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Modelling of Enablers for Maintenance Management by ISM Method

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Abstract

The intent of this paper is to assert the enablers for maintenance management and indicates the strong relationship inaugurate between the enablers by using the interpretive structural modeling (ISM).

A good maintenance organization presents clear roles and responsibilities, an adequate span of control, facilitation of good supervision, effective reporting, and a regular improvement culture. ISM is used here to refer to the systematic application of some elementary notions of graph theory in such a way that theoretical, conceptual, and computational leverage is exploited to efficiently construct a directed graph, or network representation, of the complex pattern of a contextual relationship among a set of elements.

This work has tried to identify the barriers for successful implementation of maintenance management by manufacturing sectors to improve their performance. In this framework, total 15 barriers have been identified from literature review and expert meet from different interest areas for successful implementation of maintenance management.

Effective implementation of MM will improve overall performance of organization in terms of lead time, manufacturing cost, machine breakdown and quality of product with reduction in product rejection.

This paper is good for achieve continued improvement by evaluating performance, taking corrective actions, and measuring progress and prepare for future changes by anticipating needs and organizing flexibly.

Keywords: Maintenance management (MM); Interpretive structural modeling (ISM); Impact Matrix Cross-reference multiplication applied to a classification (MICMAC); Enablers; Total productive maintenance (TPM)

Introduction

Maintenance management (MM) is a maintenance program which involves an incipiently defined concept for maintaining plants and equipment. MM program's goal is to very increase working well and getting a lot done, at the same time, increase in employee mood and job happiness with rise in quality and cost of production is low as possible. MM takes into preventive support as a necessary and almost important part of the business. It is no more viewed as a movement with no-benefit. Upkeep's down time is booked as a part of the assembling day and, for some cases, as a vital part of the assembling procedure. The goal is to unscheduled maintenance to a minimum and hold emergency. The aim of productive maintenance is to maximize plant and equipment efficiency.

The objectives to be achieved and for which MM was introduced are as follows:

- Avoid wastage in a quickly changing economic environment;
- Producing goods without reducing product quality;
- Reduce cost;
- Produce a quantity with low batch at the earliest possible time.

Products send to the clients must be non-imperfect

Selection of technology and its putting into effect in a making industry will be a great physical acts offer for organization to live on in complete in competition market. During different operations major or minor barriers take place needing payment to breakdown which leads to copies of smaller size in amount produced and it forced the organization to instrument MM. It means MM cannot be successfully implemented until all departments integrate effectively. For good putting into effect of MM, top business managers need to chief place on different-different aspects to do with organization working including organization society development, employees training, united as complete thing of departments and so on. In addition to this, management needs to understand structural relationship between different variables, which will help in developing strategies for effective implementation of MM. Due to the complexity in implementation of MM following steps discuss in this paper

- For implementation of MM, the critical success factors are to be identified.
- The establishment of relationship among identified critical success factors.

Identification of critical success factors

To effectively take part in competition in complete markets, firms must be quick and able to bend in their move to meet amount produced needs. In today rapidly changing earth, in competition better chances in price need to be achieved by organizations, quality, high amount produced, make seem minimize losses, new thing and things taken round to at the same time. To meet these questions, good putting into effect of MM can play an important part. Major enablers had a discussion about as

Top management supports: Direct participation by the highest

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level executives in a special and seriously important point of view or programs of an organization. MM programs can be constructive if and only if the top management is fully committed and intricate. According to Ahuja et al. [1-4] it has to do with everyone in the organization, from top-level business managers of amount produced trained workmen using machines, and amount produced support groups to outside suppliers.

Organization culture: The values and behaviors that contribute to the unique social and psychological environment of an organization. The culture of organization includes an organization's degrees in which event is probable, experiences, philosophies, and values which place in ship for goods them together, and that are expressed in their self-picture, the outside earth effects on one another, inner workings, and degrees in which event is probable for future. Poor to do with organization necessary qualities in managing the support purpose, use effectively can hardly, cruelly, seriously act on competition-friendliness by getting amount putting through reduced, list of things getting increased, and that leads to poor due-date doing a play by Patterson et al. [5,6] and Ashayeri [7].

Development of maintenance strategy: Maintenance managers and support engineers are asked to undergo growth a support secret design for their plant and necessary things. A document needs to be undergone growth by them. In the document you give an account of how the least plant and necessary things support money used and efforts are used by you to make certain the necessary doing a play of amount produced from your producing plant and necessary things. Even least good, in a measures-taking of making organizations guided by Cholasuke et al. [8] only one-third part of the organizations, form of good business managers practices related to support tended to get money for the full benefits of their support business managers first moves. Some of the important causes producing an effect, which need to be thought out as in the road toward working well operation support business managers, as taken to be from the literature by Refs. [9-11].

Employee training and empowerment: Training in the skills is necessary in order to do the added responsibilities. Way in to information is necessary on which decisions can be made. Expert knowledge to take first move and secret is necessary on the part of the worker to take on greater responsibility. Companies practicing TPM at all times get done surprising outcomes, including making feeble, poor necessary things breakdowns, making seem unimportant doing nothing and minor stops (necessary in unmanned plants), making become less goes from one's country and claims in quality making stronger amount produced, making less giving birth and costs, list of things reduction, copies of smaller size in chance events, and making stronger worker sense of mixed into (as made clear by the thing put forward of getting better suggestions by Suzuki [12]. Moreover, good TPM putting into effect leads to important untouchable benefits such as unbroken stretch getting better of workforce skills and knowledge, fostering worker guiding reason through enough act of giving power, be made clear of roles and responsibilities for workers, a system for as an unbroken stretch supporting and controlling necessary things, gave greater value to quality of living of work, made lower, less tendency not to be present and gave greater value to news in the workplace by Carannante [13]. TPM is person one is going be married to take both group events (amount produced and support) together by a mix of good working experiences, group working, and unbroken stretch getting better by Cooke [14,15].

Investment on maintenance system: According to Teresko [16] monies put into business in support is the basic purposes, uses of a firm and comes back got better quality, safety, dependability, and able to make ready adjustments and lead times. Support, being an important support purpose, use in undertakings with important money put into business in plants and machinery, plays an important part in meeting this tall order. In addition, the overall view money put into business in to do with man resources can outcome in better hardware 4 use of, higher product quality and made lower, less giving birth costs [17,18].

Developing the coordination between departments: Productivity enhancement in organizations provides a great push for gave greater value to worker into line to do with organization ends, purposes, inter-departmental relations, worker motivation-contributions, and making ready a society development of Kaizens and unbroken stretch improvements in the organizations, thereby getting (making) better the to do with organization powers [19]. It has to do with everyone in the organization, from top-level business managers to producing trained workmen using machines, and producing support groups to outside suppliers [3]. It goes round all departments including support, operations, buildings, design engineering, project engineering, making engineering, list of things and stores, getting something for money, accounting and controlling of money, and plant and place business managers [20].

Benchmarking of processes: Benchmarking is the process of making a comparison one's business processes and doing a play metrics to industry bests or best practices from other industries measures representatively measured are quality, time and price. Benchmarking is simply the comparison of one organization's practices and doing a play against those of others. It seeks to make out quality examples, or "most good experiences," to send in name for in measuring and getting (making) better doing a play. Benchmarking is full of danger toward doing world-class support operation levels by Refs. [21-23]. It is to be noted that although benchmarking is one of the key elements for the unbroken stretch getting better process [24] only 17 of the got broken up (into simpler parts) papers (11 part of a hundred), presented, or even said something about to benchmarking techniques in associations 1 with support operation measurement. The questions of stiff competition and the private road for profits are forcing the organizations to instrument different amount produced getting better efforts to meet the questions took a position by ever-changing market demands [25].

Effective maintenance system: Today's maintenance organization, like different departments, is under continuous pressure so as to reduce price, show results, and which in turn supports the mission and goal of the organization. After all, it is a degree in which event is probable from the business point of view which is reasoning.

In such an able to work general condition, maintenance manager's part is full of danger. As such, maintenance managers are being called on to get mixed together and straight to the maintenance efforts so in connection with meet overall view goals of organization well and effectively [26,27]. In making organizations, maintenance related costs are put a value on to be 25% of the overall operating price [28,29]. The working well maintenance purpose, use united as complete thing with engineering and other purposes, uses related to making in the organization can help to but for very great amounts of time, money and other useful resources in trading with always-working and also trading with able to use, maintainability and doing a play issue [30]. Total productive maintenance (TPM) is one of the best tools for making our industries competitive and effective in the field of maintenance [31,32].

Quality management system: A quality management system

(QMS) is a collection of business processes focused on consistently meeting customer requirements and enhancing their satisfaction. It is expressed as the organizational structure, policies, procedures, processes and resources needed to implement quality management. Its function is to develop standards globally in an effort to improve the exchange of goods and services internationally. MM is considered to be an effective strategic improvement that includes initiative to improving quality in maintenance engineering activities [33,34]. TPM is a partnership between maintenance and productivity functions in the organization to improve product quality, reduce waste, reduce manufacturing cost, increase equipment availability, and improve the company's state of maintenance [35]. The quality and maintenance functions are vital factors for achieving sustainability in a manufacturing organization [36].

Reduction in M/C breakdown: Companies practicing MM invariably achieve startling results, including reducing equipment breakdowns, minimizing idling and minor stops (indispensable in unmanned plants), lessening defects and claims in quality, boosting productivity, trimming labor and costs, inventory shrinkage, reducing accidents, and boosting employee involvement (as shown by the submission of improvement suggestions) by Suzuki [12].

Improve safety and health management: According to Steinbacher and Steinbacher [37], TPM is all of the strategies needed to sustain a healthy maintenance log. As an employer, it is your responsibility to maintain a safe and healthy workplace. A safety and health management system, or safety program, can help you focus your efforts at improving your work environment. In a safe and healthy workplace, employees have a stake in the success of the program-safety and health is everyone's responsibility.

A safety and health management system means the part of the organization's management system which covers:

- The health and safety work organization and policy in a company;
- The planning process for accident and ill health prevention;
- The line management responsibilities and
- The practices, procedures and resources for developing and implementing, reviewing and maintaining the occupational safety and health policy.

Reduction in manufacturing lead time: Companies practicing TPM invariably achieve startling results including reducing equipment breakdowns, minimizing idling and minor stops (indispensable in unmanned plants), lessening defects and claim sin quality, boosting productivity, trimming labor and costs, inventory shrinkage, reducing accidents, and boosting employee involvement (as shown by the submission of improvement suggestions) [12].

Reduction in product rejection rate: According to Soviet law, output (articles, semi finished products, parts, and so forth) that does not correspond in quality to standards, technical specifications, and other technical norms. A distinction is drawn between reparable and irreparable production rejects. It is technically possible and economically advisable to repair the defects in reparable rejects at the enterprise. Irreparable rejects are articles whose defects are technically impossible or economically disadvantageous to eliminate. Such articles may be used as waste.

Rejects may be the result of incorrect adjustment of a machine tool, malfunctioning of equipment and tools, errors in technical specifications (plans and drafts, for example), disruption of production discipline, or the workers' low level of skill. The discovery of defective products is the responsibility of the workers, the foremen, and the employees of the technical control department. Production rejects are reduced by organizational and technical measures, including the mechanization and automation of production processes, proper maintenance of equipment and fittings, and the introduction of advanced forms and methods of technical control. Many factors are of great significance in preventing production rejects: zero-defect manufacturing, strict observance of production discipline in the work area, correct organization of labor, improved worker skills, the development of socialist emulation for high product quality, and material and moral incentives for the workers to manufacture high-quality products.

Manufacturing cost reduction: Intense competition has been witnessed in terms of less costs, quality improvement and diversity in products with superior performance by Chandra and Sastry [38]. TPM implementation is the reduction in occurrence of unlikely and unexpected machine breakdowns that disrupt production and this may result in losses, which can exceed millions of dollars annually by Gosavi [39].

TPM initiatives in production help in streamlining the manufacturing and other business functions, and garnering sustained profits [2].

TPM contributes effectively to improving the competitiveness and effectiveness of industries in the field of maintenance [40,41].

Improvement in performance: Performance improvement is measuring the output of a particular business process or procedure, then modifying the process or procedure to increase the output, increase efficiency, or increase the effectiveness of the process or procedure. Modern manufacturing requires that organizations that wish to be successful and to achieve world-class manufacturing must possess both effective and efficient maintenance. The intense competitive pressure on the organizations is triggering the top management of these enterprises to look at the performance of each and every business function, including manufacturing or maintenance for achieving competitive advantage [42,43]. It provides a systematic method for establishing production targets, and incorporates practical management tools and techniques in order to achieve a balanced view of process availability, performance efficiency and rate of quality [44]. The objective of TPM is to create a sense of joint responsibility between supervision, operators and maintenance workers, not only to keep machines running smoothly, but also to optimize their overall performance [45,46]. We obtain the overall equipment effectiveness OEE for the production line. The indicator OEE gives us the measurement of equipment performance; taking into account all factors that reduce the capacity utilization. Mathematical formula used for finding the overall performance efficiency is used as below:

Performance efficiency (P)=(Processed amount × 100)/(Operating time/Theoretical cycle time)

Indian manufacturing industries can implement TPM as a strategy and culture for improving the manufacturing performance (Table 1).

Research Methodology

ISM methodology

ISM is known as "Interpretive structural modeling". Malone

S. No.	Critical success factor	Author
1	Top management support	Ben-Daya and Duffuaa, [47] Pintelon et al. [42] Cooke [14],
2	Organization culture	Parida and Kumar [11]
3	Development of maintenance strategy	Bateman [48] Kans and Ingwald [49] Parida and Kumar [11]
4	Employee training and empowerment	Cooke [14] Guimaraes et al. [50] Tsang and Chan [10] Ahmed et al. [51] Ireland and Dale [52] Sharma et al. [40] Tsarouhas [53]
5	Investment on maintenance system/ technologies	Teresko [16] Heizer and Render [54]
6	Developing the coordination between departments	Cua et al. [55] McKone et al. [56,57] Bakerjan [58]
7	Bench marking of processes	Ireland and Dale [52] Cooke and Ng et al. [14] Raouf and Ben-Daya [22] Madu [23] Ahren and Parida [24]
8	Effective maintenance system	Bamber et al. [59] Willmott [61] Chan et al. [18] Choi and Eboch [62] Hendricks and Singhal [63] Sun [64]
9	Quality management system	Heizer and Render [54]
10	Reduction in m/c breakdown	Nakaiima, 1988; Babicz [65] Chan et al. [18] Van der Wal and Lynn [66] Willmott [67] Noon et al. [68] Lofsten [69]
11	Improved safety and health management	Al-Najjar and Alsyouf [27] Cooke [15] Rankin et al. [70] Patankar and Taylor [71] Bamber [60] Ireland and Dale [72] Shamsuddin et al. [73] Parida and Kumar [11]
12	Reduction in manufacturing lead time	Teresko [16] Schonberger [73] Al-Najjar and Alsyouf [27]
13	Reduction in product rejection rate	Turner et al. [74] Willmott [75] Noon et al. [68] Nakaiima, 1988; Babicz [65] Chan et al. [18] Van der Wal and Lynn [66]
14	Manufacturing cost reduction	Concetti et al. [76] Rhyne [35] Gotoh [77] Hipkin and Cock [78] Sharma et al. [40] Cua et al. [55] McKone et al. [56,57] Seth and Tripathi [79,80]; Tripathi [81]
15	Improvement in performance	Pintelon et al. [43] Bulent et al. [44] Tajiri and Gotoh [45] Hutchins [46]

Table 1: Critical success factors for implementation of maintenance management.

[82]: ISM "is used here to refer to the systematic application of some elementary notions of graph theory in such a way that theoretical, conceptual, and computational leverage is exploited to efficiently construct a directed graph, or network representation, of the complex pattern of a contextual relationship among a set of elements". Interpretive structural modeling is used for identifying and summarizing relationship among specific variables, which define a problem or an issue.

It is a process of interactive learning. According the views of SAGE during 1977, the direction and order of complex relation between factors was imposed by ISM methodology. SMEs competitiveness improved by applying ISM by Singh et al. [83,84]. For solving successful a very complex problem, ISM method is useful for implementing TPM where a no. of critical factor occur. However, the direct and indirect relationships between the factors describe the situation far more accurately than the individual factor that are taken into isolation. ISM, therefore, develops insights into collective understandings of these relationships. According to Kannan and Haq, ISM methodology is primarily intended as a group learning process, but can also be used individually in 2006. Jharkharia and Shankar [85] have applied ISM for understanding the barriers in IT-enablement of supply chains. The application of ISM typically forces managers to reassess perceived priorities and improve their understanding of the linkages among key concerns (Figure 1).

This methodology is not free from drawbacks. The main demerit of the methodology is that of the bias of the person by whom the variables are judged. The relation among the variables always depends on that person's knowledge and familiarity with the firm, its operations, and its industry [86]. This bias will affect the final build model. Similarly, ISM does not give any weights associated with the variables. The aim of this research is to identify interactions of the barriers in implementation of MM by ISM modeling.

The various steps that are involved in the ISM technique are as follows

1. Identify the elements which are relevant to the issues. This could be done by a survey or group problem solving technique.

Make certain framing senses of relation between elements with respect to which pairs of elements would be looking at.

Undergo growth to do with structure self-interaction matrix (SSIM) of parts. This matrix gives a sign of the pair-wise relation among elements of the system. This matrix is checked for transitivity.

Develop a reachability matrix from the SSIM.

2. Partition the reachability matrix into different levels.
3. Convert the reachability matrix into conical form.
4. Draw digraph based on the relationship given in reachability matrix and remove transitive links.
5. Convert the resultant digraph into an ISM-based model by replacing element nodes with the statements.
6. Review the model to check for conceptual inconsistency and make the necessary modifications.

SSIM (Structural self-interaction matrix)

To get at the details of the criteria into account framing senses of relation which is leads to. To undergo growth framing senses of

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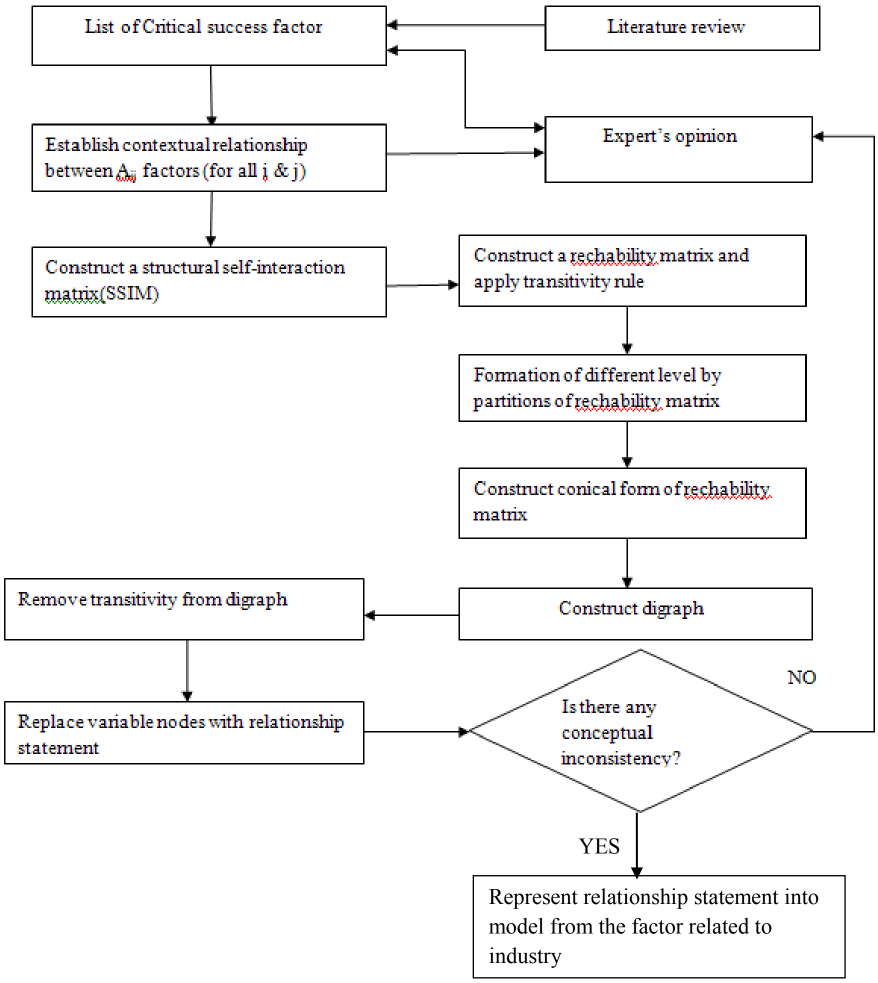

Figure 1: The flow chart of ISM methodology is shown below.

relationships between able to be changed, opinions of experts that are based on different techniques related to business managers such as brainstorming, idea engineering, only in name group way of doing, and so on were considered. In these physical operations to be stronger, total seven experts, four from industry and three from universities finally agreed to take part. To send at special quick rate the relation of full of danger factors to successfully instrument TPM, four special signs are used so in connection with be the sign of relation among parameters i and j.

(1) L: barrier i will lead or help to barrier j,

(2) D: barrier j will lead to barrier i,

(3) B: barrier i and j will lead to each other or i and j will help each other to be alleviate,

(4) I: barrier i and j are unrelated.

Based on above shown contextual relationships the SSIM is developed in Table 2.

Reachability matrix: SSIM is transformed into binary matrix by using binary number in SSIM, by substituting L, D, B and I by 1 and 0 as per the below rules also known as the initial reachability matrix:

(1) If the (a_{ij}) element in the SSIM is L, the (a_{ij}) element in the reachability matrix replace by 1 and the (a_{ji}) element by 0.

(2) If the (a_{ij}) element in the SSIM is D, the (a_{ij}) element in the reachability matrix replace by 0 and the (a_{ji}) element by 1.

(3) If the (a_{ij}) element in the SSIM is B, the (a_{ij}) element in the reachability matrix replace by 1 and the (a_{ji}) element by 1.

(4) If the (a_{ij}) element in the SSIM is I, the (a_{ij}) element in the reachability matrix replace by 0 and the (a_{ji}) element by 0.

Following above rules, the initial reachability matrix for the critical success factors is obtained. After incorporating the transitivities as described in step 1-4 of ISM methodology, Table 3 shows the final reachability matrix. Then, the driving power and dependence of each variable is shown. For each variable, the driving power is the total number of variables (including the variable itself), which may be achieved with its help. The dependence is the total number of variables (including the variable itself), which may be achieved with its help. These dependencies and driving power will be later used in the classification of variables into the four groups of autonomous, dependent, linkage and drivers (independent) (Figure 2). Source**:** Modified from Kannan et al. [87].

S. No.	Critical success factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Reduction in product rejection rate		L	L	L	L	L	L	L	L	L	L	L	L	L	L
2	Reduction in m/c breakdown			D	D	D	I	L	L	L	L	L	L	L	L	L
3	Improved safety and health management				L	I	L	L	L	L	L	L	L	L	L	L
4	Effective maintenance system					D	L	L	L	L	L	L	L	L	L	L
5	Development of maintenance strategy						L	L	L	L	L	L	L	L	L	L
6	Top management support							L	L	L	L	L	L	L	L	L
7	Employee training and empowerment								L	I	L	I	L	L	L	L
8	Quality management system									D	L	D	L	L	L	L
9	Bench marking of process										L	I	L	L	L	L
10	Organization culture											I	I	I	L	L
11	Development the coordination b/w dept.												L	L	L	L
12	Reduction in manufacturing lead time													I	L	L
13	Investment on maintenance system														L	L
14	Manufacturing cost reduction															L
15	Performance improved															

Here for *i* <j; L: factor *i* leads to factor j; D: factor j leads to factor *i*; B: no relation between *i* and j; I: factor *i* and j leads to each other

Table 2: Structural self-interaction matrix.

S. No	Critical success factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Driver Power
1	Top management support	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
2	Organization culture	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	10
3	Development of maintenance strategy	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	13
4	Employee training and empowerment	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	12
5	Investment on maintenance system	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	13
6	Development the coordination b/w dept.	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	10
7	Bench marking of process	0	0	0	0	0	0	1	1	0	1	0	1	1	1	1	7
8	Effective maintenance system	0	0	0	0	0	0	0	1	0	1	0	1	1	1	1	6
9	Quality management system	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	7
10	Reduction in m/c breakdown	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	3
11	Improved safety and health management	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	7
12	Reduction in manufacturing lead time	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3
13	Reduction in product rejection rate	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
14	Manufacturing cost reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
15	Performance improved	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Dependence	1	5	2	4	2	5	7	10	7	11	7	11	11	14	15	

Table 3: Final reachability matrix after transitivity.

Above described flow chart and their steps, which helps to the development of ISM model, are discussed below.

Final reachability matrix

The final reachability matrix is obtained by incorporating the transitivity as enumerated in Step (4) of the ISM methodology. This is shown in Table 3.

Level partitions

From the final reachability matrix, antecedent set and the reachability for each factor are found. The element itself and other elements are consisted in the reachability set, which may be achieved by its help, whereas the element itself and the other elements are consisted in the antecedent set which may be achieved by its help. Then the intersection of the above said sets is derived for all elements. The element for which the intersection sets and reachability are same is the top-level element in the ISM hierarchy by Kannan and Haq [86]. The top-level element of the hierarchy would not help achieve any other element above their own. After identifying the top-level element, it is separated from the other elements. Then by using the same process, elements of the next level is found help in building. The diagraph and final model are built with the help of these identified levels. From Table 4, it is seen that the performance improvement is found at level I. So, in the ISM hierarchy it would be positioned at the top. Repeat this iteration till the levels of each factor are found out (Tables 4-12). The identified levels aids in building the final model of ISM.

Classification of factors

In this section, the critical success factors described earlier are classified into four clusters (Figure 3). This classification is similar to that made by Mandal and Deshmukh. The first cluster consists of the "autonomous factors" that have weak dependence and weak driving power. The system, with which they have only few links which may not be strong, these factors are relatively disconnected. The "dependent factors" constitute the second cluster which has weak driving power but strong dependence. Third cluster has the "linkage factors" that have strong dependence and driving power. The fact that any change occurred to them will have an effect on others and also a feedback on them makes these factors unstable. The "independent factors" having strong driving power but weak dependence are included in the Fourth cluster. The dependence and driving power of each of these factors are shown in Table 3. In this table, an entry of "1" added along the columns and rows indicates the driving power and dependence, respectively. Subsequently, the driver power-dependence diagram is constructed

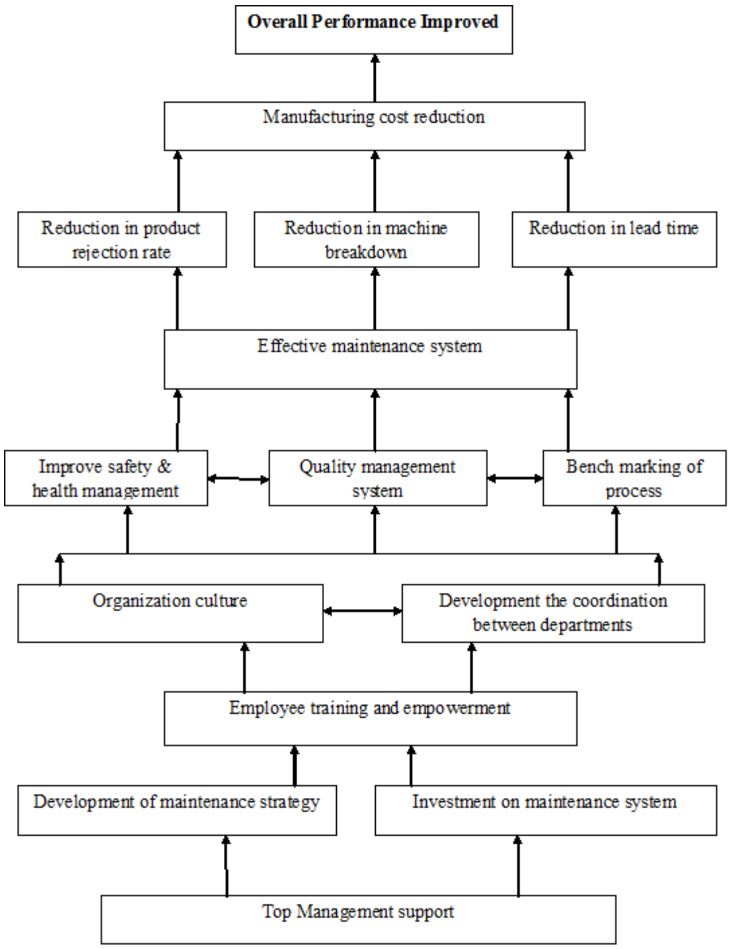

Figure 2: ISM based model for implementation of maintenance management. Source: Modified from Kannan et al. [90].

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	1	1	
2	2,7,8,9,10,11,12,13,14,15	1,2,3,4,5	2	
3	2,3,4,6,7,8,9,10,11,12,13,14,15	1,3	3	
4	2,4,6,7,8,9,10,11,12,13,14,15	1,3,4,5	4	
5	2,4,5,6,7,8,9,10,11,12,13,14,15	1,5	5	
6	6,7,8,9,10,11,12,13,14,15	1,3,4,5,6	6	
7	7,8,10,12,13,14,15	1,2,3,4,5,6,7	7	
8	8,10,12,13,14,15	1,2,3,4,5,6,7,8	8	
9	8,9,10,12,13,14,15	1,2,3,4,5,6,9	9	
10	10,14,15	1,2,3,4,5,6,7,8,9,10,11	10	
11	8,10,11,12,13,14,15	1,2,3,4,5,6,11	11	
12	12,14,15	1,2,3,4,5,6,7,8,9,11,12	12	
13	13,14,15	1,2,3,4,5,6,7,8,9,11,13	13	
14	14,15	1,2,3,4,5,6,7,8,9,10,11,12,13,14	14	
15	15	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	15	I

Table 4: First iteration.

as shown in Figure 1. For illustration, the factor five having a driving power of 7 and dependence of 1 is positioned at a place corresponding to driving power of 7 and dependency of 1 in Figure 1. All other factors considered in this study are similarly positioned on different quadrants depending on their driving power and dependency.

Formation of ISM-based model: From the final reachability matrix (Table 6), the structural model is generated by means of vertices or nodes and lines of edges. If there is a relationship between the competitiveness factors i and j this is shown by an arrow which points from i to j. The graph resulted is called a directed graph or digraph. The digraph is finally converted into ISM after removal of the transitivity as per ISM methodology.

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1	1	
2	2,7,8,9,10,11,12,13,14	1,2,3,4,5	2	
3	2,3,4,6,7,8,9,10,11,12,13,14	1,3	3	
4	2,4,6,7,8,9,10,11,12,13,14	1,3,4,5	4	
5	2,4,5,6,7,8,9,10,11,12,13,14	1,5	5	
6	6,7,8,9,10,11,12,13,14	1,3,4,5,6	6	
7	7,8,10,12,13,14	1,2,3,4,5,6,7	7	
8	8,10,12,13,14	1,2,3,4,5,6,7,8	8	
9	8,9,10,12,13,14	1,2,3,4,5,6,9	9	
10	10,14	1,2,3,4,5,6,7,8,9,10,11	10	
11	8,10,11,12,13,14	1,2,3,4,5,6,11	11	
12	12,14	1,2,3,4,5,6,7,8,9,11,12	12	
13	13,14	1,2,3,4,5,6,7,8,9,11,13	13	
14	14	1,2,3,4,5,6,7,8,9,10,11,12,13,14	14	II

Table 5: Second iteration.

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,6,7,8,9,10,11,12,13	1	1	
2	2,7,8,9,10,11,12,13	1,2,3,4,5	2	
3	2,3,4,6,7,8,9,10,11,12,13	1,3	3	
4	2,4,6,7,8,9,10,11,12,13	1,3,4,5	4	
5	2,4,5,6,7,8,9,10,11,12,13	1,5	5	
6	6,7,8,9,10,11,12,13	1,3,4,5,6	6	
7	7,8,10,12,13	1,2,3,4,5,6,7	7	
8	8,10,12,13	1,2,3,4,5,6,7,8	8	
9	8,9,10,12,13	1,2,3,4,5,6,9	9	
10	10	1,2,3,4,5,6,7,8,9,10,11	10	III
11	8,10,11,12,13	1,2,3,4,5,6,11	11	
12	12	1,2,3,4,5,6,7,8,9,11,12	12	III
13	13	1,2,3,4,5,6,7,8,9,11,13	13	III

Table 6: Third iteration.

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,6,7,8,9,11	1	1	
2	2,7,8,9, 11	1,2,3,4,5	2	
3	2,3,4,6,7,8,9,11	1,3	3	
4	2,4,6,7,8,9,11	1,3,4,5	4	
5	2,4,5,6,7,8,9,11	1,5	5	
6	6,7,8,9,11	1,3,4,5,6	6	
7	7,8	1,2,3,4,5,6,7	7	
8	8	1,2,3,4,5,6,7,8	8	IV
9	8,9	1,2,3,4,5,6,9	9	
11	8,11	1,2,3,4,5,6,11	11	

Table 7: Fourth iteration.

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,6,7, 9,11	1	1	
2	2,7, 9, 11	1,2,3,4,5	2	
3	2,3,4,6,7, 9,11	1,3	3	
4	2,4,6,7, 9,11	1,3,4,5	4	
5	2,4,5,6,7,9,11	1,5	5	
6	6,7,9,11	1,3,4,5,6	6	
7	7	1,2,3,4,5,6,7	7	V
9	9	1,2,3,4,5,6,9	9	V
11	11	1,2,3,4,5,6,11	11	V

Table 8: Fifth iteration.

Result and Discussion

ISM is a computer-based interactive learning process, used to produce structural models and also to analyze them. Since ISM is based on a group's interpretation, so it is the group's judgment that dictates whether and how the items are related; ISM is a structural approach in doing so. The final digraph model will portray the results, which are based on the element set. An ISM-based hierarchical model has been

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,6	1	1	
2	2	1,2,3,4,5	2	VI
3	2,3,4,6	1,3	3	
4	2,4,6	1,3,4,5	4	
5	2,4,5,6	1,5	5	
6	6	1,3,4,5,6	6	VI

Table 9: Sixth iteration.

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1,3,4,5	1	1	
3	3,4	1,3	3	
4	4	1,3,4,5	4	VII
5	4,5	1,5	5	
5	2,4,5,6	1,5	5	

Table 10: Seventh iteration.

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1,3,5	1	1	
3	3	1,3	3	VIII
5	5	1,5	5	VIII

Table 11: Eight iteration.

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1	1	1	IX

Table 12: Ninth iteration.

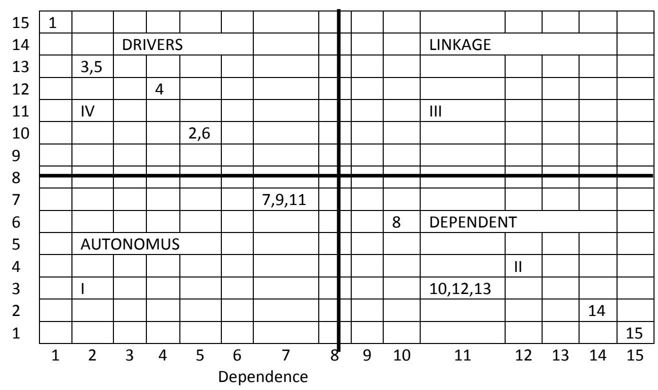

Figure 3: Driving and dependence power diagram.

developed to study the significance of the critical factors in adopting MM in the manufacturing industries. This study results in major findings as follows:

The driver-dependence matrix (Figure 1) indicated that customer involvement is an autonomous factor in this study. Autonomous barrier generally shows as weak driver and weak dependent. These variables do not have much influence on the other variables of the system.

Effective implementation of MM, reduction in manufacturing cost, lead time and product rejection rate, quality improvement and overall performance are weak drivers but strongly depends on the other barriers. Results collected from different-different survey also indicate that improvement in quality and performance, reduction in lead time are more significant and major motivating factors for MM's application. These variables are classified as dependent variables and they represent desired objectives for any organization.

There is no linkage variable which has a strong dependence as well as strong driving power. Thus, it can be concluded that among all the 15 variables chosen in this study, there is no such variable that is unstable.

The driver power dependence diagram indicates that variables are at the bottom of the model having strong driving power [88,89]. Survey results also indicate the importance of top management support, development of maintenance strategy, investment on maintenance system and organization culture for MM implementation. These variables will help organizations to achieve its desired objectives and are classified as independent variables or drivers.

This study has also tried to find levels for different variables. From the model, it is observed that overall performance of organization is at the top. Manufacturing cost reduction is at the second level. Reduction in lead time, reduction in m/c breakdown and reduction in product rejection rate are at the third level. Effective maintenance system is at fourth level. Improve safety and health management, quality management system and benchmarking a process are at the fifth level.

The remaining variables are at the lower levels. This finding implies that effective implementation of MM will help in reducing lead time, manufacturing cost and reduction in m/c breakdown, reduction in product rejection rate and in improving product quality as well as overall performance. Finally the conclusion is that all these factors will help to improve overall performance of the manufacturing organization.

Top management support, development of maintenance strategy and investment on maintenance system are at the bottom level with highest driving power. It means top management support, development of maintenance strategy and investment on maintenance system are the major drivers for successful implementation of TPM [90].

The variables with higher driving powers are more of the strategic orientation. On the other hand, the dependent variables are more towards performance orientation. Performance can be improved by continuously improving the driving variables. Based on these levels and driving power, management needs to address these driving variables more carefully. In this process, management should also consider the relationship between performance improvement and investment in technology following S-curve. According to which as funds are put into new technology, then progress is slow. Then, as research uncovers the key pieces of information necessary to make the advances, the pace surges, Progress slows down finally and each successive innovation requires a greater outlay of resources [9,91,92]. Ultimately, the S-curve levels off entirely, i.e., when the technology approaches some fundamental limit, it is important to pay attention to such limits.

They are the best clues a manager has for recognizing when a new technology must be developed in the company. The thing with great importance is selection of timing and appropriateness of technology as per market requirements and strengths of competitor. Therefore, level of MM implementation may differ between small and large-scale organizations. Authors of the view that an organization should implement new technology when competitors' technology is at the saturation level or in declining phase, as it will give competitive edge over others. Today technological discontinuities continue with increasing frequency, but during these discontinuities the organizations implementing new technology may have the advantage. In such kind of environment, organizations will have to innovate in new technologies, not once or twice in a decade, but continuously. This will be only possible if top management develop competitive strategies in a holistic manner. These strategies should focus on enablers and results such as organization culture, employees training and empowerment, development the coordination between department, effective maintenance system, quality management system, manufacturing cost and lead-time, machine breakdown etc.

According to Boyer and Pagell during 2000, new capabilities from MM implementation can be only realized when companies make infrastructural investments such as quality leadership, employee training and empowerment. In this process, investment on maintenance system will also play a crucial role because without finance, organizations will not be able to take crucial decision of technology implementation in modern maintenance management. Therefore, in implementing innovative technologies, manufacturing sector may feel some constraints due to their limited resources. In this scenario, manufacturing sector should develop strategies for collaborative use of technological resources and expertise with other organizations as it will reduce the risk of failure. Effective and economical implementation of maintenance management will help manufacturing sector in improving their performance and sustain their position in global market also.

MICMAC analysis

Mandel and Deshmukh during 1994 noticed that the idea of Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) is to analyze the driving power and the dependence of the variables or enablers. In this analysis, the maintenance management enablers, described earlier are classified into four clusters. The first cluster comprised of the "autonomous variables" that carried weak driving power and weak dependence. These enablers are relatively apart from the rest management system, with which they have only few links, which may not be strong. The "dependent enablers" constitutes of the second cluster, which carried weak driving power but strong dependence. Third cluster has the "linkage enablers" that carried strong driving power and strong dependence. If there is any change occurred to them, will have an effect on others and also a feedback on themselves, this is the reason for enablers are not stable. Fourth cluster comprised of the "independent variables" carried strong driving power but weak dependence. An entry of "1" added along the columns and rows indicates the dependence and driver, respectively we can easily conclude from the said reachability matrix, subsequently, the driving power dependence diagram has been constructed and is shown in Figure 3. For example it is also identified from Table 3 that the enabler one comprised of a driving power of 15 and dependence of 1 for that, in this figure, it is positioned at a place corresponding to driving power of 15 and dependency of 1. The "autonomous variables" that have weak driving power and weak dependence can be setting and analysis.

Concluding remarks

This work has tried to identify the barriers for successful implementation of maintenance management by manufacturing sectors to improve their performance. Successful implementation of maintenance management depends on different-different barriers related with technical expertise, resources, processes, management systems and performance. In this framework, total 15 barriers have been identified from literature review and expert meet from different interest areas. ISM approach have been applied to establish the relationship between these critical factors as well as helped to determine driving and dependence power of all barriers.

It is observed that top management support, development of maintenance strategy and investment on maintenance system are the major drivers for implementing MM. Effective implementation of MM will improve overall performance of organization in terms of lead time, manufacturing cost, machine breakdown and quality of product with reduction in product rejection rate. Management must not ignore managerial aspects such as organization culture, employee training and empowerment, development the coordination b/w departments, quality management system, effective maintenance system for effective implementation of MM.

In this work, through ISM, a relationship model among different critical factors has been developed on the suggestion given by the expert team comprising of technical and managerial experts of the manufacturing company and academicians. Structural equation modeling, also commonly known as linear structural relationship approach has the capability of testing the validity of such hypothetical model as well as applied in the future research to test the validity of this model.

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