance system by incorporation of total productive maintenance, six-sigma and lean tools and techniques [5]. The point of world class manufacturing is to achieve worldwide power by taking on the diverse standards, for example, "no waste", "no stock", "no disappointment", "no imperfection"[6].Identified WCM enablers and their groupig is as follows:

E1:Focus on 'Competitive Quality

1. Needs of customers [7], [17-18], [26], [28-29]
2. Total quality control [3], [7], [18], [20], [23], [28-29]
3. Intelligent manufacturing [7], [23]
4. Total quality management [7], [12], [16], [19], [23], [25]
5. Kaizen [8], [13-16], [24]
6. Kaizen blitz [8], [14], [29]
7. Kaikeku [8], [14], [29]
8. Focused Improvement [9], [14-15], [26], [29]
9. Strategic flexibility [11]
10. Improvement cuture [14], [28]
11. Top Management Commitment [3], [14], [16-18]
12. Process Quality Management [17]
13. Six Sigma [12], [16], [19]

E2: Implementation of Lean manufacturing System

14. Just In Time Production [3], [7], [21], [23], [25]
15. Just In Time Purchasing [3], [7], [23]
16. Kanban[7], [15], [23]
17. Logistic management
18. Optimised production technology [7]
19. 5S [3], [15], [19]
20. Lean six sigma [10]
21. MUDA [13]
22. MURI Analysis [15]
23. Mura Analysis [15]

24. Single Minute Exchange of Dies [3], [15]

E3: Total Productive Maintainence

25 Autonomous and professional maintenance [8], [15], [26]

26 Early Equipment Maintenance [15], [26], [29]

27 Early Product Management [15], [29]

28 AM Tag [15], [29]

29 WO tag [15], [29]

30 PM tag [15], [29]

31 Maintenance cycles [15], [29]

32 Control cycles [15], [29]

33 Poke yoke [3], [15-16]

34 Standard Operating Procedure [14]

E4: Cost Efficiency

35 Cost deployment [9], [15], [26]

36 Electronic Data Interchange [7], [23]

37 Simultaneous Cngineering[7], [23]

38 Reduced Operating Costs [7] , [29]

39 Manufacturing Resource Planning [7], [21], [23]

40 Business Process Re-engineering [7], [13], [23]

41 Material Requirement Planning [7], [23]

E5:Customer Focus

42 Response of customers [7], [29]

43 Logistics and Customer services [9], [15], [19], [28]

44 Customer management [14], [16], [21]

E6:Company Policies

45 Global Issues [7], [15-16], [26]

46 Local Competitiveness [7], [29]

47 Improving the range and quality of services [7], [29]

48 Take advantage of being an early adopter [7], [29]

49 Avoiding losing market share to competitors who are already implementing [7], [29]

50 New Opportunities [7], [29]

51 Time to Market [7], [18], [29]

52 Electronic Commerce [7], [23]

53 Enterprise Resource Planning [7], [23]

54 Supply Chain Management [7], [14], [17], [23], [28]

55 Safety [9], [15], [26], [28]

56 Energy [15]

57 Supplier Relationship Management [17], [19], [21]

E7: Human Resources

58 Quality circles [7], [23]

59 People Development Programs [9], [14-15], [26], [28]

60 Employee Involvement [14], [17]

61 Team Work [14], [17]

62 Quality Culture [14], [17]

E8 Manufacturing Practices

63 Flexible manufacturing system [7], [16], [21], [23]

64 Computer Aided Design [7], [21], [23]

65 Computer Aided Manufacturing [7], [21], [23]

66 Computer Integrated Manufacturing [7], [21], [23]

67 Group Technology [7]

68 Agile Manufacturing [19], [21], [27]

E9. Quality Tools

69 Statistical Process Control [3]

70 x-Matrix [15]

71 Material matrix [15]

72 QA Matrix [15]

73 QA network [15]

74 Inspection cycles [15]

75 5W+IH [15]

76 4M [15]

77 5G [15]

78 Shop Floor Management [14]

79 Benchmarking [7], [14], [19], [21], [23]

2.2 Interpretive Structural Modelling

In order to obtain an optimal solution researchers are facing many problems which need to be resolved. These difficulties mostly arise because of the higher complexity level which is observed because of existence of a large number of factors and relationships among these factors [30]. These factors affects directly or indirectly to system having complex structure. Different methodologies have been used for achieving this goal, one of them is ISM. ISM technique was developed by Warfield [31] and Sage [32] and it is a variation of paired-comparison methods. Interpretive Structural Modeling is anapproach in which a collection of elements which have different and direct relationship arestructured into a systematic model. The basic theory behind this is to use practical experience and knowledge of experts to develop the hierarchy of the complex system. The method is called interpretive because in this the judgment of a group takes decision whether and how variables are related to each other; it is structural in a manner that on the basis of the developed relationship among the variables, an overall structure is prepared from a complex set of variables; and it is modeling because the relationship among variables and overall structure are displayed in a diagraph model [32]. It is a suitable modeling technique for predicting the effect of one variable of the system on the other variables. With the help of ISM researchers and managers can gain a deep understanding of the relationship among key variables for a particular problem.

ISM methodology have been applied in various fields over the past few years but have not been applied yet for modelling of WCM enablers for Indian manufacturing organisations different areas in which ISM have been applied in recent years have been shown in the Table 1.

Table 1. Application of ISM in different fields

S.NO.	Author	Research Field
1.	Kumar et al.[33]	Barriers in green lean six sigma product development process
2.	Mannan et al.[34]	Integrating sustainability with innovation for Indian small- and medium-scale manufacturing enterprises
3.	Raut et al.[35]	Implementation of sustainable Supply Chain Management in context of oil and gas industries
4.	Sindhwaniand Malhotra [36]	Agile manufacturing system
5.	Jain et al. [37]	TPM implementation in Indian SMEs
6.	Jawahar and Garg [38]	Improving logistic service in India
7.	Ali et al.[39]	Barriers to reverse logistics in the computer supply chain

3. Research Methodology

79 WCM enablers have been identified through the literature review and validated with the help of a survey conducted in the industries. After validation of enablers these have been divided into nine groups E1,E2,E3,E4,E5,E6,E7,E8,E9. For understanding the contextual relationship of groups of enablers ISM approach have been applied.

4. APPLICATION OF ISM ON WCM ENABLERS

For application of ISM on WCM enablers WCM enablers have been categorized into 9 groups which are as follows:

1. Focus on Competitive Quality (E1)
2. Implementation of Lean manufacturing system (E2)
3. Total Productive Maintenance (E3)
4. Cost Efficiency (E4)
5. Customer Focus (E5)

6. Company Policies (E6)
7. Human Resources (E7)
8. Manufacturing Practices (E8)
9. Quality Tools (E9)

After the categorization of the WCM enablers ISM technique have been applied for development of the model. The flow chart for the development of the ISM model for WCM enablers have been shown in Figure 1.

Step1: SSIM (Structural self-interaction matrix)

For development of the SSIM, expert's views are used for defining contextual relationship among variables. The entire list of WCM enablers from literature review was presented to industry experts and academicians. Following four symbols and SSIM developed is shown in Table no. 2.

- V: enabler j will be attained with the assistance of enabler i
- A: enabler i will be attained with the assistance of enabler j
- X: enabler i and j will be attained with the assistanceof each other,
- O: enabler i and j are unrelated.

Step 2: Development of Reachability Matrix

Now the SSIM is converted into the binary matrix form known as Reachability Matrix. In this the V, A, X, O symbols in SSIM are replaced by 0 and 1. Following are the rules for replacing the V, A, X and O for obtaining Initial reachability Matrix and initial reachability matrix have been shown into Table 3.

- In the SSIM , if entry in (i, j) is V, then in the reachability matrix ; (i, j) entry is replaced by 1 and the (j, i) entry is replaced by 0;
- In the SSIM , if entry in the (i, j) is A, then in the reachability matrix; the (i, j) entry is replaced by 0 and the (j, i) entry is replaced by 1;
- In the SSIM, if entry in the (i, j) is X, then in the reachability matrix the (i, j) entry is replaced by 1 and the (j, i) entry is also replaced by 1;
- In the SSIM, if entry in the (i, j) is O, then in the reachability matrix (i, j) entry is replaced by 0 and the (j, i) entry is also replaced by 0.

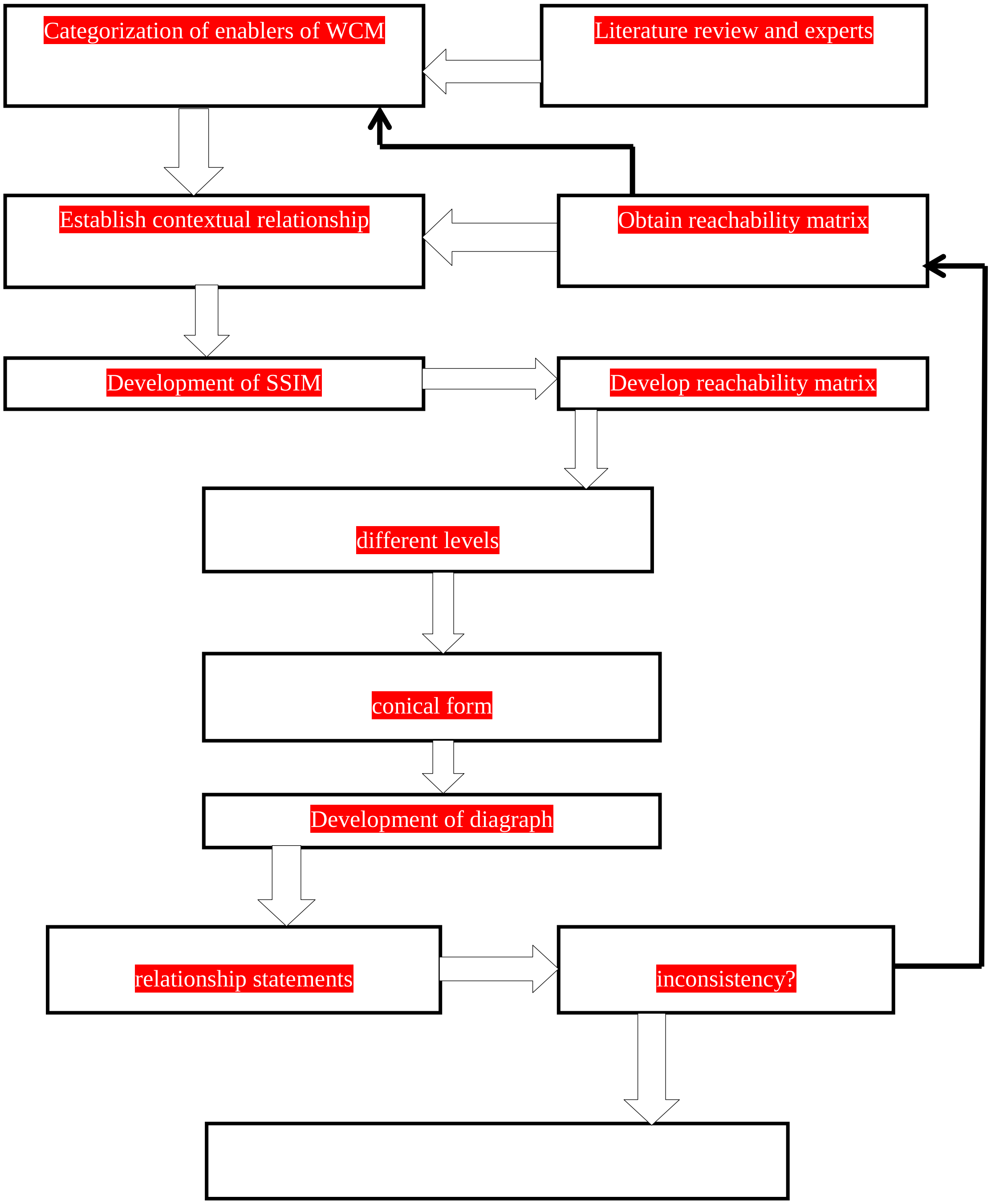

Figure 1. Flow Chart for ISM modelling process for WCM enablers (modified from Raut et al. [35])

Table 2.Structural Self Interaction Matrix

Enablers	E2	E3	E4	E5	E6	E7	E8	E9
E1	V	V	O	A	V	V	V	A
E2		V	V	O	O	O	A	A
E3			O	O	O	O	V	O
E4				O	V	V	A	A
E5					V	V	V	A
E6						A	O	O
E7							V	V
E8								O

STEP 3: Final Reachability Matrix

Now the final reachability matrix is obtained by incorporating the concept of transitivity. Transitivity concept is defined as: If A=B and B=C then from the concept of transitivity A=C and the places where transitivity have been incorporated have been marked with 1* final reachability matrix has been shown in Table 4.

Table 3. Initial Reachability Matrix

Enablers	E1	E2	E3	E4	E5	E6	E7	E8	E9
E1	1	1	1	0	0	1	1	1	0
E2	0	1	1	1	0	0	0	0	0
E3	0	0	1	0	0	0	0	0	0
E4	0	0	0	1	0	1	1	0	0
E5	1	0	0	0	1	1	1	1	0
E6	0	0	0	0	0	1	0	0	0
E7	0	0	0	0	0	1	1	1	1
E8	0	1	1	1	0	0	0	1	0
E9	1	1	1	1	1	0	0	1	1

Table 4. Final Reachability Matrix

Enablers	E1	E2	E3	E4	E5	E6	E7	E8	E9
E1	1	1	1	1*	1*	1	1	1	1*
E2	0	1	1	1	0	1*	1*	0	0
E3	0	0	1	0	0	0	0	0	0
E4	0	0	0	1	0	1	1	1*	1*
E5	1	1*	1*	1*	1	1	1	1	1*
E6	0	0	0	0	0	1	0	0	0
E7	1*	1*	1*	1*	1*	1	1	1	1
E8	0	1	1	1	0	1*	1*	1	1
E9	1	1	1	1	1	1*	1*	1	1*

Step 4: Level Partition

With the help of the final reachability matrix the antecedent set and the reachability for each group of WCM enablers are obtained. The reachability set comprises of the individual WCM enabler itself and the enablers which it may help to attain. The horizontal factors of final reachability matrix are the reachability set. While the antecedent set consist of the WCM enablers themselves and the other enablers, which may help in achieving it. Antecedent set is comprises of vertical factors of final reachability matrix. After this the intersection of antecedent and reachability set is obtained for each factor. The top-level element in the ISM hierarchy is the element for which identical reachability and intersection sets exixts. The top-level element of the hierarchy would not lead any other element above their own. After, the top-level element is attained; it is separated out from the other elements. Then the same process is repeated for finding the, the next level of elements. With help of these identified levels diagraph and final model are built. Then this iteration is repeated till the levels of each factor are obtained. Now, with identified levels the final model of ISM is obtained. Here 5 iterations have been performed and end result of level partition is shown in Table 5.

Step 5: Development of Conical Matrix

By putting together all enablers on the same level, in rows and columns of the final reachability matrix a conical matrix is established, as shown in Table 6. Conical Matrix helps in finding the driving and dependence power of the all WCM enablers. Driving power of an enabler means that how much enablers that particular enabler is driving and dependence power of an enabler depicts the no of enablers which are driving that particular enabler to achieve the end goal. The conical matrix has been shown in Table 6.

Table 5. Level of Enablers for ISM model

Enablers	Reachability Set	Antecedent Set	Intersection Set	Level
E1	E1,E2,E3,E4,E5,E6,E7,E8, E9	E1,E5,E7,E9	E1,E5,E7,E9	V
E2	E2,E3,E4,E6,E7	E1,E2,E5,E7,E8,E9	E2,E7	III
E3	E3	E1,E2,E3,E5,E7,E8,E9	E3	I
E4	E4,E6,E7,E8,E9	E1,E2,E4,E5,E7,E8,E9	E4,E7,E8,E9	II
E5	E1,E2,E3,E4,E5,E6,E7,E8, E9	E1,E5,E7,E9	E1,E5,E7,E9	IV
E6	E6	E1,E2,E4,E5,E6,E7,E8, E9	E6	I
E7	E1,E2,E3,E4,E5,E6,E7,E8, E9	E1,E2,E4,E5,E7,E8,E9	E1,E2,E4,E5,E7,E8, E9	II
E8	E2,E3,E4,E6,E7,E8,E9	E1,E4,E5,E7,E8,E9	E4,E7,E8,E9	IV
E9	E1,E2,E3,E4,E5,E6,E7,E8, E9,	E1,E4,E5,E7,E8,E9	E1,E4,E5,E7,E8,E9	IV

Table 6. Conical Matrix

Enablers	E3	E6	E4	E7	E2	E5	E8	E9	E1	Driving Power
E3	1	0	0	0	0	0	0	0	0	1
E6	0	1	0	0	0	0	0	0	0	1
E4	0	1	1	1	0	0	1	1	0	5
E7	1	1	1	1	1	1	1	1	1	9
E2	1	1	1	1	1	0	0	0	0	5

E5	1	1	1	1	1	1	1	1	1	9
E8	1	1	1	1	1	1	1	1	0	8
E9	1	1	1	1	1	1	1	1	1	9
E1	1	1	1	1	1	1	1	1	1	9
Dependence Power	7	8	7	7	6	5	6	6	4	

Step 6: Development of Diagraph

In this process the top position of the diagraph is acquired by top level enabler and second position is acquired by second level enablers and this process is continued until all enablers acquires their positions. The diagram developed for WCM implementation has been shown in Figure 2.

Step 7: Formation of the ISM model

In the next step the developed diagraph is converted into an ISM model by replacement of nodes of the elements with factors. The ISM model for WCM implementation has been shown in Figure 3.

5. MICMAC ANALYSIS

For analysis of the driving and dependence power of the enablers MICMAC analysis is performed. On the basis of the driving and dependence power of the enablers these have been divided into four clusters.

- **Autonomous enablers:** Enablers having weak drive power and weak dependence power are autonomous enablers. These have very little impact on the system, so are relatively disconnected from the system. Here in WCM model there no autonomous enabler is present. These enablers have been shown in quadrant I.
- **Dependent enablers:** Enablers having weak drive and dependence power come under this category. These include TPM, implementation of lean manufacturing system, cost efficiency and company policies. These enablers are present in 2nd quadrant in Figure 4.
- **Linkage enablers:** Enablers which have strong driving and dependence power comes under this category. Human resources, manufacturing practices and quality tools are under this

category. These are very flexible and if one changes will affect the overall system. These have been shown in quadrant III in Figure 4.

- **Independent enablers: E**nablers having strong drive power and weak dependence power are independent enablers. These enablers are key enablers as these have high driving powers. Here key enablers are customer focus and focus on competitive quality. These have been shown in quadrant IV in Figure 4.

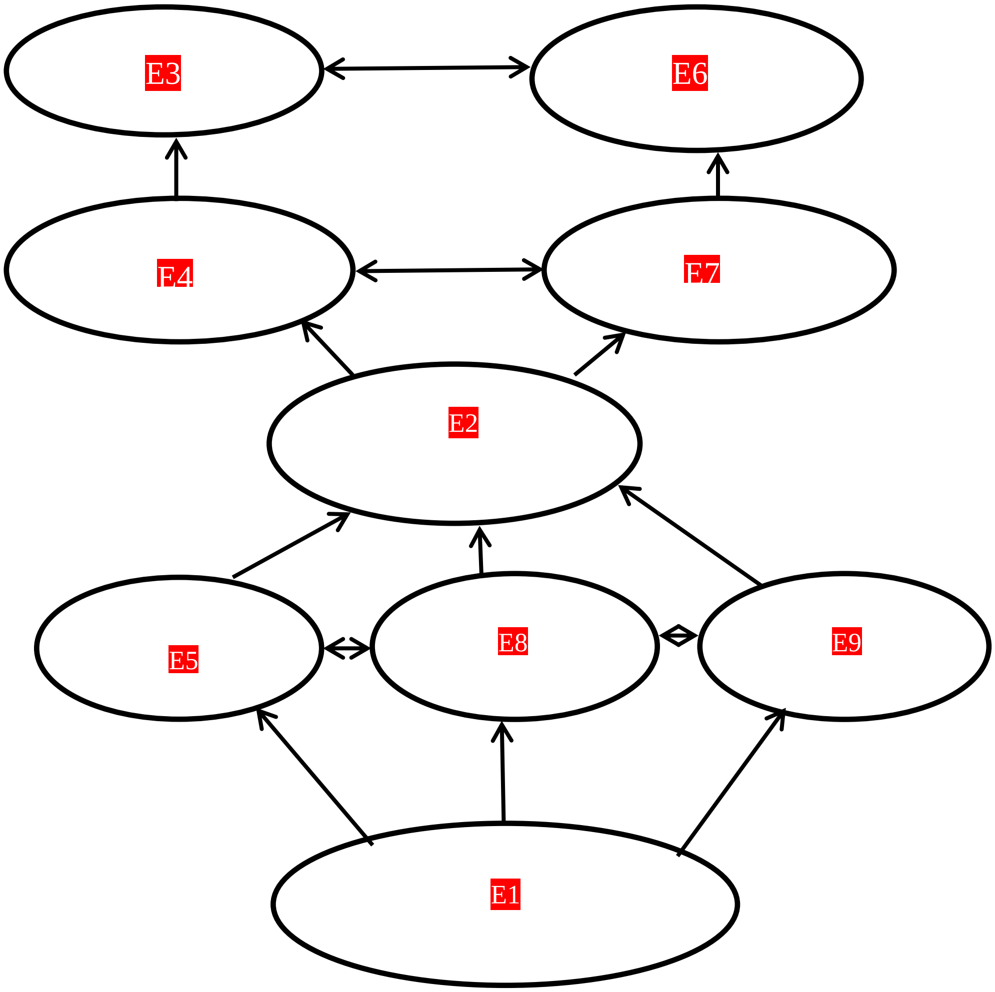

Figure 2. Diagraph for WCM enablers

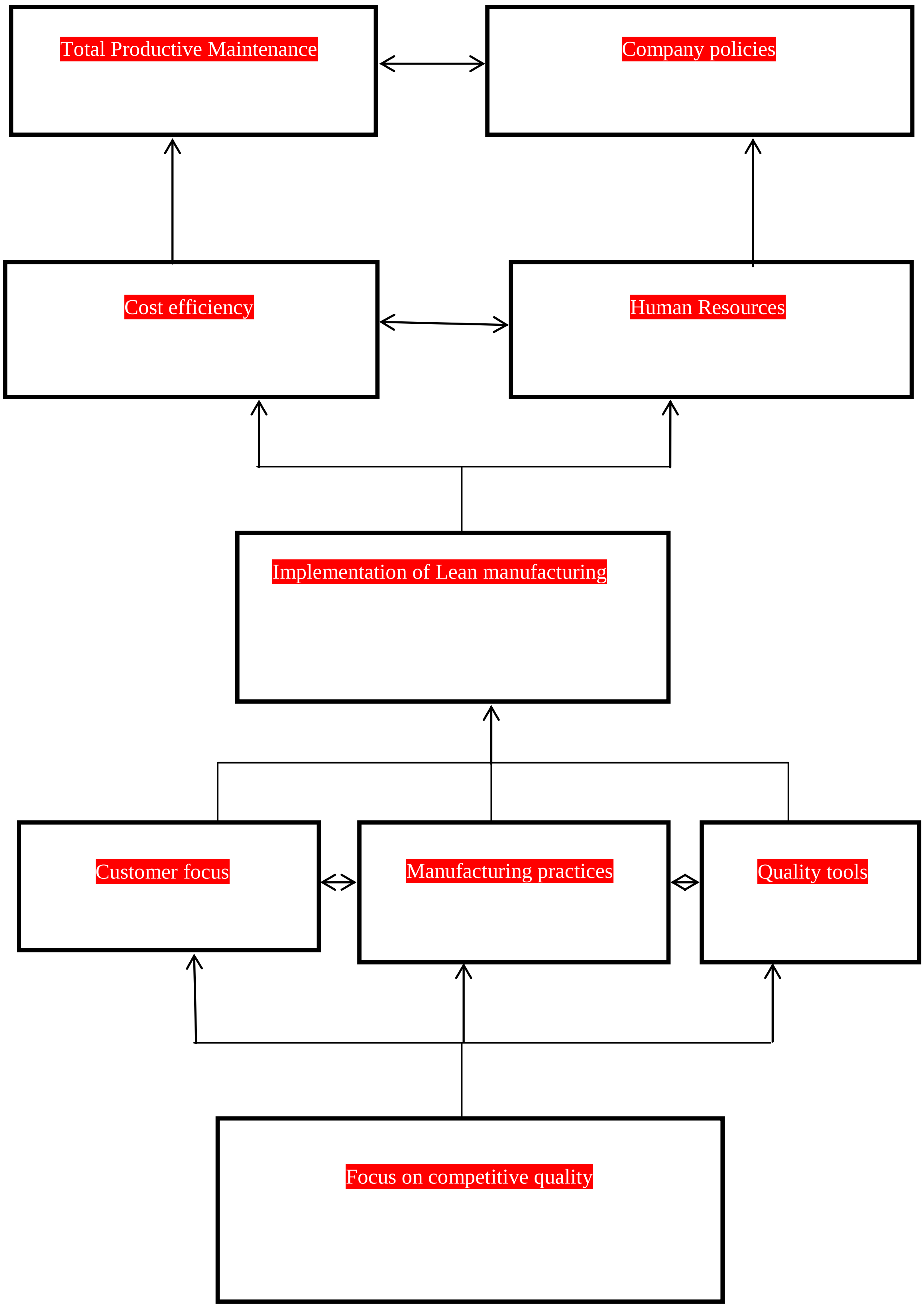

Figure 3. ISM Model for WCM Implementation

9	**IV**			**E1**	**E5**	**E9**	**E7**				**III**	
8				**E1**	**E5**	**E8**						
7									**Linkage**			
6	**Independent**											
5						**E2**	**E4**					
4												
3		**Autonomous**						**Dependent**				
2												
1	**I**						**E3**	**E6**			**II**	
Driving	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**			
power	**Dependence Power**											

Figure 4. MICMAC analysis of WCM enablers

5. Reaults and Analysis

ISM WCM implementation model have been developed after the categorization of 79 enablers into nine groups. The ISM model (Figure 3) revealed the contextual relationship of identified WCM enablers. The driver-dependence diagram provides some understandingsabout the relative significance of WCM enablers and interdependencies among them. The digraph illustrates the relationships among various enablers. The top two enablers of the WCM structural model namely TPM (E3) and company policies (E6)were found to play the least influential role as compared to the other seven groups of enablers. These enablers have less influence in the implementation of WCM. Focus on competitive quality (E1) is found to be most influential enabler with 9 driving power and 4 dependence power. Customer focus (E5), manufacturing practices (E9) and quality tools (E9) are driven by focus on competitive quality and in turn drive the enabler implementation of lean manufacturing system.Cost efficiency (E4) and human resources (E7) are driven by implementation of lean manufacturing system and act as drivers for the TPM and company policies. Customer focus, manufacturing practices and quality tools have bi-directional relationship. Enablers cost efficiency and human resources also have bi-directional relationship.

The MICMAC analysis, shown in Figure 4, indicates that cluster 1 has zero enablers which have weak dependence and driving power. On the other hand, there are four enablers (E2, E3, E4, and E6) that have strong dependence but a weak driving power (cluster II). Enablers (E7, E8, and E9) have a strong driving power and a high dependence power (cluster III). The cluster IV (E1, E5) reflects the barriers with a strong driving power but weak dependence power; these enablers demand the maximum attention and are the key enablers.

6. Conclusion and Future Scope

In this research study, an effort has been done for identifying the enablers that facilitate successful implementation of WCM practices in Indian manufacturing firms. The implementation of these WCM enablers is difficult and long process because it consists of various tools and techniques used within manufacturing firm‗s policies. The study gives a complete view regarding enablers of WCM and can be helpful for the experts. Successful implementation of WCM model depends on the successful implementation of the enablers; total 79 enablers have been identified in present study. It is difficult to apply the ISM approach alone on the 79 enablers so enablers have been divided into nine groups. With the help of ISM approach contextual relationship between the nine groups of enablers have been developed.ISM model helps in finding the driving and dependence powers of one group of enablers on the other while AHP gives weightage to the enablers to whom the more focus should be given. The focus on the competitive quality is main driver in the ISM model which will drive all the groups of enablers.

This study suffers from few limitations also. The contextual relationships among the variables always depend on the expert‗s knowledge about the firms and its operations and survey results also depends on the knowledge of the person who have filled the survey. The bias of the person who is judging the variables might, therefore, influence the final result. And since the models used can differ from industry to industry; accuracy determination and comparison is difficult due to lack of any common base or context.

In future other different approaches may also be applied with the ISM like AHP, TISM, DEMATEL, IRP, and ANP for better understanding of the relationships between the WCM enablers. The WCM enablers may be identified for a particular industry and then model can also be prepared.

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