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ScienceDirect

Procedia CIRP 98 (2021) 241–246

www.elsevier.com/locate/procedia

28th CIRP Conference on Life Cycle Engineering

Development of a Model for Total Productive Maintenance Barriers to Enhance the Life Cycle of Productive Equipment

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Abstract

The main intention of the organization is to focused on enhancing its efficiency, life cycle, and productivity by maintaining better delivery time so that customer satisfying can be guaranteed. One way to achieve this intention is by implementing the concept of Total Productive Maintenance (TPM). In this study, barriers faced by Indian manufacturing organizations in the new emerging market had been determined through the questionnaire survey with the help of renowned academician and industrial experts. These barriers had been divided into key areas namely behavioral, organizational, cultural, technological, departmental, operational, and financial barriers. The barriers had positive as well as negative effects on the actual implementation of TPM aligned with life cycle engineering of productive equipment. The study identifies the crucial barriers to TPM employment in Indian manufacturing industries from the literature review and industrial experience. Hence, a unique model was developed for the determination of the driving and dependence power of the barriers to TPM execution to enhance the life cycle of productive equipment using Interpretive Structure Modelling (ISM).

Keywords: Interpretive Structural Modeling; Total Productive Maintenance; Barriers; Life Cycle; Manufacturing

1. Introduction

Over the period, the manufacturing sector has been struggling to remark its importance through various strategies. Since globalization is growing day by day, there exist at most requirements for better productivity, so that the manufacturing industry can succeed in the global marketplace. Organizations are continually trying out different strategies to advance their manufacturing potential. Cooke [1] with his work made it very clear that growing competition in manufacturing units directly proportional to quality enhancement practices. Rapid growth in competition has developed a threat for manufacturing industries since customer expectations are raising continuously. Numbers of quality practices have been employed by manufacturing firms all over the world, TPM is one of the popular choices to get profit. With TPM firm productivity as well as efficiency can be improved in the maintenance activities.

The main intention behind the present work is to identify the key barriers to implement total productive maintenance in Indian manufacturing through a detailed literature review. The study provides an inter-relationship among the major barriers to the TPM implementation. This shall directly be helpful for Indian management to understand the role of each barrier. This further can be successful implementation using the TPM program into the organization. An interpretive structural modeling methodology can be employed that determines inter-relationships among the key obstacles. These obstacles can be further linked with literature review and can develop a pair-wise relationship among them. In addition to the inter-relationships, the barriers, driving power, and dependence power of the barriers can be determined by MICMAC

10.1016/j.procir.2021.01.037

analysis. MICMAC analysis categorized by TPM implementation barriers can be split into four groups namely Autonomous, Linkage, Independent, and Dependent. A hierarchy model of these barriers can be proposed by level partition.

The prime aspect of the study is to focus on getting better efficiency, higher life cycle, and more stable productivity. In addition to recognize and minimize the crucial obstacles to TPM employment in manufacturing industries in the Indian context, so that customer is always under satisfied condition.

2. Literature review

2.1. Total productive maintenance

TPM is a strategy that is proposed to exaggerate the productivity of a manufacturing firm as well as the efficiency of the equipment during the course of its usage in the operations by whole contribution and enthusiasm of all its personnel [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 employee, empowerment concerning manufacturing, maintenance, and industrial function [3]. The principle motive behind the TPM terminology is minifying the waste incurred in the 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 et al. [5] discovered key factors arousing effect on the employment of the TPM in small to medium industries in the UK and developed a generic model of the factors. Cooke [1] a 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 a laborious job gloomily affected by the various obstacles such as financial, governmental, divisional, etc. Kumar et al. [6] conducted a questionnaire survey of the machinery and automobile industry all over India and examined the influence of total productive maintenance practices on Indian manufacturing output.

2.3. Indian manufacturing industry –A review

Several researchers had carried out the study on the organizations that implemented or implementing the TPM program into their manufacturing and maintenance functions across the world. Indian industry is in quick need to identify and understand the key barriers to TPM implementation to compete with the rivals in the global marketplace. To achieve maintenance excellent in the competitive environment; major Indian manufacturing organizations are also adopting the maintenance strategy. Ahuja et al. [7] highlighted major hurdles in the implementation of the TPM program, severely influencing the overall performance of the Indian manufacturing industry. Although global organizations are quick to adopt quality improvement initiatives in the contest of the rivalry, The Indian manufacturing industry still facing the challenge in achieving globalization [8].

3. TPM barriers for Indian manufacturing industries

In this study, barriers faced by Indian manufacturing organizations have been determined through the face to face questionnaire survey, interviews, and informal conversation with the academician and industrial experts. All the academician and industrial experts were from manufacturing domain. These barriers have been divided into behavioral, organizational, cultural, technological, departmental, operational, and financial barriers [7]. These barriers are discussed in detail as follows:

3.1. Organizational barriers

- Lack of top level management commitment
- Ineffective top level management to execute TPM practices
- Ineffective organization to change the culture
- Unaware to real prospective of TPM in the organization
- Ineffective organization to change the employees attitude
- Focus on numbers of maintenance practices at a single time
- Improper consideration of the TPM rules
- Lack of appropriate plans
- Middle managements attitude towards not empowering the bottom level operators
- Ineffective management to firmly follow the TPM principles
- Organization' s incapability to improve employees skill towards work
- Unfriendliness of employees towards development practices in the organization
- Lack of suitable services for the organization's workers
- Lack of appropriate measurement system for measuring organization's performance
- Lack of reward and promotions for the employees in the organization

3.2. Cultural barriers

- Employee's resistance towards the culture change
- Lack of quality perception in the organizational culture
- Lack of motivation of the employees towards the organization's goal
- Employees rigid attitude towards adapting new approaches or practices
- Lack of skill employees in the workplace
- Lack of employees participation in the decision making
- Lack of quality expertise in production to reduce rework

3.3. Behavioral barriers

- Employee's resistance to familiarize themselves for new changes
- Lack of cross functional working teams

- Inadequate motivation among organization's employees for its growth and development
- Lack of efforts of the employees towards learning multi –skills and updating their skills
- Unwillingness of employees to learn new practices in production and maintenance department
- Employee's resistance to change because of fear of job loss
- Employee's preference towards traditional practices
- Lack of support and understanding in the management behaviour

3.4. Technological barriers

- Lack of importance on the production potential further than the design
- Lack of adequate system for assessing the reliability of the organization and faster delivery of the products
- Lack of adequate predictive maintenance services in the organization
- Lack of adequate computerized maintenance management systems (CMMS) services in the firms
- Unawareness of incompetence of losses occurs in the production platform system and reworks that affecting manufacturing development
- Lack of flexibilities in the production system because of long set up times
- Lack of knowledge in the employees toward new technologies because of improper training
- Less emphasis on preservation practices for improvements in the existing system
- Efficiency of production system is not of good quality

3.5. Operational barriers

- Accepting high level of the defects in jobs with less significance to the quality improvement techniques such as 6σ and 6s principles
- Lack of execution of the standard operating measures
- Lack of the empowerment of the workers in decision making related to organization's equipment and machinery
- Unavailability of check sheets for effective scheduled maintenance
- Top level management's failure to implement safe work environment for workers
- Employee's resistance to accomplish single maintenance task in the production department
- Inadequate environment conditions in lack of the 5 S implementation in the organization
- More emphasis on repair of the facilities rather than stoppage of the breakdown
- More focus on routine production goals rather than continuous process improvements

3.6. Financial barriers

- Lack of adequate system for assessing the execution of the TPM in the initial stage
- Ineffective top level to provide support the improvement program
- Lack of proper reward, incentive and credit system for motivating its employees
- Lack of the standard quality measurement system due to economic condition of the organization

3.7. Departmental barriers

- Lack of coordination among various departments in the firm
- Unwillingness of maintenance workers to adopt autonomous maintenance program as their routine function
- Separation of responsibilities in departments
- Lack of trust on efficient employee's skills for independent maintenance jobs

4. Development of a Model for TPM Barriers

Interpretive structural modeling (ISM) is a process of establishing an inter-relationship among the barriers. Expert judgments help to decide the inter-relation between the barriers. ISM structures a model corresponding to the inter-relationship among the variables. Warfield [9] developed ISM. Numbers of researchers had used ISM in different areas. Mandal and Deshmukh [10] applied ISM for the selection of vendors, Raj et al. [11] proposed a model of enablers affecting the Indian flexible manufacturing system. Soti et al. [12] employed ISM for modeling the critical factors of Six Sigma. ISM methodology includes the following steps:

4.1. Identification of TPM barriers

Once the problem statement is clear, barriers affecting the problem are identified through the 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 1. Four symbols are used to inter-relate the barriers (i.e. i and j). These are:

- Symbol V represents that enabler i would lead enabler j.
- Symbol A represents that enablers 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 expert's opinions is shown in the Table 1.

Table 1. Structural self-interaction matrix

S.N.	Barriers	1	2	3	4	5	6	7
1	Organizational Barriers	X	X	X	V	V	V	V
2	Cultural Barriers	X	X	X	X	V	O	O
3	Behavioural Barriers	X	X	X	O	V	O	V
4	Technological Barriers	A	X	O	X	V	A	O
5	Operational Barriers	A	A	A	A	X	X	X

6	Financial barriers	A	O	O	V	X	X	O
7	Departmental Barriers	A	O	A	O	X	O	X

4.3. Development of Reachability matrix

The structural self-interaction matrix (SSIM) obtained in the previous step is then transformed into an 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 2, a final reachability matrix is formulated integrating the transitivity in it. The final reachability matrix is shown in Table 3.

Table 2. Initial reachability matrix

S.N.	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	Behavioural 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 the initial reachability matrix is obtained, the 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 in the row, whereas the antecedent set is the group of the variables that consists of 1 in the column.
The Intersection of reachability and antecedent set provides an intersection set. Level partition has been done based on the intersection criteria, more number of the variable from the reachability set interesting with the antecedent, that barrier has been given the priority. This provides the levels of barriers. Once the 1st level barrier is obtained, it is removed from the remaining variables.

Table 3. Final reachability matrix with driving power and dependence
RK- rank, DP- driving power, DEP- dependence

S. N.	Barriers	1	2	3	4	5	6	7	DP	RK
1	Organizational Barriers	1	1	1	1	1	1	1	7	I
2	Cultural Barriers	1	1	1	1	1	1	1	7	I
3	Behavioural Barriers	1	1	1	1	1	1	1	7	I
4	Technological Barriers	1	1	1	1	1	1	1	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	1	1	3	II
	DEP	4	4	4	5	7	7	6		
	RK	IV	IV	IV	III	I	I	I I		

This procedure continues until all the levels are determined. Table 4, 5, and 6 shows I, II, and III level of the ISM hierarchy respectively.

Table 4. Level partition of the TPM Barriers - I[st] 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 5.Level partition of the TPM Barriers - 2nd 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 6.Level partition of the TPM Barriers – 3rd Iteration

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

4.5. Development of ISM Model

Once the level partition has been completed, a structural model of the barriers to TPM implementation is developed. The hierarchy of the 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", indicate the relationship between barrier i and j. The obtained hierarchy of the ISM model for TPM barriers is shown in Figure 1. Diagraph for TPM barrier is obtained from the final reachability matrix with driving and dependence power as shown in Figure 2.

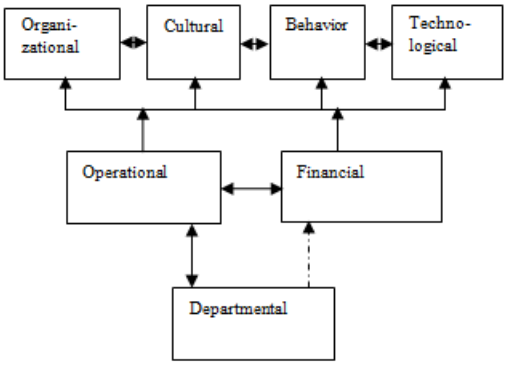

Fig. 1. The hierarchy of ISM Model for TPM barriers

5. Results and discussions

The ultimate 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 of as shown in Figure 2. Driving power and dependence barriers are identified in the final reachability matrix, as shown in Table 3. These four categories are as follows:

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

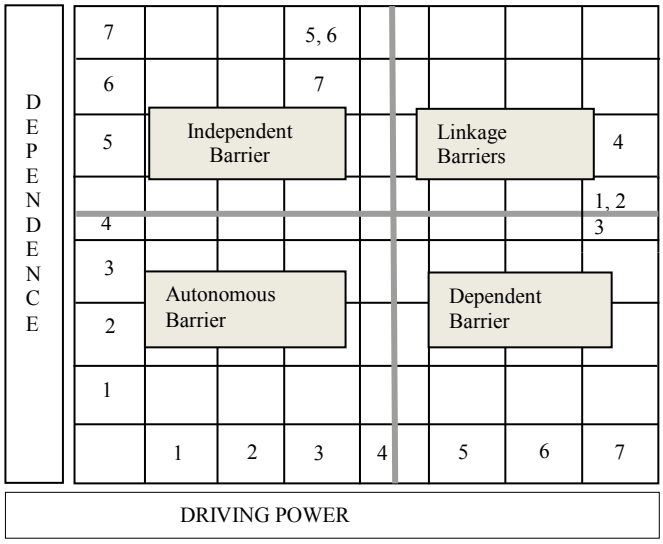

Fig. 2. Driving power and dependence digraph for TPM barriers

The study identifies the crucial barriers to TPM employment in Indian manufacturing industries from the literature review and industrial experience. Inter-relations 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 digraph has been developed by final reachability matrix using driving and dependence power as shown in figure 2.

The study shows that organizational, cultural, behavioral, and technological barriers are at the top of the hierarchy having strong driving power. Organizations must focus to consider the role of these barriers in the TPM implementation. The middle of the ISM hierarchy consists of operational and departmental barriers whereas the bottom of the hierarchy consists of financial barriers.

Study of the driving and dependence power of the barriers affects the execution of TPM program in an organization using MICMAC methodology. In MICMAC analysis the TPM barriers are divided into four groups as shown in Figure 2. No autonomous barriers have been identified in this digraph. Dependent barriers consist of organizational, cultural, and behavioral barriers in its category. Technological is the only linkage barrier. Independent/driver-category consists of operational, departmental, and financial barriers.

6. Conclusions

It can be noted that the present situation of competition across the among organizations had increasing continuously. There is an instant need to adopt maintenance practices to compete with competitors. The primary focus of every organization is to improve its efficiency and enhance productivity by lowering delivery time so those customers are made happy. To achieve this goal organization must implement some new maintenance practices and TPM is one of them. In this study, a hierarchy model of TPM barriers was developed using an integrated ISM and MICMAC analysis. This approach had helped organizational management to identify the significance of TPM barriers and enable TPM into their system. MICMAC analysis was done for identifying autonomous, linkage, dependent, and independent barriers.

The purpose of this research work was to recognize the crucial obstacles to TPM employment in manufacturing industries in the Indian context based on literature review and experience. Presented work was focused on inter-relationship among the barriers of the TPM implementation. This can be helpful for the organizational managers to understand the role of each barrier to the successful implementation of the TPM program into the organization. An integrated ISM and MICMAC interpretation were also employed to determine the inter-relationships amongst the obstacles to TPM implementation. Furthermore, ISM provides a pair-wise relationship between the barriers and MICMAC analysis provides the driving power and dependency power. Finally, Autonomous, Linkage, Independent, and Dependent obstacles were identified by driving and dependence power, and a hierarchy model of these barriers was proposed by level partition.

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