Implementation of Maintenance Management in a Medium Size Industry for Optimization of Maintenance Cost: A Case Study

Abhishek Jain*, Harwinder Singh and Rajbir S Bhatti*****

Maintenance in Indian Small and Medium Enterprises (SMEs) is regarded as a capital-extensive approach rather than profit-making approach. The position of management is held by the owner himself in most of the Indian organizations and management always thinks to optimize the overall expenditure on equipment maintenance in SMEs. In this paper, the authors introduce a new concept of Total Productive Maintenance (TPM) as Maintenance Management (MM) for optimizing recurring maintenance costs by using Interpretive Structural Modeling (ISM) approach. The effective maintenance strategies in the manufacturing organization can help to save a huge amount of time, money and other useful resources. Generally, owners are worried about low production and its product quality, but do not try to find the causes behind this problem in SMEs. The authors in this study identify many difficulties and suggest an action plan for the same after finding the causes of these problems. The authors observe a drastic change in the targeted organization after adoption of MM.

Introduction

Most of the Indian Small and Medium Enterprises (SMEs) consider a maintenance function as a potential source of cost savings in this competitive scenario. Maintenance in Indian SMEs is regarded as a capital-extensive approach rather than profit-making approach. The position of management is held by the owner himself in most of the Indian organizations and the management always thinks to optimize the overall expenditure on equipment maintenance in SMEs. In this paper, the authors have

* Research Scholar, I K Gujral PTU, Jalandhar, Punjab, India; and is the corresponding author. E-mail: abhi_mpct@rediffmail.com

** Professor and UGC Research Awardee, Mechanical Engineering Department, GNDEC, Ludhiana, Punjab, India. E-mail: harwin75@rediffmail.com

*** Associate Professor, Mechanical Engineering Department, SBSSTC, Ferozepur, Punjab, India. E-mail: rajbirbhatti@gmail.com

focused on equipment maintenance and the expenditure incurred on this maintenance in Indian SMEs. In this setting the operators should identify the problem in machines before they can impact on production. The purpose of this case study is to implement the Maintenance Management (MM) concept in the medium size organizations. Overall maintenance cost includes recurring (regular) or non-recurring (one-time) cost (Barnabas and Janani, 2015). Failure rates, frequency of preventive maintenance, labor cost, administration cost, material cost, service cost and other miscellaneous costs of an organization can vary its overall maintenance cost. The function of this pillar is to optimize the maintenance cost. Production and maintenance units should work jointly to implement this new concept. To achieve this objective, the SMEs need better management of maintenance tasks and expenditure incurred on these tasks. MM is one of the individual pillars of the proposed Total Productive Maintenance (TPM) model for SMEs (Jain *et al.*, 2014a).

Total Productive Maintenance

The term TPM originated for the improvement of manufacturing performance, maintenance, operations and quality of product in 1971 in Japan. It has been identified as a tool by a researcher as renowned as Nakajima in 1988 for better maintenance strategies by involvement of total employees. In most of the Indian organizations, production operators are not considered as maintenance personnel, but in the concept of TPM, they should be trained for routine maintenance of their machines. Although TPM implementation gives a drastic change in manufacturing performance, still Indian manufacturing organizations are facing a lot of challenges in TPM implementation (Tripathi, 2005; Ahuja and Khamba, 2007 and 2008; Shahanaghi and Yazdia, 2009; Almeanazel, 2010; Amin *et al.,* 2013; and Jain *et al.,* 2015).

The Indian organizations have been classified on the basis of investment in plant and machinery in manufacturing and service industries as Micro, Small and Medium Enterprises (MSMEs)[1]. The micro enterprises are those in which the investment on plant and machinery does not exceed ₹25 lakh in manufacturing and ₹10 lakh in service industry. Smaller enterprises are those in which the investment on plant and machinery should be in the range of ₹25 lakh to 5 cr in manufacturing and in the range of ₹10 lakh to ₹2 cr in service industry. The medium enterprises are those in which the investment on plant and machinery should be in the range of ₹5 cr to ₹10 cr in manufacturing and ₹2 cr to ₹5 cr in service industry. Indian SMEs have some distinct limitations. Most of the SMEs do not have any well-defined approach due to the fact that the owner is in management by heredity, not by quality in these organizations. The ability of an organization (SMEs or large) to survive in this global competition depends on how well the organization adapts to market demands imposed by a changing market scenario to satisfy their customers.

[1] http://www.dcmsme.gov.in/faq/faq.htm

Literature Review

The quality and maintenance functions are vital factors for achieving sustainability in manufacturing organizations (Kaur *et al.*, 2013). The most suitable tool in the field of maintenance for making manufacturing organizations more effective is TPM (Sharma *et al.*, 2012). TPM implementation takes time and change in the attitude of both employees and management (Panneerselvam, 2012). TPM can only be implemented when both management and employees are committed, otherwise it fails. Total employee involvement, education and training of employees and continuous improvement are very strongly linked with TPM concept (Ferrari *et al.*, 1998). The skill level difference must also be considered in TPM implementation (Proma *et al.*, 2010). TPM implementation initiatives have always contributed in Indian industry to meet the challenges posed by global competition (Ahuja and Kumar, 2009). Implementation of TPM enhances the Overall Equipment Effectiveness (OEE) of machines in any organization by increasing availability, quality and performance (Wakjira and Singh, 2012). TPM implementation improves not only the OEE of large industries but also the OEE of SMEs. Implementation of mobile maintenance, a pillar of the proposed TPM model for SMEs, in a small-scale industry has increased OEE of each machine by 10-20% (Jain *et al.*, 2015). Operators on the shop floor must involve in maintenance operation and solve problems as early as possible and also try to eliminate most of the waste (Almeanazel, 2010).

The top management commitment and support are the most important success factors for enhancing employee motivation (Lazim *et al.*, 2009). Training plays a vital role in order to get success in TPM implementation (Gupta *et al.*, 2006). Jain *et al.* (2014b) said that Indian SMEs are lagging in adopting improvement philosophies like TPM, TQM, CI, etc. on the basis of literature review of a total 148 research papers published between 1988 and 2014 in various international journals published by Emerald, Science Direct, Springer, and ASME, and in conferences, books and other research outlets. According to Baglee and Knowles (2010), finance, time, skill and management awareness are the main barriers to TPM implementation in SMEs. Pramod *et al.* (2007) said that quality of maintenance tasks can be improved by implementing TPM, while Ahuja and Kumar (2009) said that overall company performance can improve with TPM implementation. A number of researchers (Nakajima 1988; McKone *et al.,* 1999; Tripathi 2005; and Ahuja and Khamba 2007) have discussed the various benefits of TPM implementation. Attri *et al.* (2012), Panneerselvam (2012) and Poduval *et al.* (2015) identified many barriers to implementing TPM in an organization by using the Interpretive Structural Modeling (ISM) approach. Cooke (2000) discussed in his study that the implementation of TPM is inhibited by political, financial, department and inter-occupational barriers, and Baglee and Knowles (2010) also identified a number of TPM implementation barriers in SMEs. Sage (1977) said that the ISM approach is suitable for establishing relationships among several factors. SMEs should be capable of giving training to their employees. Since the number of employees is very less in SMEs and they work very close to each other, it is very easy to train them as compared to large organizations (Yusof and Aspinwall, 2000). A set of typical problems and limitations in SMEs are:

- Lack of understanding regarding various improvements;
- Domination of breakdown maintenance system over preventive maintenance in most of the cases;
- Unsupportive organizational structure;
- Low level of skill/knowledge of manpower;
- Lack of specialist expertise;
- Equipment deterioration;
- A low standard of equipment maintenance;
- Lack of human resources;
- Lack of in-house training facilities;
- Lack of long-range vision and plans;
- Limited use of modern techniques;
- Lack of time to think; and
- Limited resources such as finance, time and marketing knowledge.

It is observed from the above review that literature discusses barriers to and success factors of TPM implementation, benefits, performance improvement, improvement in maintenance issues, etc., but there is no study on costs incurred on equipment maintenance. Maintenance cost is a crucial factor, especially in SMEs. The top management of Indian SMEs is always thinking to reduce the cost incurred on maintenance. Thus, the main objectives of this paper are to:

- Identify the level of various maintenance costs incurred in a medium size organization.
- Identify the interrelationship among various maintenance costs by using the ISM approach and build ISM model.
- Find the effect of MM concept in optimizing maintenance cost in the considered organization.

Maintenance Management

Nowadays, optimizing maintenance cost is of prime concern in any organization in this competitive scenario. It is very difficult to forecast the cost expended on maintenance tasks. As the performance of the equipment deteriorates over the time period, the equipment's efficiency decreases, power consumption increases, throughput is reduced and operating costs rise. The maintenance cost includes labor, administration, materials, services, failure and other miscellaneous costs (Murty and Naikan, 1995). One-time cost is known as non-recurring cost. This non-recurring cost includes design cost, implementation cost, new technology cost, training cost, warehouse cost, etc. (Carlo and Arleo, 2013). Both recurring and non-recurring costs should be considered while calculating overall maintenance cost. The authors have considered only the recurring cost in this study.

Machines or equipments have been running at risk for a long time and due to that downtime increased. Preventative maintenance is the maintenance system which can prevent failure before a problem with equipment arises. This will increase the reliability and life span of equipments and reduce the breakdown time. It is to be avoided to run machines at risk and try to keep equipments more effective to optimize maintenance costs. The top management has to take a significant responsibility to control maintenance costs. For this, a maintenance manager is primarily concerned with managing labor, materials, and overhead costs. This MM concept can play a vital role for large industries as well as SMEs to optimize maintenance costs. Maintenance managers must concentrate on the reduction of the maintenance cost. Proper maintenance schedule or charts must be displayed on board in maintenance department and also on individual machines. A poor maintenance policy can increase production costs that are many times bigger than those attributable to maintenance labor, materials, parts, and overhead. The concept of MM is contributing in production, quality and maintenance. According to Al-Najjar (2007), maintenance can affect production in two ways. The first is to reduce production costs by elimination of stoppage, increased availability, reduction of repair costs, increasing service intervals, etc., and the second way is to increase productivity by providing better maintenance actions. Also, it can affect product quality by well-maintained equipment and machines.

Purpose of Maintenance Management

The purpose of maintenance management is to:

- Reduce the equipment maintenance cost.
- Identify the actual problem in the machine so that they can take the right decision either to repair the part or change the part.
- Reduce the negligence by maintenance workers in the maintenance work so that the part will either be repaired or changed as early as possible.
- Improve the safety and morale of the staff.
- Reduce equipment breakdowns or increase the life of equipments.

Target of Maintenance Management

- Reduce Mean Time to Repair (MTTR).
- Improve Mean Time Between Failure (MTBF).

- Reduce maintenance cost by 40%.
- Keep all equipments in optimum working condition.

Data and Methodology

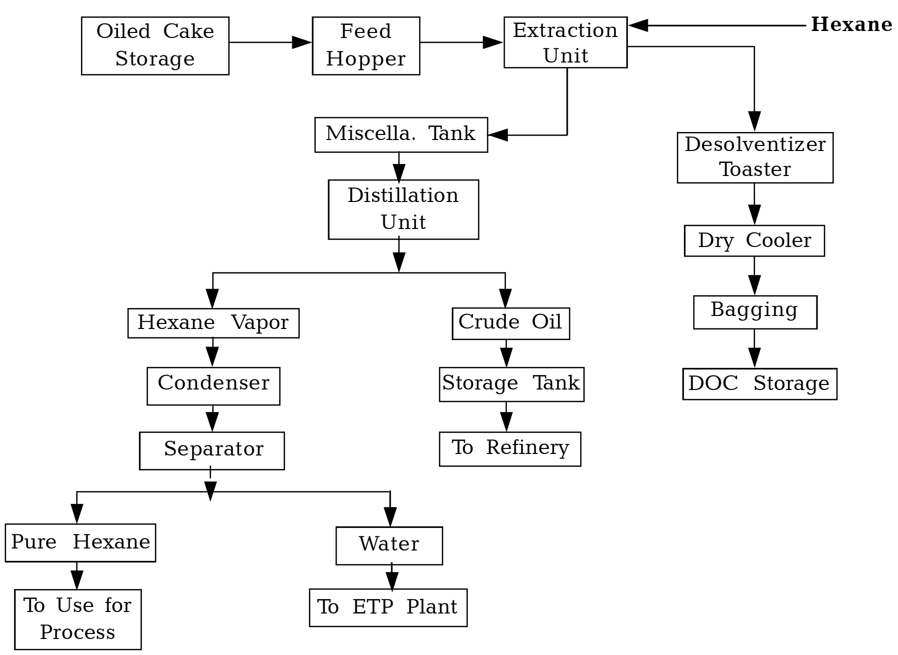
The case study technique has been applied in the present paper. This case study is based on implementation of MM in a medium size enterprise to optimize maintenance costs. The available improvement techniques do not include the calculation or optimization of maintenance cost. To optimize maintenance costs, maintenance team is being asked to do more with less.

The Sample Company

A medium size oil extraction plant situated in Banmore industrial area of Madhya Pradesh was considered for this study. This oil extraction unit consists of oiled cake storage, feed hopper, extraction plant, desolventizer toaster, dry cooler, missile tank, distillation unit, De-Oiled Cake (DOC) storage, condenser, separator, hexane tank, crude oil storage tank, etc. as shown in Figure 1.

The company chosen in this case study to evaluate the impact of MM implementation is a medium-sized enterprise (with turnover of more than ₹5 cr, but less than ₹10 cr). It is an oil extraction plant. The raw material used in this plant is mustard oil cake, which is available on expeller, and finished goods are edible oil and DOC. This medium

Figure 1: Block Diagram of Oil Extraction Unit



size industry is having one oil extraction unit of capacity 500 MT/day and one refinery unit of 50 MT/day. It also has a cooling tower for the cooling of water and boiler used in refinery unit. The total area on which the plant is installed is 15 Bigha. The maintenance department of this industry has maintenance manager, engineers and also foremen and fitters. The production department includes one production head, two production engineers, supervisors and operators. They all are working under a general manager and all other operators are working under production and maintenance head. The equipment, on average, is 3 to 5 years old.

Solvent Extraction Process

Extraction is a process where two immiscible liquid phases come in contact through mixing. An extraction procedure is one that separates one constituent phase from another. The solvent extraction process is used to recover more than 99% of oil from the input material. It is the most popular method for extraction of oils due to its high percentage of oil recovery. It can also be used to recover oil from pre-pressed oil cakes obtained from high oil content materials. The optimum size of input material should be maintained for the proper preparation of materials before extraction process for the efficient use of this extraction unit. The optimum size of material is not too large or too small. Figure 2 illustrates the solvent extraction plant.

Figure 2: Oil Extraction Plant

Problem Statement

The maintenance department of the considered organization does not have proper manuals and always tried to find solutions to problems in their own way; for example, the maintenance personnel just changed the items or equipments which failed. Maintenance system in this considered organization was not good as observed during visits by the authors. The organization uses 85% breakdown and 15% preventive type maintenance as shown in Figure 3.

This poor maintenance system has an adverse effect on machine conditions, productivity and company growth. Figure 4 illustrates that 3% of idle time is due to shortage of manpower, 5% of the idle time is due to power failure, 2% of the idle time is due to unavailability of spare parts, 6% of the idle time is due to negligence, and the remaining 84% of idle time is due to breakdown of machines and other minor stoppages. The authors also conducted personal interviews with employees and asked a few

Figure 3: Maintenance Policy of the Company

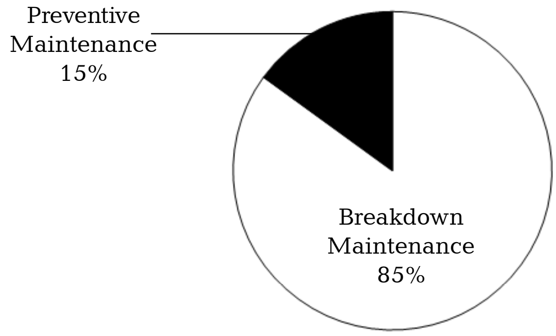
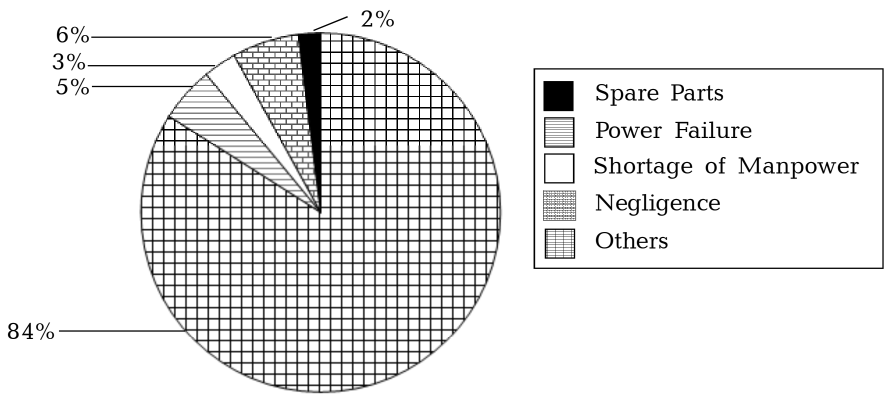


Figure 4: Idle Time Distribution



questions and recorded their responses, which are consolidated and presented in Table 1, to get the actual status of maintenance in the targeted medium size industry.

The authors observed that the top management of the company instructs the operators to run their machines without delay and they are supposed to concentrate on production target and not on maintenance issues. The maintenance manager had not identified which maintenance strategy is suitable for different machines in various circumstances. As a result of the unplanned maintenance strategy of equipments, unorganized maintenance or production teams, frequent breakdowns of machines, unavailability of parts, unskilled manpower, etc., expenditure incurred in maintenance was increasing day-by-day.

The authors also collected the details of maintenance cost incurred in the last six months as shown in Table 2. Maintenance cost incurred on various maintenance tasks was very high. The various maintenance costs incurred were near about 15% on outsourcing maintenance, 28% on consumable items, 32% on spare parts, 9% on over time and total 16% on the other cost as shown in Figure 5.

Table 1: Personal Interview with Employees

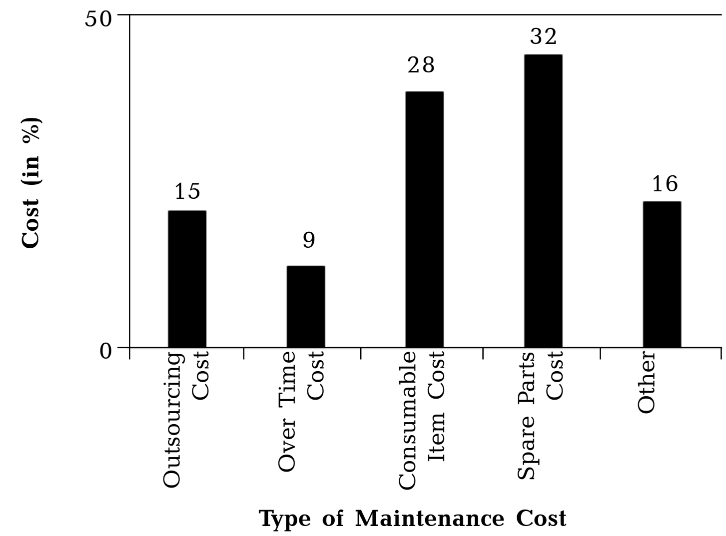
(in %)

S. No.	Questions Asked to Operators (50)	No	Not Sure	Yes
1.	You all are feeling empowered by contributing your ideas for continual improvement.	**68**	20	12
2.	There is any policy of awarding operators for their valuable contribution.	**64**	28	8
3.	There is any idle machine time due to any cause as power failure, shortage of spare parts, etc.	30	20	**50**
4.	Top management is focused on production targets.	10	20	**70**
5.	Top management is focused on maintenance issues.	**56**	24	20
6.	Maintenance department and top management are responsible for maintenance.	22	28	**50**
S. No.	**Questions Asked to Engineers or Managers (10)**	**No**	**Not Sure**	**Yes**
1.	You explain to your employees the mission and vision of the company.	**70**	20	10
2.	Employees know the company maintenance goals.	**60**	20	20
3.	There is any continuous improvement philosophy in your company.	**80**	20	–
4.	There is any autonomous maintenance system in your company.	**80**	20	–
5.	There is a breakdown maintenance concept in your company.	10	20	**70**
6.	There is a preventive maintenance concept in your company.	**60**	20	20
7.	Maintenance benchmarking is done.	**70**	20	10
8.	Maintenance manual is available in your company.	**60**	20	20
9.	There is any specific maintenance strategy for breakdown in various circumstances.	**80**	20	–
10.	There is unwillingness in your employees to take part in maintenance tasks.	10	20	**70**
S. No.	**Questions Asked to All the Employees (60)**	**No**	**Not Sure**	**Yes**
1.	Your top management is thinking of cost-effectiveness during maintenance.	**67**	25	8
2.	There is any training program conducted for employees in your company.	**77**	20	3
3.	Management is visibly involved in developing a maintenance culture.	**83**	10	7
4.	A mutually supportive partnership between management and employees exists.	**80**	13	7
5.	Top management is interested in continual improvement of maintenance functions.	**70**	25	5
6.	There is any measurement of maintenance performance.	**83**	17	–
7.	Everyone is responsible for maintenance.	**50**	27	23

Table 2: Details of Maintenance Costs, Down Time and Production Before MM Implementation

Cost/ Month	Maintenance Cost (in ₹)							Total Down Time (in h)		Production (in ton)	
	Out-sourcing Cost (C1)	Consu-mable Items (C2)	Spare Parts (C3)	Over Time Cost (C4)	Other Service Cost (C5)	Other Material Cost (C6)	Total Cost (in ₹)	Small Break-down Time	Shut Down Time	Edible Oil	DOC
Jan 14	4,840	6,440	8,680	1,220	1,760	2,140	25,080	64	12	1030	11,500
Feb 14	3,720	8,840	9,830	4,720	960	3,740	31,810	68	16	850	10,080
Mar 14	4,660	7,880	8,700	1,780	1,940	2,890	27,850	71	20	920	10,700
Apr 14	4,420	6,900	7,910	1,440	1,460	2,420	24,550	64	12	980	11,500
May 14	4,340	9,110	9,840	4,080	1,220	2,720	31,310	65	16	930	10,500
June 14	4,210	8,880	8,460	2,260	2,120	3,140	29,070	66	20	1060	11,700
Total	26,190	48,050	53,420	15,500	9,460	17,050	169,670	398	96	5770	65,980
% Cost	15.4	28.4	31.6	9.1	5.5	10	**100**				
Mean	**4,363**	**8,008**	**8,903**	**2,583**	1,576	2,842	28,278	66	16	962	10,997

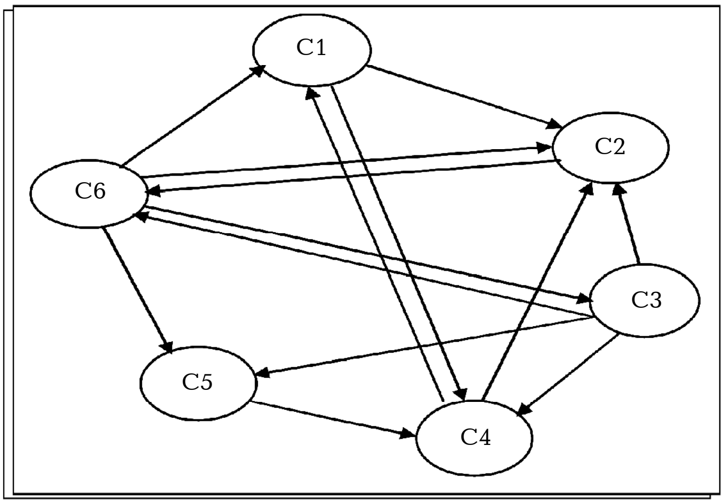
Figure 5: Classification of Maintenance Cost



ISM Technique

ISM is an appropriate method to study the interrelationship or interdependencies among factors or to find the factors that play a dominant role in a specific issue. The ISM approach has been applied in many fields for analyzing the interrelationship among factors as barriers, success factors, etc. The authors found six costs like: outsourcing cost (C1), consumable items cost (C2), spare parts cost (C3), over time cost (C4), other service cost (C5), and other material cost (C6) in this study. In this paper, the authors needed to find the most crucial or influencing costs so that they could work on these particular costs for the reduction of total recurring maintenance cost, because every individual cost is linked with the other remaining costs. The authors present a diagram showing the interrelationship or interdependencies among these six various costs as per the suggestions given by the experts of the same organization (Figure 6). A diagram is defined as a set of nodes which are interlinked together as per the relationship in the matrix (F, R, FR or X) and all the links are shown as arrows indicating the direction from one node to the other. Hence, these costs should be leveled. For leveling these costs, the authors used the concept of ISM technique. Following are the steps of the ISM approach used in this case study.

Figure 6: Diagram for Various Costs



Developing Structural Self-Interaction Matrix (SSIM)

The interrelationships among various costs have been identified as shown in the diagram. Now this pairwise relationship is built into a matrix. Let us explain this procedure of making the matrix by taking all six costs as C1, C2, C3, C4, C5 and C6 in this specific problem. These costs are written on the Y and X axes of the matrix. Cell Cij of the matrix indicates the relationship direction between the cost Ci (on the Y-axis) to the cost Cj (on the X-axis). For example, C46 indicates the relationship between C4 on the Y-axis and C6 on the X-axis. Let us define the following relationships:

- F: Forward relationship from Ci to Cj, i.e., Ci helps to achieve or influences Cj;
- R: Reverse relationship from Cj to Ci, i.e., Cj helps to achieve or influences Ci;

- FR: Dual directional relationship, i.e., Ci and Cj help to achieve or influence each other; and
- X: No relationship exists between Ci and Cj.

A typical SSIM for this specific problem is shown in Figure 7.

Figure 7: Structural Self-Interaction Matrix (SSIM)

Axis	X-Axis							
Y-Axis	Cost		C1	C2	C3	C4	C5	C6
	C1	Outsourcing cost	1	F	X	FR	X	R
	C2	Consumable items cost		1	R	R	X	FR
	C3	Spare parts cost			1	F	F	FR
	C4	Overtime cost				1	R	X
	C5	Other service cost					1	R
	C6	Other material cost						1

Developing Reachability Matrix

After making the SSIM, the authors prepared a reachability matrix by substituting the value of F, R, FR and X by 1 and 0 as per the case. The conversion of SSIM into the reachability matrix is according to the rule given in Table 3.

Table 3: Binary Format Conversion

	Cij	Cji
F	1	0
R	0	1
FR	1	1
X	0	0

The reachability matrix for this study is presented in Table 4. Just to understand the procedure, take the example of the relationship between C2 and C5; the relationship being X, the cells C25 and C52 in the reachability matrix are designated as 0. Another example is the relationship between C3-C4; the relationship being forward (F), the cell C34 is designated as 1 and C43 is designated as 0. This means that factor C3

Table 4: Reachability Matrix

Costs	C1	C2	C3	C4	C5	C6
C1	1	1	0	1	0	0
C2	0	1	0	0	0	1
C3	0	1	1	1	1	1
C4	1	1	0	1	0	0
C5	0	0	0	1	1	0
C6	1	1	1	0	1	1

helps to reach or achieve factor C4, but not vice versa. One more example of the relationship is C5-C6; the relationship being reversed (R), the cell C56 is designated as 0 and C65 is designated as 1. Lastly, the relationship between C2 and C6; the relationship being dual (FR), both the cells C26 and C62 are designated as 1.

Defining Reachability, Antecedent and Intersection Sets

The reachability matrix can be used to develop a hierarchical restructuring. For this, the authors have to first define reachability and antecedent sets. The set for each cost contains costs whose cells in the row pertaining to the cost are allotted '1' in the reachability matrix as reachability set. For example, for cost C1, the reachability set is (C1, C2 and C4). Similarly, the set for each cost contains costs whose cells in the column pertaining to the costs are allotted '1' in the reachability matrix as antecedent set. For example, for factor C3, the antecedent set is (C3 and C6). Reachability and antecedent sets of the remaining costs can be thus found out in the same way. The costs common to both reachability and antecedent sets belong to the intersection set. Table 5 represents the reachability, antecedent and intersection set in a reachability matrix of all the six costs.

Developing Level Partitions

This matrix for reachability set, antecedent set and intersection set is the final reachability matrix that is used for building the ISM. The level partitions, i.e., different levels, are to be developed based on a series of iterations. The level for which the reachability and intersection sets are the same in the final reachability matrix is known as Level-1.

Table 5: Reachability, Antecedent and Intersection Sets for Reachability Matrix

Costs	Reachability Set	Antecedent Set	Intersection Set	Remarks
C1	C1,C2,C4	C1,C4,C6	C1,C4	
C2	**C2,C6**	**C1,C2,C3,C4,C6**	**C2,C6**	**Level-1**
C3	C2,C3,C4,C5,C6	C3,C6	C3,C6	
C4	C1,C2,C4	C1,C3,C4,C5	C1,C4	
C5	C4,C5	C3,C5,C6	C5	
C6	C1,C2,C3,C5,C6	C2,C3,C6	C2,C3,C6	
2nd Interaction				
C1	**C1,C4**	**C1,C4**	**C1,C4**	**Level-2**
C3	C3,C4,C5	C3	C3	
C4	**C1,C4**	**C1,C3,C4,C5**	**C1,C4**	**Level-2**
C5	C4,C5	C3,C5	C5	
C6	C1,C3,C5	C3	C3	

Table 5 (Cont.)

Costs	Reachability Set	Antecedent Set	Intersection Set	Remarks
3rd Interaction				
C3	C3,C5	C3	C3	
C5	**C5**	**C3,C5**	**C5**	**Level-3**
C6	C3,C5	C3	C3	
4th Interaction				
C3	**C3**	**C3**	**C3**	**Level-4**
C6	**C3**	**C3**	**C3**	

Level-2 is developed by removing the costs occupying Level-1 and also from the reachability, antecedent and intersection sets of the cost which does not occupy Level-1. Similarly, Level-3 and Level-4 are found. In our example, only C2 occupies Level-1 and hence the row of cost C6 and cost C6 from all the rows are to be removed in the first interaction. Similarly, Level-2, Level-3, and Level-4 can be found out as shown in Table 5.

Developing Conical Matrix with Driving and Dependence Power

It is evolved by organizing the costs depending on their levels across the rows and columns of the reachability matrix (Attri *et al.*, 2012; 2013a; and 2013b). In this case, the cost is written based on their levels starting from Level-1 on the X-axis and Y-axis. In our example, the cost C2 occupies the Level-1 and is first written on the X and Y axes. The costs C4 and C1 both occupy the Level-2 and are written after Level-1. The cost C5 occupies Level-3, and at the last, costs C6 and C3 both occupy Level-4. The conical matrix is similar to the reachability matrix with the exception that the costs in the conical matrix are written on the X and Y axes based on their levels. The conical matrix for our example is given in Table 6.

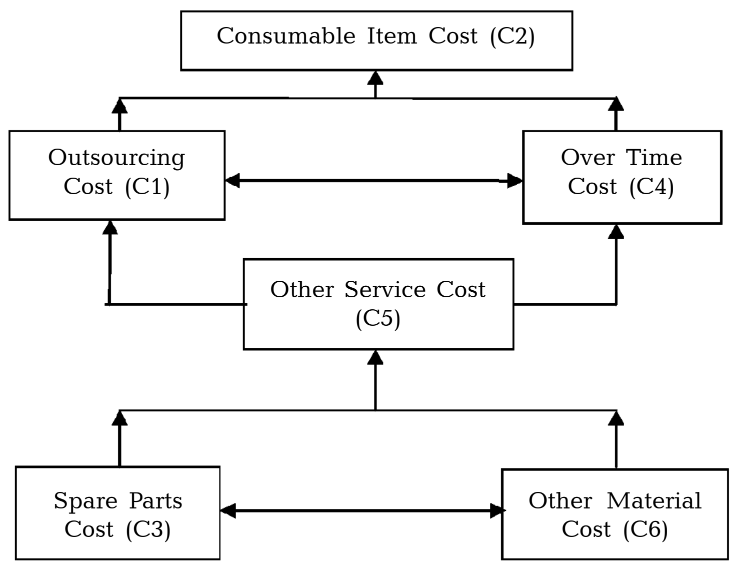
Table 6: Conical Matrix

Costs	C2	C4	C1	C5	C6	C3	Driving Power
C2	1	0	0	0	1	0	2
C4	1	1	1	0	0	0	3
C1	1	1	1	0	0	0	3
C5	0	1	0	1	0	0	2
C6	1	0	1	1	1	1	5
C3	1	1	0	1	1	1	5
Dependence	5	4	3	3	3	2	

Building Interpretive Structural Model

The ISM for our example is shown in Figure 8. The ISM helps us to derive the relationships between the various costs in this problem. It is also a matter of interest to know the degree to which each cost influences and gets influenced by the other costs in this problem. This is done by using MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) analysis.

Figure 8: ISM Model



Implementation of Maintenance Management

Most of manufacturing organizations still consider equipments maintenance as a low priority, which is one of the main barriers (Ahmed *et al.*, 2004). Plant maintenance may vary with size, type, age, complexity of the organization, operator's attitude, investment strength and skill level differences. Due to lack of finance, time, skill and awareness, most of the Indian SMEs are already facing problems.

To reduce maintenance expenditure in this medium size enterprise, the MM strategy should be adopted and supported by preventive maintenance and maintenance planning strategies for successful implementation. For employees to perform each and every task efficiently, the authors feel that there is an urgent need for training for production and maintenance operators. Training should be given:

- For 100% visual inspection for detection of leakage, vibrations, etc.
- To maintenance employees to check each and every machine component of an extraction plant at regular time intervals.

- To maintenance employees to perform preventive maintenance task at regular interval to prevent breakdowns.
- To operators for routine maintenance of machines as oil, hexane, steam pressure, and water checking to promote ownership.
- To all the employees at all levels to focus on reducing overall maintenance cost.
- To operators by shop floor in-charge regarding how to check the size of mustard oil cake before entering into the conveyor.
- To shift engineers to maintain product quality through PDCA cycle.
- To shift in-charge to maintain good relationship between maintenance and production departments.
- To untrained production and maintenance personnel to perform their task very efficiently.

A well-organized maintenance system in an organization increases machine availability and reduces downtime of machine, production losses and overtime cost. It also improves the safety of all the employees.

Data Collection

The unexpected breakdowns of machines can be reduced by implementing TPM. These breakdowns disrupt production, increase losses and finally exceed the annual expenditure. The company should use systematic maintenance in which the failure and their causes should be recorded. The authors also observed some difficulties and classified them on the basis of man, material, machine and method. Table 7 illustrates these difficulties and their action plan.

The authors also identified various routine abnormalities in this extraction unit and recorded the location of these abnormalities, its effect, causes and countermeasures and also the person responsible for individual abnormalities (Table 8). Extraction unit needs to improve its process and maintenance system.

Based on the findings, the authors have given a few suggestions to the production and maintenance teams.

Suggestions for Production Department

- The mustard oil cake should be cracked into optimum size.
- Large variation of size leads to improper cracking results in the high residual oil content in DOC. High oil content in seed leads to high phosphatides content in crude oil.
- Retention time in Desolventizer Toaster (DT) should be more than 1 hour.
- The foreign matter in the seed before procurement was in excess, i.e., more

Table 7: Difficulties and their Action Plan		
S. No.	**Difficulty**	**Action Plan**
Material		
1.	The large size of the input Mustard Oil Cake (MOC)	Size of MOC should be optimized, not very large or very small, before entering into the conveyor.
2.	Improper storage of MOC	Provide a closed space for MOC.
3.	Old MOC mixed with fresh MOC	Collect dirty MOC from the floor and clean before mixing with fresh MOC.
4.	Uneven quality of input material	Check quality of MOC in laboratory before entering into the conveyor.
Man		
1.	Untrained operator	Provide training to operators.
2.	Sometimes casual labor	Depute only trained operators.
3.	Fatigue of operators	Depute extra operator.
Machine		
1.	Bearing jamming	Provide preventive maintenance (oil, grease, etc.) at regular interval.
2.	Loose hopper	First tighten it.
3.	Loose screw fitting	Make preventive maintenance schedule.
4.	Conveyor chain breaks	Make preventive maintenance schedule.
5.	Emergency switch damage	Correct all these damages immediately.
6.	Varying speed of band conveyor	It is the duty of shift in-charge to check it hourly.
7.	Improper maintenance of level indicators	Make preventive maintenance schedule.
Method		
1.	Improper method of loading MOC into hopper	MOC should be loaded with instrument into hopper and gloves should be worn by operators.
2.	Improper hexane supply	To be checked on an hourly basis by shift in-charge.
3.	High consumption of hexane	Make preventive maintenance schedules and prevent leakages.
4.	Uncleaned workplace	Depute extra workforce for cleaning of work place.
5.	Operators are not wearing gloves	Provide hand gloves to all the operators during working hours.

Table 8: Problem Identification Chart in Extraction Unit

S. No.	Abnormality	Location	Abnormality Effect	Cause of Abnormality	Countermeasures	Responsibility
1.	Tool table oily	Near extraction unit	Looks bad	Negligence	Clean it properly	Maint.
2.	Loose screws	Gate of extraction unit, conveyor, miscellaneous tank, desolventizing toaster, etc.		Negligence	Tighten and check it regularly	Maint.
3.	Oil split while cleaning	Every unit	Oil wastage	Oiling method is not proper	Improve oiling method	Maint.
4.	Machine base found unclean	Every stage	Looks bad	Negligence	Clean it properly	Product.
5.	Electric wires not covered	Two to three places in this unit	Power failure due to tripping	Negligence	Cover these wires properly	Maint.
6.	Screws are missing	Oil storage tank	Oil wastage	Negligence	Repair	Maint.
7.	Pipe joint leakage	Near storage tank	Oil wastage	Negligence	Repair	Maint.
8.	Electric wires open	Near DOC storage	Looks bad	Negligence	Provide cover	Maint.
9.	Electric panel loose	Near extraction unit	Accident occurs	Negligence	Tighten it properly	Maint.
10.	Chain break	Extraction conveyor	Stop process	Not checked regularly	Should be checked at regular interval	Maint.
11.	Chain break	Chain conveyor	Stop process	Not checked regularly	Should be checked at regular interval	Maint.
12.	Motor smoke	Main conveyor	Stop process	Not checked regularly	Should lubricated at regular interval	Maint.
13.	Bearing jamming	Main motor	Stop process	Not checked regularly	Arrange spare motor	Maint.

Table 8 (Cont.)

S. No.	Abnormality	Location	Abnormality Effect	Cause of Abnormality	Countermeasures	Responsibility
14.	Control panel dirty	Main	Looks bad	Negligence	Clean it properly	Product.
15.	Emergency switch not working	Conveyor	Accident occurs	Not repaired	Repair	Maint.
16.	Conveyor belt slip	Main conveyor	Stop process	Not maintained	Check it at regular interval	Maint.
17.	Floor area not clean	Overall	Looks bad	Negligence	Clean it on daily basis	Product.
18.	Loose screw	Hopper	Vibration	Negligence	Tighten it properly	Maint.
19.	Condenser not working	Main unit	Show error	Not maintained	Check it at regular interval	Maint.
20.	Level indicators	All	Show error	Not checked	Check these at regular interval	Maint.
21.	Loose joint	Hexane pipe supply	Hexane vaporize	Negligence	Tighten it properly	Maint.
22.	Work place dirty	Overall	Looks bad	Negligence	Clean it at regular interval	Product.
23.	Untrained manpower	Overall	Indirect losses	Lack of awareness	Arrange training program	Product.
24.	Large size of MOC	At input stage	Indirect losses	Negligence	Paste details of size of MOC at input stage; also provide training	Product.
25.	Fatigue of operators	All	Indirect losses	Lack of awareness	Provide extra operators	Product.

than 2-3%. The excess foreign matter will damage the machinery. So it should be reduced.

- The solvency ratio (solvent/seed) should be in the range of 0.8~0.9. High solvent ratio results in high load on distillation plant and low solvent ratio increases the high residual oil content in DOC.
- The input hexane in the extractor should be such that the miscellaneous concentration is in the range of 25~35%.
- Hexane drainage time in extractor should increase to maintain the hexane concentration in wet DOC in the range of 30~35%.
- Hexane loss in Solvent Extraction Plant (SEP) should be in the range of 2.0~3.0 L/ton of seed process.
- The oil content in DOC should be in the range of 0.6-0.8%.
- The refined oil should be stored at room temperature to avoid oxidation of the oil.
- The refined oil should be packed with nitrogen gas media to avoid oxidation of the oil.

Suggestions for Maintenance Department

- Maintenance retention time in the extractor unit should be in the range of 1.5-2.5 h.
- Low temperature (as minimum as 6 °C) should be maintained for condenser cooling.
- Adequate steam supply (quantity and pressure) should be ensured without interruptions by the boiler.
- Cooking temperature should be maintained in the range of 70~80 °C. Low cooking temperature results in poor flaking and high cooking temperature darkens the color of the crude mustard oil.
- Stripping and flash point temperature of crude mustard oil should be more than 100 °C and temperature at top of DT should be maintained in the range of 70~72 °C.
- Introduce and prepare a preventive maintenance schedule for all the machines.
- Maintain optimum bed thickness and steam pressure in the desolventization compartment of DT.

Results and Discussion

Table 9 clearly shows that the percentage reduction of outsourcing cost, consumable items cost, spare parts cost, overtime cost, other service cost and other material cost are 46.5, 50.2, 62.1, 88.7, 18.3 and 44.1 respectively after implementation of MM.

Table 9: Details of Maintenance Costs After MM Implementation											
Cost/ Month	Maintenance Cost (in ₹)							Total Down Time (in h)		Production (in ton)	
	Out Sourcing Cost (C1)	Consu-mable Items (C2)	Spare Parts (C3)	Over Time Cost (C4)	Other Service Cost (C5)	Other Material Cost (C6)	Total Cost (in ₹)	Small Break-down Time	Shut Down Time	Edible Oil	DOC
Oct 14	2,780	3,940	3,670	900	1,170	1,710	14,170	36	6	1050	11500
Nov 14	1,940	4,140	3,280	–	1,470	1,400	12,230	40	6	1175	12500
Dec 14	2,270	3,880	3,160	–	1,220	1,660	12,190	32	8	1160	12300
Total	6,990	11,960	10,110	900	3,860	4,770	38,590	108	20	3385	36300
% Cost	18.1	31	26.2	2.3	10	12.4	**100**	–	–	–	–
Mean	2330	**3986**	**3370**	300	1287	1590	12863	**36**	7	1128	12100
% Cost Reduction	46.5	50.2	62.1	88.7	18.3	44.1	54.6	–	–	–	–

The main aim of this paper was to identify the most influencing maintenance costs and how to reduce various recurring maintenance costs. First of all, the authors classified all recurring maintenance costs in six different categories which are collected from the targeted medium size organization and also conducted personal interviews with employees at various levels to find out the overall maintenance status of the organization. The authors used ISM technique for leveling these various recurring maintenance costs for identifying the most influencing maintenance cost. This study indicates that the consumable item cost (C2) is at Level-1 and outsourcing cost (C1) and overtime cost (C4) are occupying Level-2 in ISM model. The authors have considered only the first three maintenance costs (C1, C2 and C4) from the ISM model for optimization. All the recurring maintenance costs (C1 to C6) are interlinked with each other as shown earlier. Hence, the remaining maintenance costs such as spare parts cost (C3), other service cost (C5) and other material cost (C6) will also be affected with optimization of the first three maintenance costs. The authors observed some difficulties in this organization and classified them on the basis of material, man, machine and method and tabulated them with their action plan. The authors also prepared a problem identification chart for the maintenance department to perform preventive maintenance.

Conclusion

Competition among SMEs and continuously increasing standards of customer satisfaction are never-ending. Indian SMEs are not aware of the fact that adoption of at least a few pillars of TPM will definitely enhance the performance and culture of the organization. Most of SMEs have adopted the reactive maintenance system. But the main disadvantages of adopting reactive maintenance are higher maintenance costs and un-identification of the main cause of the problems, which in turn leads to higher maintenance cost. Cost incurred on maintenance tasks in SMEs is a very critical issue nowadays. This paper focuses on optimization of various recurring maintenance costs. It also explains the concept of MM in detail for understanding the actual aim of this concept. The authors conducted personal interviews with all the employees to get the actual status of maintenance in this targeted medium size organization and noted down the difficulties faced by the employees. Then, they analyzed the causes of these difficulties and made the action plan to resolve these difficulties. The maintenance system of this considered medium size oil extraction plant was too poor as observed by the authors. However, this targeted medium size industry experienced drastic changes in the form of reduction in breakdowns and shut down time of machines and maintenance cost by more than 50%. Thus, in this study the authors discuss the importance of the MM concept in the survival of Indian SMEs.

The main findings are as follows:

- Leveling of various recurring maintenance costs has been done by using ISM techniques to identify the most influencing cost and the costs in the descending order of influence are C2, C4, C1, C5, C6 and C3.
- All recurring maintenance costs are interlinked with each other hence improvement in C2, C4 and C1 will definitely influence all other remaining costs.
- The results of this research clearly show that the percentage reduction of various maintenance costs such as outsourcing cost, consumable item cost, spare parts cost, overtime cost, other service cost and other material cost are 46.5, 50.2, 62.1, 88.71, 18.3 and 44.1 respectively after implementing MM concept which is more than 40% is almost all the cases.
- This research also shows that the mean breakdown and shut down time has reduced (66 h and 16 h to 36 h and 7 h respectively) as well as production of edible oil and DOC has increased after MM implementation.
- Preventive maintenance concept and maintenance planning are the supportive pillars for MM implementation to reduce or optimize maintenance cost.

Limitations and Scope for Future Research: This study suffers from a limitation, that is, for maintenance cost optimization by MM, only recurring cost has been considered. Therefore, in future studies:

1. Nonrecurring costs can also be considered in cost optimization.
2. A linear programming model can be developed for optimization of overall maintenance cost.
3. Analysis and interpretation of data can be carried out by using the SPSS programming.❖

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