Analysis of TPM Barriers using ISM-MICMAC Approach

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Abstract. Total Productive Maintenance in the organizations is a challenging issue for Indian manufacturing industries. There is a rapid need to analyze the behavior of the barriers faced by Indian manufacturing industries for efficacious implementation of TPM. The purpose of this study is to recognize the mutual interaction among the barriers of Total Productive Maintenance (TPM) and to develop a hierarchy of barriers to TPM implementation. An interpretive structural modelling (ISM) - MICMAC methodology is employed to identify the inter-relationships among the barriers of TPM implementation. A hierarchy model of these barriers is developed; by driving and dependence power of the barriers. MICMAC methodology determines driving and driven barriers based on their driving and dependence power.

Keywords: ISM; managers; Manufacturing industries; MICMAC; TPM

1 Introduction

Over the period, manufacturing sector has been struggling in the race to achieve eminency in manufacturing domain through various strategies. Since the globalization is in ascent, there is urgency to ameliorate the productivity as well as competency of the manufacturing industry to succeed in global market place. Organizations are espousing different strategies to advance their manufacturing potential.

Vigorously growing competition in the realm of manufacturing resulted in all-inclusive espousal of the quality enhancement practices [1]. Rapidly increasing competition is weighing a big threat for manufacturing industries since the customer expectation is also increasing. Numbers of quality practices have been employed by the manufacturing firms all over the world, Total Productive Maintenance is one of them to ameliorate the organizational productivity as well as efficiency to improve in the maintenance activities.

The motivation behind this study is to identify the key barriers of implementation of the Total Productive Maintenance (TPM) in the Indian manufacturing diligences through literature review. The study which provides an inter-relationship among the

major barriers to TPM implementation, would be helpful for mangers in Indian manufacturing sector to understand the role of each barrier in fruitful implementation of the TPM program in the organization.

An interpretive structural modelling (ISM) methodology was employed to determine an inter-relationships among the key obstacles that have been excerpted from literature review and develops a pair wise relationship among them. In addition to the inter-relationship among the barriers, driving power and dependence power of the barriers are determined by MICMAC analysis. MICMAC analysis categorized TPM implementation barriers into four groups 1) Autonomous, 2) Linkage, 3) Independent and 4) Dependent. A hierarchy model of these barriers is proposed by level partition.

This study has been structured in the following order. The second section briefs the literature review. Section three discusses ISM methodology for development of the model using pair-wise relationship. MICMAC interpretation was performed to identify driving power and dependence power of the barriers. Last section presents the results and conclusions of this research.

2 Literature Review

2.1 Total Productive Maintenance

Total Productive Maintenance is a strategy which proposed to enhance the productivity of a manufacturing firm and also the efficiency of equipment during the course of its usage in the operations. This is achieved through contribution and enthusiasm of each employee in a manufacturing firm [2]. TPM is a systematic program focused on production enhancement which deals with the reliability of the firm's facilities and successful organization of plant resources by continuous involvement of employees, empowerment by concerning manufacturing, maintenance, and industrial function [3]. TPM terminology is minimizing the waste incurred in various operations thus cutting down the overall cost by enhancing its productivity and generating excellent quality products [4].

2.2 TPM barriers in Literature

Bamber discovered key factors leading to an increasing effect on the employment of the TPM in small to medium industries in the UK and developed a generic model of the factors [5]. Cooke conducted study of four processing/manufacturing companies that faced problems in adopting the TPM program and observed that implementation of TPM in the organization is laborious task gloomily affected by the various obstacles such as financial, governmental and divisional [1]. Kumar conducted a questionnaire survey of machinery and automobile industry and examined the influence of total productive maintenance practices on Indian manufacturing output [6].

2.3 Indian Manufacturing Industry - A Review

Numerous researchers have carried out studies on the organizations that have implemented or are currently implementing the TPM manufacturing and maintenance functions across the world. The Indian industry urgently needs to identify and understand the key barriers of TPM implementation to compete with the rivals in global market. To achieve maintenance excellence in the competitive environment; major Indian manufacturing organizations are also adopting the maintenance strategy. Ahuja highlighted major hurdles in the implementation of TPM program, influencing the overall performance of Indian manufacturing industry [7].

Although global organizations are to adopt the quality improvement initiatives due to competitive market, Indian manufacturing industry is still facing challenges in finding a foot in global market [8].

3 TPM Barriers in Indian Manufacturing Industry

In this study, barriers faced by Indian manufacturing industries have been determined through questionnaires, surveys, interviews and informal conversations; the barriers have been divided into behavioural, organizational, cultural, technological, departmental, operational and financial barriers [7]. These barriers are discussed in detail in Table 1 are as follows:

Table 1. TPM Barriers from Literature

Barriers	Author(s)
Organizational barriers	
Lack of top level management commitment	Ahuja and Khamba, (2008); Tsang and Chan, (2000); Attri et al., (2014); Poduval et al.,(2013); Panneerselvam , (2012); Cooke, (2000); Bamber et al., (1999); Davis, (1997)
Ineffective top management to firmly follow the TPM principles	Ahuja and Khamba (2008); Attri et al. (2014)
Unaware of real prospective of TPM in the organization (Lack of knowledge about TPM)	Ahuja and Khamba, (2008); Attri et al., (2014); Panneerselvam, (2012); Kocher et al. (2012)
Ineffective organization to change the employees attitude	Ahuja and Khamba, (2008a, 2008b); Bamber et al., (1999); Attri et al., (2014); Poduval et al., (2013); Kocher et al. (2012); Cooke, (2000); Patterson et al., (1995); Lawrence (1999)
Focus on numbers of maintenance practices at a single time	Ahuja and Khamba (2008); Attri et al. (2014); Panneerselvam, (2012); Poduval et al., (2013); Kocher et al. (2012); Bakerjan (1994)
Improper consideration of the TPM rules	Ahuja and Khamba (2008); Davis (1997)
Lack of appropriate plans	Ahuja and Khamba (2008); Bamber et al., (1999); Attri et al. (2014)

Middle managements attitude towards not empowering the bottom level operators	Ahuja and Khamba, (2008a, 2008b); Bamber et al., (1999); Nakajima, (1989); Poduval et al., (2015); Cooke, (2000)
Organization' s incapability to improve employees skill towards work	Ahuja and Khamba, (2008); Poduval et al.,(2015)
Unfriendliness of employees towards development practices in the organization	Ahuja and Khamba, (2008); Cooke, (2000)
Lack of suitable services for the organization's workers	Ahuja and Khamba, (2008); Kocher et al., (2012)
Lack of appropriate measurement system for measuring organization's performance	Ahuja and Khamba, (2008); Balzarova et al., (2004)
Lack of reward and promotions for the employees in the organization	Ahuja and Khamba, (2008a, 2008b); Attri et al., (2014); Poduval et al., (2015); Haleem et al.,(2012)
Cultural barriers	
Employee's resistance towards the culture change	Cooke,(2000); Patterson et al., (1995); Lawrence, (1999); Panneerselvam , (2012)
Lack of quality perception in the organizational culture	Ahuja and Khamba (2008a, 2008b); Panneerselvam, (2012)
Lack of motivation of the employees towards the organization's goal	Ahuja and Khamba (2008a, 2008b); Bamber et al.,(1999); Maroofi , (2013); Kocher et al.,(2012); Tsang and Chan, (2000)
Employees rigid attitude towards adapting new approaches or practices	Ahuja and Khamba, (2008); Poduval et al., (2015); Attri et al. (2014); Balzarova et al., (2004)
Lack of skilled employees and human resources in the workplace	Ahuja and Khamba, (2008); Kocher et al., (2012)
Lack of employees participation in the decision making	Ahuja and Khamba,(2008); Nakajima, (1989); Panneerselvam,(2012); Bamber et al., (1999); Swanson (1997)
Lack of quality expertise in production to reduce rework	Ahuja and Khamba, (2008); Panneerselvam ,(2012)
Behavioral barriers	
Employee's resistance to familiarize themselves to new changes	Ahuja and Khamba, (2008); Cooke,(2000); Patterson et al.,(1995); Lawrence, (1999)
Lack of cross functional working teams	Ahuja and Khamba, (2008); Blanchard, (1997); Panneerselvam (2012)
Inadequate motivation among organization's employees for its growth and development	Ahuja and Khamba, (2008a, 2008b); Bamber et al.,(1999)
Lack of effort from employees towards learning multi –skills and updating their skills	Ahuja and Khamba, (2008); Poduval et al.,(2013); Panneerselvam, (2012)

Unwillingness of employees to learn new practices in production and maintenance department	Ahuja and Khamba, (2008); Panneerselvam, (2012); Suzuki ,(1994); Poduval et al., (2013); Attri et al., (2014); Kocher et al.,(2012)
Employee's resistance to change because of fear of job loss	Ahuja and Khamba, (2008); Panneerselvam, (2012); Attri et al., (2014)
Employee's preference towards traditional practices	Ahuja and Khamba ,(2008); Panneerselvam,(2012); Attri et al., (2014)
Lack of support and understanding in management behaviour	Ahuja and Khamba, (2008); Davis,(1997); Tsang and Chan, (2000); Patterson et al., (1995); Nakajima ,(1989); Bakerjan, (1994)
Technological barriers	
Lack of importance on the production potential further than the design	Ahuja and Khamba,(2008): Suzuki, (1994); Attri et al., (2014)
Lack of adequate system for assessing the reliability of the organization and faster delivery of the products	Ahuja and Khamba,(2008); Panneerselvam, (2012); Haleem et al.,(2012)
Lack of proper predictive maintenance system in the organization	Ahuja and Khamba,(2008); Poduval et al., (2013)
Lack of adequate computerized maintenance management systems (CMMS) services in the firms	Ahuja and Khamba,(2008); Attri et al., (2014); Panneerselvam,(2012)
Unawareness of losses occurs in the production department and reworks that affects manufacturing development	Ahuja and Khamba, (2008a,2008b); Panneerselvam, (2012); Poduval et al., (2015)
Lack of flexibilities in the production system because of long set up times	Ahuja and Khamba, (2008)
Lack of knowledge in the employees toward new technologies because of improper training	Ahuja and Khamba, (2008); Bamber and Sharp, (1999); Panneerselvam,(2012); Bakerjan, (1994); Bamber et al.,(1999); Suzuki,(1994); Swanson, (1997); Blanchard, (1997); Poduval et al., (2013), Davis, (1997)
Less emphasis on preservation practices for improvements in the existing system	Ahuja and Khamba, (2008)
Efficiency of production system is not of good quality	Ahuja and Khamba (2008); Panneerselvam, (2012)
Operational barriers	
Accepting high level of the defects in jobs with less importance on quality improvement techniques such as 6sigma and 6s principles	Ahuja and Khamba (2008); Panneerselvam,(2012);Haleem et al., (2012)
Lack of execution of the standard operating measures	Ahuja and Khamba (2008); Attri et al. (2014); Poduval et al., (2013);
Lack of the empowerment of the workers in decision making related to organization's equipment and machinery	Ahuja and Khamba (2008)

Unavailability of check sheets for effective scheduled maintenance	Attri et al. (2014); Ahuja and Khamba (2008)
Top level management's failure to implement safe work environment for workers	Attri et al. (2014); Ahuja and Khamba (2008); Poduval et al., (2015)
Employee's resistance to accomplish single maintenance task in the production department	Ahuja and Khamba, (2008)
Inadequate environment conditions in lack of the 5 S implementation in the organization	Ahuja and Khamba (2008); Panneerselvam, (2012); Haleem et al.,(2012)
More emphasis on repair of the facilities rather than stoppage of the breakdown	Ahuja and Khamba (2008); Poduval et al., (2013)
More focus on routine production goals rather than continuous process improvements	Ahuja and Khamba (2008); Haleem et al., (2012); Poduval et al.,(2015)
Financial barriers	
Lack of adequate system for assessing the execution of the TPM in the initial stage	Attri et al. (2014); Ahuja and Khamba (2008)
Ineffective top level to provide economic support and funds	Ahuja and Khamba, (2008); Kocher et al., (2008)
Lack of proper reward, incentive and credit system for motivating its employees	Ahuja and Khamba, (2008); Attri et al. (2014); Poduval et al., (2015), Haleem et al., (2012)
Lack of the standard quality measurement system due to economic condition of the organization	Ahuja and Khamba, (2008); Balzarova et al., (2004)
Manpower costs, Tools and instruments cost, Holding large inventory cost	Ahuja and Khamba, (2008); Attri et al. (2014); Suzuki, (1994); Kocher et al., (2012)
Departmental barriers	
Lack of coordination among various departments in the firm	Ahuja and Khamba, (2008a, 2008b); Maroofi,(2013); Attri et al. (2014); Panneerselvam, (2012)
Unwillingness of maintenance workers to adopt autonomous maintenance program as their routine function	Ahuja and Khamba,(2008); Attri et al. (2014); Kocher et al.,(2012)
Separation of responsibilities in departments	Ahuja and Khamba,(2008); Cooke, (2000); Panneerselvam, (2012)
Lack of trust on efficient employee's skills for independent maintenance jobs	Ahuja and Khamba, (2008)
failure to allow sufficient time for the evolution	Ahuja and Khamba, (2008); Bakerjan, 1994); Kocher et al. (2012); Bamber et al., (1999)

4 Methodology

Interpretive Structural Modeling (ISM) is a method of establishing an inter-relationship among the barriers. Expert's judgments help to decide the inter-relationship between the barriers. ISM structures a model corresponding to the inter-relationship among the variables.

Warfield had first proposed the concept of ISM in 1974 [9]. Number of researchers had used ISM in different realm. Mandal and Deshmukh applied ISM for selection of vendors [10], Raj et al., proposed a model of enablers affecting the Indian flexible manufacturing system [11]. Soti et al. employed ISM for modelling the critical factors of Six Sigma [12].

ISM methodology includes the following steps [9, 13]:

4.1 Identification of TPM barriers

Once the problem statement is clear, barriers affecting the problem are identified through literature review, industry or academic experience, personal interviews or questionnaire survey.

4.2 Construction of structural self-interaction matrix (SSIM)

With pair wise assessment between the barriers, a structural self-interaction matrix is established by expert's opinions as shown in Table 2. Four symbols are used to interrelate the barriers (i.e., i and j). These are [13]:

- Symbol V represents that enabler i would lead enabler j.
- Symbol A represents that enabler j would lead enabler i.
- Symbol X represents that enabler i and j would help to attain one other.
- Symbol O represents that there is no relation between enabler i and j.

Structural self-interaction matrix obtained from experts is shown in the Table 2.

4.3 Development of Reachability matrix

The structural self-interaction matrix (SSIM) obtained in the previous step is then transformed into initial reachability matrix by replacing variables V, A, X and O through 1 and 0 as per the methodology [13]. Further from the initial reachability matrix, shown in Table II, a final reachability matrix is formulated integrating the transitivity in it. The final reachability matrix is shown in Table 4.

Table 2. Structural self-interaction matrix

Serial Number	Barriers	1	2	3	4	5	6	7
1	Organizational Barriers		X	X	V	V	V	V
2	Cultural Barriers			X	X	V	O	O
3	Behavioral Barriers				O	V	O	V
4	Technological Barriers					V	A	O
5	Operational Barriers						X	X
6	Financial barriers							O
7	Departmental Barriers							

Table 3. Development of Reachability matrix

Serial Number	Barriers	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	Organizational Barriers	1	1	1	1	1	1	1
2	Cultural Barriers	1	1	1	1	1	0	0
3	Behavioral Barriers	1	1	1	0	1	0	1
4	Technological Barriers	0	1	0	1	1	0	0
5	Operational Barriers	0	0	0	0	1	1	1
6	Financial barriers	0	0	0	1	1	1	0
7	Departmental Barriers	0	0	0	0	1	0	1

4.4 Canonical matrix by level partitions

After obtaining the final reachability matrix from initial reachability matrix, level partition has been accomplished on it. The variables are grouped into two categories that are reachability and antecedent set respectively. Reachability set is the group of the variables that consists of 1's in the rows, whereas antecedent set is the group of the variables that consists of 1's in the column.

Intersection of reachability and antecedent set provides intersection set. Level partition has been done based on the intersection criteria, more the number of variable from the reachability set interesting with antecedent, that barrier has been given the priority. This provides the levels of the barriers. Once the 1st level barrier is obtained, it is removed from the remaining variables. This procedure runs until all the levels are determined. Table 5, 6, and 7 show I, II and III levels of the ISM hierarchy respectively.

4.5 Development of ISM Model and Directed graph

Once the level partition has been completed, a structural model of the barriers to TPM implementation is developed. The hierarchy of ISM model is obtained by level partition and the connection among the barriers is obtained by removing the transitivity from the

final reachability matrix. Arrows from barrier "i" to barrier "j", indicates a relationship between the barrier i and j. The obtained hierarchy of ISM model for TPM barriers are shown in "Fig. 1". Diagraph for TPM barrier is obtained from the final reachability matrix with driving and dependence power as shown in "Fig. 2".

Table 4. Final reachability matrix with driving power and dependency

Serial Number	Barriers	1	2	3	4	5	6	7	Driving Power	Rank
1	Organizational Barriers	1	1	1	1	1	1	1	7	I
2	Cultural Barriers	1	1	1	1	1	0	0	7	I
3	Behavioral Barriers	1	1	1	0	1	0	1	7	I
4	Technological Barriers	0	1	0	1	1	0	0	7	I
5	Operational Barriers	0	0	0	0	1	1	1	3	II
6	Financial barriers	0	0	0	1	1	1	0	3	II
7	Departmental Barriers	0	0	0	0	1	0	1	3	II
Dependence		4	4	4	5	7	7	6		
Rank		IV	IV	IV	III	I	I	II		

Table 5. Level partition of TPM barriers- First Iteration

Barriers	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,6,7	1,2,3,4	1,2,3,4	I
2	1,2,3,4,5,6,7	1,2,3,4	1,2,3,4	I
3	1,2,3,4,5,6,7	1,2,3,4	1,2,3,4	I
4	1,2,3,4,5,6,7	1,2,3,4,6	1,2,3,4,6	I
5	5,6,7	1,2,3,4,5,6,7	5,6,7	
6	4,5,6	1,2,3,4,5,6,7	4,5,6	
7	5,6,7	1,2,3,4,5,7	5,7	

Table 6. Level partition of TPM barriers- Second Iteration

Barriers	Reachability set	Antecedent set	Intersection set	Level
5	5,6,7	5,6,7	5,6,7	II
6	5,6	5,6,7	5,6	
7	5,6,7	5,7	5,7	II

Table 7. Level partition of TPM barriers- Second Iteration

Barriers	Reachability set	Antecedent set	Intersection set	Level
6	6	6	6	III

5 ISM – MICMAC Analysis

The main objective is to determine the driving and dependence power of the barriers to TPM execution that is furnished by employing the MICMAC analysis into practice. The analysis categorized the barriers into four groups as shown in *"Fig. 2"*. Driving power and dependence barriers are identified in the final reachability matrix, as shown in the Table 4. These four categories are as follows:

- Autonomous barriers: These are the barriers which have poor driver power and poor dependence.
- Linkage barriers: These are the barriers of robust driver power and dependence. These barriers are unstable and will affect other barriers.
- Dependent barriers: These are the barriers of weak driver power but high dependence power.
- Independent barriers: These are the barriers of strong driver power whereas poor dependence power. Barriers of high driver power, known as crucial barriers might be independent or linkage barriers.

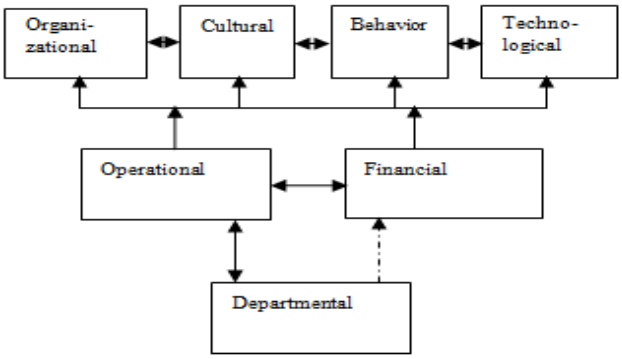

Fig. 1. The hierarchy of ISM model for TPM barriers

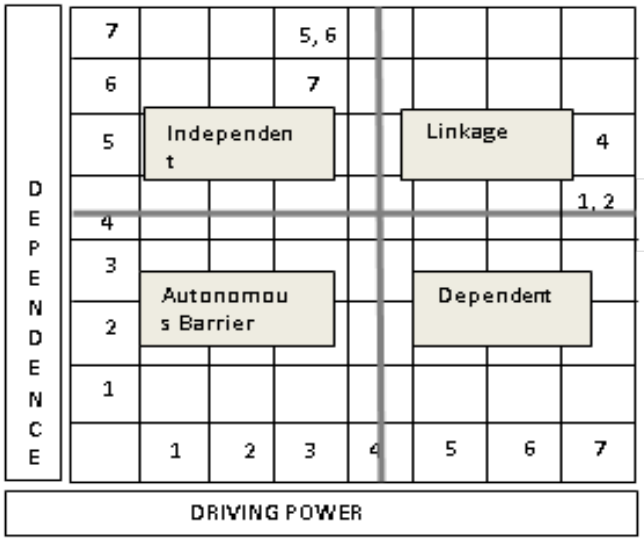

Fig. 2. Driving power and dependence digraph for TPM barriers

6 Results and Discussions

The study identifies the crucial barriers to TPM employment in Indian manufacturing industries from literature review and industrial experience. Inter-relationships between these barriers have been achieved from the group judgments of the experts. An ISM methodology has been used to inter-relate the barriers. ISM diagraph has been developed by final reachability matrix using driving and dependence power as shown in *"Fig.2"*.

The study shows from the ISM model that organizational, cultural, behavioral, and technological barriers are at the top of the hierarchy; have strong driving power. Organizations must focus on considering the role of these barriers in the TPM implementation. Second level of the hierarchy consists of operational and departmental barriers whereas bottom level of the hierarchy consists of financial barriers.

Study of the driving and dependence power of the barriers affects execution of TPM program in an organization using MICMAC methodology. In MICMAC analysis the TPM barriers are divided into four groups as shown in *"Fig.2".*There are no autonomous barriers found in this digraph. Dependent barriers consist of organizational, cultural and behavioral barriers in its category. There is one linkage barrier in the digraph which is technological barriers. Independent/driver category consists of operational, departmental, and financial barriers.

7 Conclusion

Currently, while competition among organizations is increasing continuously there is an instant need to adopt the maintenance practices to compete the rivals. In the present time, primary purpose of every organization is to improve its efficiency and productivity with reducing delivery time and satisfying customer expectations. To achieve this goal organization must implement some maintenance practices and Total Productive Maintenance (TPM) is one of them.

In this study, a hierarchy model of TPM barriers has been developed using an integrated ISM and MICMAC analysis that would be helpful to the organizational management to identify the significant TPM barriers and implementing TPM into their organizations. MICMAC analysis has been done for identifying autonomous, linkage, dependent and independent barriers.

The purpose of this study was to recognize the major obstacles to TPM employment in manufacturing industries in Indian context based on literature review and experience. Study presents that an interrelationship among the barriers of the TPM implementation would be helpful for the organizational managers to understand the role of each barrier to successful implementation of the TPM program in the organization.

An integrated interpretive structural modelling (ISM) and MICMAC interpretation was employed to determine the inter-relationships amongst the obstacles to TPM implementation. ISM provides a pair-wise relationship between the barriers and MICMAC analysis provides the driving power and dependency power. Autonomous, Linkage, Independent, and Dependent obstacles have been identified by driving and dependence power and a hierarchy model of these barriers is proposed by level partition.

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