# MQFD: A MODEL FOR SYNERGIZING TPM AND QFD

*A Thesis*

*Submitted by*


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# Certificate

This is to certify that the thesis entitled **"MQFD: A Model for Synergizing TPM and QFD"** is a report of original work carried out by Shri.Pramod.V.R, under my supervision and guidance in School of Engineering. No part of the work reported in this thesis has been presented for any other degree from any other institution.

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# DECLARATION

I here by declare that the work presented in this thesis is based on the original work done by me under the super vision of Prof.(Dr.) V. P. Jagathy Raj, Professor, School Of Management Studies, Cochin University of Science and Technology, Kochi ~~in~~ School of Engineering . No part of this thesis has been presented for any other degree from any other institution.

Pramod .V.R

Kochi - 22

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***Pramod.V.R***

## ABSTRACT

This thesis presents the methodology of linking Total Productive Maintenance (TPM) and Quality Function Deployment (QFD). The Synergic power of TPM and QFD led to the formation of a new maintenance model named Maintenance Quality Function Deployment (MQFD). This model was found so powerful that, it could overcome the drawbacks of TPM, by taking care of customer voices. Those voices of customers are used to develop the house of quality. The outputs of house of quality, which are in the form of technical languages, are submitted to the top management for making strategic decisions. The technical languages, which are concerned with enhancing maintenance quality, are strategically directed by the top management towards their adoption of eight TPM pillars. The TPM characteristics developed through the development of eight pillars are fed into the production system, where their implementation is focused towards increasing the values of the maintenance quality parameters, namely overall equipment efficiency (OEE), mean time between failures (MTBF), mean time to repair (MTTR), performance quality, availability and mean down time (MDT). The outputs from production system are required to be reflected in the form of business values namely improved maintenance quality, increased profit, upgraded core competence, and enhanced goodwill. A unique feature of the MQFD model is that it is not necessary to change or dismantle the existing process of developing house of quality and TPM projects, which may already be under practice in the company concerned. Thus, the MQFD model enables the tactical marriage between QFD and TPM.

First, the literature was reviewed. The results of this review indicated that no activities had so far been reported on integrating QFD in TPM and vice versa. During the second phase, a survey was conducted in six companies in which TPM had been implemented. The objective of this survey was to locate any traces of QFD implementation in TPM programme being implemented in these companies. This survey results indicated that no effort on integrating QFD in TPM had been made in these companies. After completing these two phases of activities, the MQFD model was designed. The details of this work are presented in this research work. Followed by this, the explorative studies on implementing this MQFD model in real time environments were conducted. In addition to that, an empirical study was carried out to examine the receptivity of MQFD model among the practitioners and multifarious organizational cultures. Finally, a sensitivity analysis was conducted to find the hierarchy of various factors influencing MQFD in a company. Throughout the research work, the theory and practice of MQFD were juxtaposed by presenting and publishing papers among scholarly communities and conducting case studies in real time scenario.

Keywords: TPM, QFD, MQFD, Receptivity

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# NOMENCLATURE

| | |
|---|---|
| AHP | Analytical Hierarchy Process |
| HoQ | House of Quality |
| IIM | Indian Institute of management |
| INR | Indian Rupees |
| MDT | Mean Down Time |
| MQFD | Maintenance Quality Function Deployment |
| MTBF | Mean Time Between Failure |
| MTTR | Mean Time To Repair |
| OEE | Overall Equipment Effectiveness |
| PMA | Palakkad management association |
| PPH | Planned production hours |
| QFD | Quality Function Deployment |
| TPD | Tones Per Day |
| TPM | Total Productive Maintenance |
| RPN | Risk Priority Number |
| CTI | Customer Technical Interactive |
| CWTI | Correlated Weightage of Technical Language |
| PPH | Planned Production Hours |

Chapter · 1

# INTRODUCTION

*Content*

# INTRODUCTION

## 1.1. Background

Immediately after the Second World War, the world began to witness the competitive era. In order to thrive in this competitive era, mankind is forced to evolve new and better methodologies, models and innovations. Time and again, many strategies have been adopted by the global community to face this situation. Maintenance is one of such strategies used in this competitive battleground (Murthy,et al, 2002, Tsang, 1998, and Tsang and Chan, 2000). One of the most popular maintenance models that are being currently discussed curiously among the researchers and practitioners over the past two decades is "Total Productive Maintenance (TPM)". Although TPM was propagated during 1970s, it became popular among the researchers and practitioners only after late 1980s. TPM emanated due to the realization that the maintenance activities should not only be technologically improved but also blended with managerial concepts (Blanchard 1997). Particularly the relevance of implementing total quality for enhancing the quality of maintenance activities facilitated the evolution of TPM concepts. Today TPM is being implemented in numerous countries and fields (Ahmed et.al, 2005, Chan et.al,2005).

The fast rate of acceptance of TPM indicates the practitioners' thirst for improving maintenance quality. However a critical analysis of the theory indicates that TPM concepts are not yet exhaustive to effect continuous maintenance quality improvement. Presumably, due to this reason, articles introducing many new tools, techniques and approaches are intended for enhancing the efficacies of TPM keep emerging in literature world (Blanchard 1997, Bamber et. al. 1999).

In essence, TPM couples the principles of maintenance engineering and Total Quality management (TQM). While many TQM strategies have been adopted, the strategy of infusing quality in maintenance engineering in accordance to the customer reactions is yet to find its authentic place in the TPM field. Meanwhile, it is observed that in this contemporary industrial scenario, customer aspirations have become the central core of business (Paiste, 2003). While referring to various literatures on TPM, it was observed that there has been no tool or technique available in TPM to take care of customer views properly. However in TQM field, QFD has been predominantly used as an efficient tool in this direction (Chan and Wu, 2002). In this context, during the research work reported in this thesis, efforts were made to integrate the principles of QFD with that of TPM. This gave rise to the evolution of a model named "Maintenance Quality Function deployment" (MQFD). During this research work, this model was subjected to implementation studies in various industrial and educational scenarios. Further, the method of enhancing the efficacy of this model was also examined.

First, the literature was reviewed. The results of this review indicated that no activities had so far been reported on integrating QFD in TPM and vice versa. During the second phase, a survey conducted among six companies in which TPM had been implemented. The objective of this survey was to locate any traces of QFD implementation in TPM programme being implemented in these companies. This survey results indicated that no effort on integrating QFD in TPM had been made in these companies. After completing these two phases of activities, the MQFD model was designed. The details of this work are presented in this research work. Followed by this, explorative studies on implementing this MQFD model in real time environments were conducted. In addition to that an empirical study was carried out to examine the receptivity of MQFD model among the practitioners and multifarious organizational cultures. Finally, a sensitivity analysis was conducted to find the hierarchy of various factors influencing MQFD in a company. Through out the research work, the theory and practice of MQFD were juxtaposed by presenting and publishing papers among scholarly communities and conducting case studies in real time scenario.

## 1.2. Research Problem

Currently organizations have realized the importance by attaining maintenance quality continuously for attaining core competence in global market. Researchers and theoreticians have suggested the use of TPM concepts for this purpose. However, it has been observed that there is no tool and technique accommodated in TPM concepts to transfer the voice of customers into practical scenario. TPM is the conglomeration of TQM and maintenance engineering principles. When TPM concepts are studied and viewed from this perspective, it is found that TPM concepts are not exhaustive in suggesting the solutions for taking care of customer voices. However, no, maintenance model exists that can take care of customers voices. In this background, the problem of the research work has been defined as follows:

"TPM is ineffective in taking care of customer voices".

## 1.3. Research objectives

The objectives of the research are enumerated below.

1. To study the fundamental tenets of TPM and QFD.
2. To study the various models deploying TPM and QFD.
3. To design a theoretical model which would link the features of TPM and QFD
4. To conduct investigations on the theoretically designed model.
5. To explore the practical feasibility of the theoretically designed model by conducting case studies and receptivity analysis.
6. To study the behavior of the theoretically designed model in multifarious organizational cultures.
7. To carryout sensitivity analysis of various factors influencing the theoretically designed model.

## 1.4. Research methodology

The research was carried out to accomplish the objectives by following a systematic methodology. The steps followed are shown in Figure 1.1. First, the books dealing with TPM and QFD principles were studied. Then, literatures dealing with fundamentals of TPM were studied. Also, the author attended a winter school titled "Total Productive Maintenance and Strategic Maintenance Quality Engineering", organized by Dr. S.R Devadasan and Dr. S.Muthu, sponsored by All India Council of Technical Education, India, held at PSG College of Technology, Coimbatore, India. Secondly, a theoretical model titled as " Maintenance Quality Function Deployment" (MQFD) was designed by integrating TPM and QFD principles. Thirdly, investigations were conducted with the objective of studying the practical feasibility of MQFD implementation.

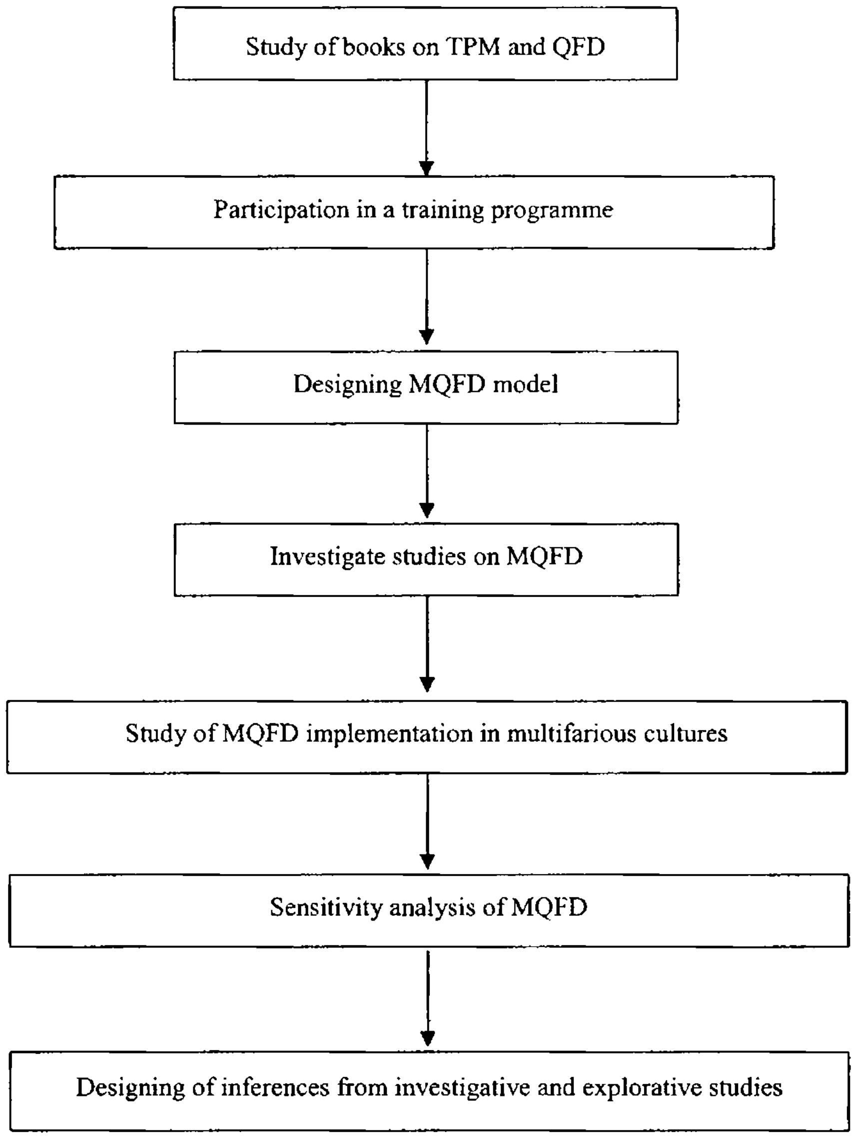



**Figure 1.1. Research methodology**

Fourthly, an empirical study was conducted to explore the practical feasibility of applying MQFD model holistically in multifarious cultures and environments. Fifthly, the sensitivity analysis of MQFD using AHP was studied. Finally the prerequisites for successfully implementing MQFD in practical environments were explored.

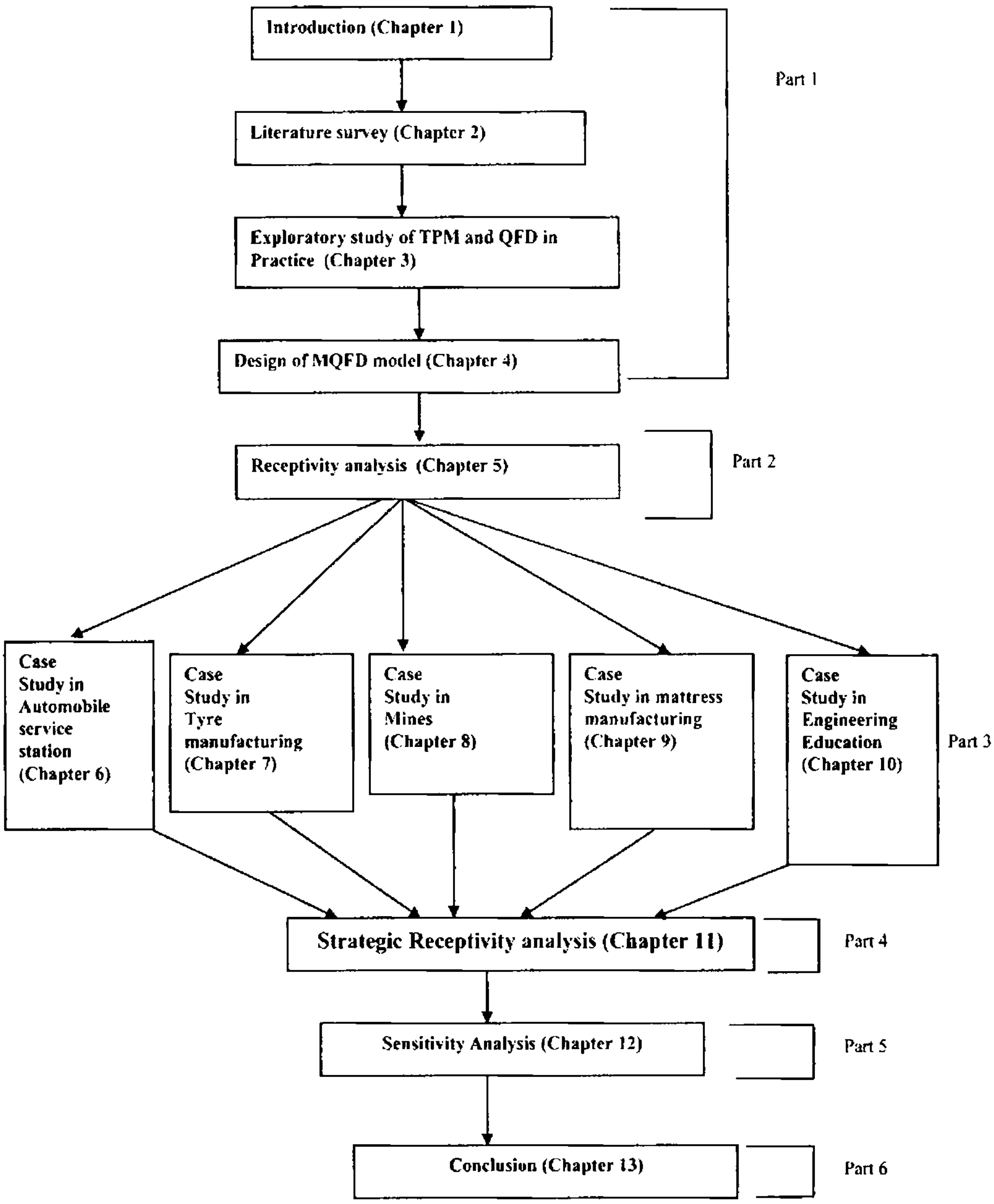



**Figure1. 2. Chapter organization of the research work**

## 1.5. Chapter organization

This research work is reported in this thesis in six parts. In the first part, the antecedent of initiating this research work has been apprised by presenting the literature survey reporting the study of previous works on TPM and QFD. After that, the principles behind designing MQFD model are described. These details are presented in the first four chapters. Second part deals with the receptivity study of MQFD, which was concluded on the podiums of academicians and practitioners. This study is discussed in the fifth chapter. Third part deals with the implementation studies. These studies are presented in chapters 6-10. Fourth part deals with the strategic receptivity of MQFD in multifarious organizational climates. This part of this research work is narrated in chapter 11. Fifth part deals with the sensitivity analysis of factors influencing MQFD implementation. The details of this study, which was carried out using the technique Analytical Hierarchy Process (AHP), are explained in chapter 12. Sixth part of the thesis deals with the concluding remarks of this research work, which are presented, in chapter 13.

## 1.6. Conclusion

This thesis reports a research work, which has resulted in the evolution of a model called MQFD. During this research work, unrealistic assumptions have been avoided. Hence, it is expected that both theoreticians and practitioners would find it convenient to read through the chapters of this doctoral thesis.

Chapter - 2

# LITERATURE SURVEY

*Content*

# LITERATURE SURVEY

## 2.1. Introduction

In this chapter, the literatures surveyed during this research work are narrated from three different views. First, the status reports of TPM and QFD have been appraised from the literature perspective. Second, the intrusion of TPM into QFD and vice versa is examined by citing relevant papers. Third, the impact of TPM and QFD in engineering education has been presented. These narrations reveal the gaps existing in research arena with respect to the integration of TPM and QFD.

## 2.2. QFD: A perspective from literature

The origin of QFD is traced to the quality tables that were developed in Kobo Shipyard, Japan in the year 1960.The formal appearance of QFD as the TQM technique was made possible through the works of Yoji Akao in the year 1972 (Akao and Mazur 2003).Thereafter the popularity of QFD spread across the world. Also a large number of case studies reporting QFD's successful implementation and its benefits appeared in literature (Chan and Wu 2002). A few researchers have brought out different definitions (Zairi and Youssef 1995) leading to the proposition that QFD is a technique used for converting customers' vague languages into technical languages. Therefore QFD facilitates deployment of customers' voices into practising environment. In this era of increasing competition, QFD is supposed to reveal the hidden and open voices of customers and support the organizational managers in meeting market requirements.

The implementation of QFD progresses through the development of a composite matrix known as House of Quality (HoQ). The conceptual features of HoQ are shown in Figure 2.1. As shown, HoQ consists of six main sub-matrices (Kumar and Midha 2002, Han et.al, 2001). The construction of HoQ begins by developing customer language matrix whose inputs are vague customer voices. Consequently, the second matrix titled 'ranking of customer languages' is developed. The values indicating the ranks of the customer languages are determined by considering the competitors' performance and companys' affordability in fulfilling the customer languages. The third matrix consisting of the technical languages corresponding to the customer languages is developed. The fourth matrix is constructed by entering values to represent the degree of relationships between customers and technical languages. The fifth matrix consisting of values representing the ranking of technical languages is then formed. The sixth and last major sub-matrix of HoQ is the correlation matrix, which is constructed by entering the values to represent the correlation among the technical languages. All these matrices developed are joined to construct HoQ.

The construction of HoQ requires the involvement of personnel with adequate theoretical and practical knowledge about the customers' voices that are under consideration. Followed by the development of HoQ, the engineers and production managers are required to study the completed QFD's contents and develop target values and process plans. Thus the customer voices are translated into technical languages through the development of HoQ, which penetrates into the field of practice.

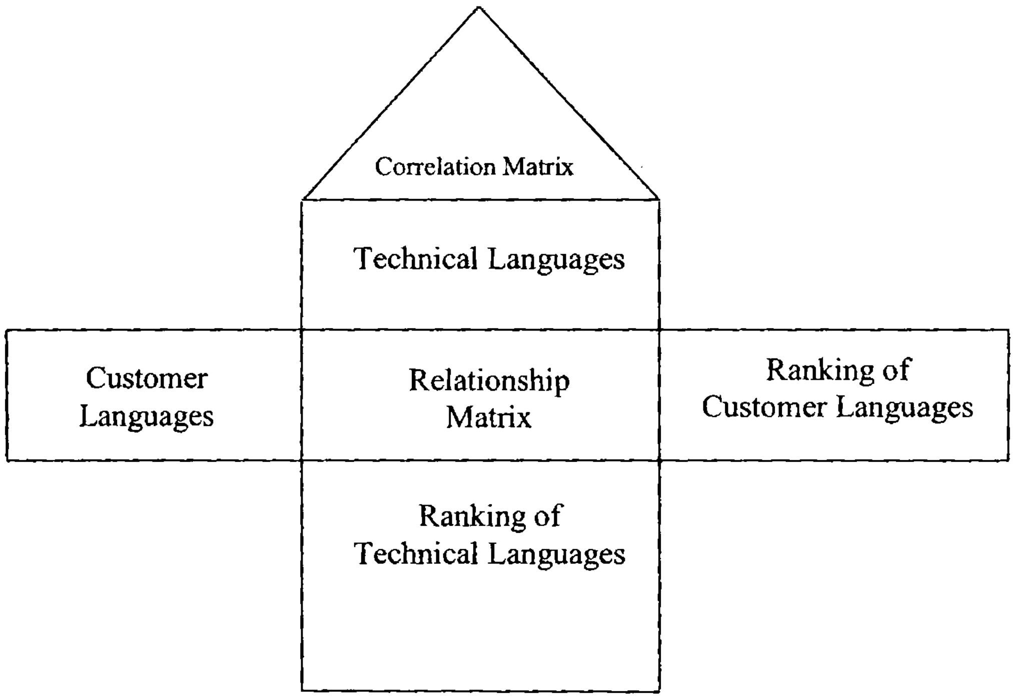



**Figure 2.1.** Format of HoQ Matrix

During the earlier days of its birth, QFD was used as a product development (Lokmay and Khurana, 1995) technique. However during the recent times, it is proved to be a feasible technique for several applications where customer voices are required to be translated into technical languages (Han and Wu, 2002; Sahney et.al.2003; Sahney et.al.2004).

## 2. 3. TPM: A perspective from literature

The origin of TPM is traced to 1970 and as in the case of QFD, its place of birth is Japan (Cooke 2002, Ireland and Dale 2001). Before the evolution of TPM, the field of maintenance engineering was adopting technology oriented approaches like condition monitoring, preventive maintenance and reliability centered maintenance. Presumably on realizing the absence of totality and human elements, the principles of TPM were promoted by Japanese Institute of Plant Maintenance (JIPM) (Bamper et.al 1999). Later it spread to different parts of the world including western countries.

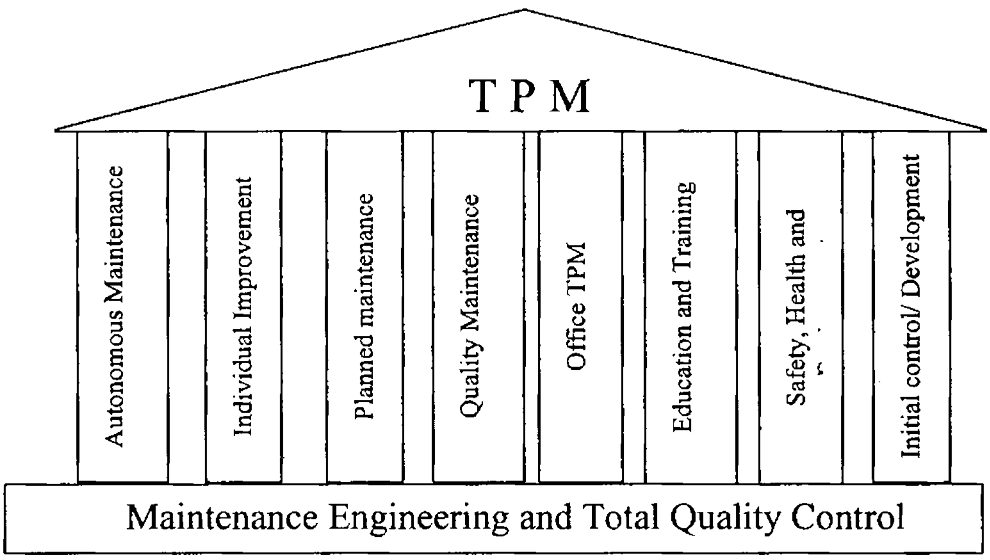



**Figure 2.2 Eight-TPM Pillars**

Fundamentally TPM encompasses various elements of TQM and maintenance engineering. In fact there have been researches linking TPM with quality (Ben-Daya and Duffuaa, 1999). Because of the shadowing of TQM, TPM envisages the total involvement of employees towards enhancing maintenance quality with equipments (Cooke 2000, Ireland and Dale, 2001). Several definitions of TPM have been brought out (Bamber et.al, 1999). Several approaches of implementing TPM have also been brought out. A bird's eye view of literature would indicate that eight pillar approach of implementing TPM is the most exhaustive one (Yamashina, 2000; Cigolini and Turco,1997). The conceptual features of this approach are depicted in Figure 2.2. As shown, maintenance engineering and total quality control form the foundation of TPM programe. After laying this foundation, TPM programme is developed by constructing the following eight pillars (Ahmed et.al, 2005). The conceptual features of these pillars briefly describe in the following eight sections. Simultaneous review of articles by Ahmed.et.al .(2005), Cigolini and Turco .(1997), Ireland and Dale (2001), Bamber et.al (1999). and Patra et.al (2005) would reveal that the pillar numbers from five to eight have grown from the earlier days of TPM to the contemporary days.

### 2.3.1. Autonomous Maintenance (A M)

According to this pillar, the sense of ownership over the equipment operated by the workers shall have to be developed. In other words, the worker should consider the equipment that he/ she operates as his/ her own child and in case of its failure, the worker should react immediately to restore its status quo. This is a contradiction to the traditional maintenance engineering approach in which even minor maintenance problems are attended by the employees working in maintenance engineering department (Cooke, 2000).

### 2.3.2. Individual Improvement (I I)

According to this pillar, the worker has to improve himself/ herself to the extent of attending to maintenance failures. He/she must also learn to analyze the cause of maintenance failures using tools like why-why analysis and performance measurement analysis. This is a contradiction to the conventional maintenance engineering approach in which, a separate team consisting of maintenance engineering professionals carries out the analysis and finds out the causes of maintenance failures. The solution provided through this conventional approach often would fail to penetrate into the field conditions because of its incompatibility.

### 2.3.3. Planned Maintenance (P M)

This pillar is a shadowed from of conventional preventive maintenance approach (Ireland and Dale 2001). In order to build this pillar, the maintenance schedule must be drawn in advance. Besides, provision should be made to allot sufficient resources to meet the planned schedule. Another aspect of this pillar is the control of maintenance costs and elimination of equipment losses. Six big losses identified in TPM field are (Chan et.al,2005),

a. Breakdown losses
b. Set-up and adjustment losses
c. Minor/ Idling stoppage losses
d. Reduced speed losses
e. Defect/ Rework losses
f. Start-up losses

### 2.3.4. Quality Maintenance (Q M)

In order to construct this pillar, the organization has to inculcate the culture of zero defect philosophy and use of all resources including equipments for attaining continuous quality improvement. In the absence of TPM, the equipment is never a focus for achieving quality of operations.

### 2.3.5. Office TPM (O TPM)

In order to construct this pillar, the smart methods and administrative activities shall have to be promoted to support TPM activities. Further cost reduction in maintenance of equipments shall have to be supported by office administration. This is a unique emphasis of TPM since no other model on continuous improvement has envisaged the supporting role of office administration in organisations.

### 2.3.6. Education and Training (E & T)

According to this pillar, the employees of different levels must be imparted education and training on TPM. Such programmes may deal with the TPM tools and techniques. Although training is imparted to employees even in conventional maintenance approach, its scope is restricted to a section of workers working in maintenance engineering department.

### 2.3.7. Safety Health and Environment (S H E)

This pillar encompasses the humane approach. According to this pillar, the TPM programme has to evolve a policy on environment, health and safety, which has to be strictly enforced with the commitment and support of the management. Further the awareness on environment, health and safety among the employees shall be effected through the adoption of top down approach, installation of relevant facilities and imparting education and training.

### 2.3.8. Initial control/ Development Management (I C/ D M)

In order to construct this pillar, the TPM programme shall allow the review of designs for preventing further mistakes, use of manufacturing process data and establishment of equipments start up times. These principles are not followed in conventional maintenance engineering approaches.

In a nutshell, the implementation of TPM is marked by the construction of the eight pillars and prevention of equipment losses. After constructing these pillars to different heights, the TPM programme is liable to contribute higher degree of maintenance quality. In order to assess the level of maintenance quality, the literature on TPM envisages the usage of the parameter known as Overall Equipment Effectiveness (OEE). The computation of OEE is carried out using the following mathematical formulae (Nakaajima, 1993).

OEE = Availability x Performance Efficiency x Rate of Quality of Products

Some authors claim that OEE is the only parameter that has got the capability to indicate the maintenance quality of equipments in organization

(Kwon and Lee, 2004). However, some authors have claimed that OEE alone cannot be considered as performance indicator of TPM programmes (Blanchard 1997). Hence it is recommended that the parameters namely Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), Performance Quality, Mean Down Time (MDT) and Availability, which require only simple computations, shall also be used for assessing maintenance quality level. According to the management policy, any one of the above performance measurement parameters or group of them shall be chosen to measure the maintenance quality level of the equipments.

Today literature is available to indicate the application of TPM to various extent in different countries (Eti et.al,2004, Tsang and Chan 2000, Ahmed et.al 2004, Cigolilini and Turco, 1997). To cap it all, TPM is considered to be one of the world class manufacturing strategies (Yamashina, 2000, Bamber et.al, 1999). These developments indicate the prowess of TPM which has played a phenomenal role in revolutionizing maintenance management and engineering approaches and thus have gained a heritage position in world class manufacturing principles. However like any other managerial and technological models, TPM also suffers from certain drawbacks. Particularly its scope is restricted to enhancing maintenance quality of equipments only. Its scope does not extent to enhancing maintenance quality of products and services offered by the organizations. Presumably, due to this limitation, TPM models have not been incorporated with customer voice adoption techniques like QFD.

## 2.4. QFD in TPM and vice versa: a literature perspective

After studying the characteristics of TPM and QFD, the author developed an impression that QFD adoption in TPM projects would be a synergizing contribution to TPM professionals. Hence the author aspired to locate any work that reports the adoption of QFD in TPM projects and vice versa. At this juncture, it was very encouraging to see an article by Chan and Wu (2002). They have reviewed as many as 650 publications, which is considered to be relatively an exhaustive literature on QFD. They have dealt with QFD right from its birth to its dissemination to various countries and fields. They have listed the popular application fields of QFD, which include product development, quality management and customer need analysis. They have also identified the industrial sectors in which QFD is applied. Some of them are transportation, communication, software systems and manufacturing. In addition to that, they have listed articles, which report the linking of QFD with simultaneous engineering, knowledge intensive engineering, quality engineering, rehabilitation engineering, requirement engineering, and so on. However this list does not include TPM. On the whole, the review of this paper clearly indicated the absence of any work linking QFD with TPM . In order to further confirm the absence of QFD application in TPM field, some more papers were reviewed in this direction. The details of reviewing these articles are briefly described in this section.

Terziovski, and Sohal, (2000) have collected responses from approximately 400 Managers. They have discussed the use of seven new quality tools, namely, Failure Mode and Effect Analysis, QFD, Creativity tools, Standardization tools and "5S" for achieving continuous improvement. They have cited that some companies use TPM as a tool for Kaizen. However they have not indicated any work involving the application of QFD in TPM and vice versa. Rho et.al (2001) concentrated on various studies designed to investigate the relationship between manufacturing strategies, practices, and performance. They have compared the results from three different nations namely Korea, U.S and Japan. They have included TPM and QFD in their studies but have not attempted to integrate them. Negri and Galli (1997) have worked on the quality improvement strategies in Italy and have cited that TPM influences process control on preventive basis and minimizes down time. They have identified QFD as one of the most effective and reliable approaches. However they have not mingled QFD and TPM with each other in their studies.

Voss and Blackmon (1998) studied the differences in manufacturing strategies between Japanese and Western manufacturing companies. Cultural differences caused difference in attitude towards the duration of implementation, which led to the adoption of long term and short term strategies. They have analyzed the data that have been drawn from 600 companies situated in 20 countries. They have mentioned that Japanese considered TPM as one of the long-term strategies. They have reported a higher level of adoption of QFD than TPM in Japan. They have also reported higher payoff of TPM than QFD, whereas this trend is reversed in western countries. However the difference in these quantified parameters is very less and hence, we inferred that TPM and QFD are dominating both Western and Japanese companies. However, this study reveals no integration between TPM and QFD principles.

After realizing the absence of any article regarding the integration of QFD and TPM, the author developed curiosity to check whether any attempts have been made to link any other manufacturing strategies with them. It was quiet surprising to see few articles, which have emerged in this direction. Those linking efforts exerted by TPM and QFD researchers and practitioners are presented in Tables 2.1 and 2.2. As seen, these articles indicate the feasibility of linking both TPM and QFD with other similar approaches with different combinations. Hence it was inferred that the synergizing of QFD and TPM principles would also be a feasible proposition.

**Table 2.1. Articles reporting the linking of TPM with other manufacturing strategies and principles**

| Articles | Contribution |
|---|---|
| McKone et. al. (2001) | Have presented a framework for linking TPM with JIT and manufacturing performance. |
| Mc Kone et. al. (1999) | Have presented a framework for linking TPM with environment, organisational and managerial contexts. |
| Cua et. Al. (2001) | Have presented a framework for linking TPM with JIT |

**Table 2.2. Articles reporting the linking of QFD with other manufacturing strategies and principles**

| Articles | Contribution |
|---|---|
| Olhager and West (2002) | An improved version of HoQ called House of Flexibility has been presented. (QFD and Manufacturing Flexibility principles are linked.) |
| Witter et.al. (1995) | A model called 'enhanced QFD has been presented. The Concept of reusability has been linked with QFD. |
| Ginn et. al. ( 1998) | A model interfacing QFD and FMEA has been proposed. |

## 2.5. TPM and QFD In Engineering Education

The ever-rising global competitive waves keep invading all fields and geographical regions. This phenomenon has been pressing mankind to infuse higher degree of quality in all spheres of products, processes and services (Prendergast.et.al ,2001,Chong and Rundus, 2004). The knowledge required for attaining higher degree of quality originates from the brains of human resources. Hence a society will be enjoying higher degree of quality of life, if its human resources are effectively groomed and developed. The responsibility for contributing highly useful human resources for the welfare of the society of all regions is lying with educational institutions. Today globalization process progresses at a faster pace making the humans face common challenges irrespective of the societies and countries to which they belong (Irandoust And Sjoberg, 2001). In most of the societies these challenges are largely tackled by engineering professionals (Paten et.al, 2005). Hence, a large portion of social contribution originates from engineering educational institutions (Johnston, 2001). Needless to mention, the engineering educational institutions have to contribute high quality human resources who are not only technocrats but also society-friendly individuals (Perez-Foguet et.al, 2005). While the business world has been reporting the adoption of different continuous quality improvement models (Kaye and Anderson,1999), the examination of their application feasibility for infusing higher degree of quality in engineering education will lead to useful contribution to all kinds of societies over the globe(Johnston,2001).

Total quality management (TQM) models have revolutionized the organizations of all types (Chong and Rundus, 2004, Hoque, 2003,Montes.et.al,2003). Presumably due to this reason, during the recent years, some engineering educationalists and researchers have been striving to apply TQM and its techniques in engineering education (Sahney et.al,2004). Some engineering educational institutions have started practising TQM (Jaraiedi and Ritz,1994, Prendergast.et.al ,2001, Swift,J.A, 1996). These efforts are getting focused on attaining specific strategies. For example, the engineering educational institutions are becoming quality system conscious since many of them have implemented ISO 9001: 2000 quality system standard. Likewise Hwarng and Teo, (2001) and Lam and Zhao, (1998) have reported the pilot implementation of QFD in engineering education. These efforts have yielded in achieving higher degree of quality in administering engineering educational institutions, testing the students' capabilities to meet the requirements of their employer and building excellence in the learning of engineering advancements (Ferrer-Balas et.al, 2004). These favourable results indicate that, on application of well-proven quality engineering and management models, the quality level of engineering education would rise. In this context, during this research work, it was foreseen that the synergising effect of implementing TPM and QFD together would trigger significant stride in attaining higher degree of quality in engineering education. However, it appears that no researcher and practitioner has so far attempted to link these two techniques and apply them in the engineering educational scenario.

## 2.6. Conclusion

The world community began to realize the importance of quality when competitive war invaded the globe after the Second World War (Cooke, 2003). Various Total Quality Management (TQM) techniques and tools were almost immediately implemented in different organizational cultures as a sequel to the competitive war (Irani et al.,2004, Kaynak, 2003, Hoque,2003, Jung and Wang ,2004, Sahney et al,2004, and Montes et al., 2003). Amidst this visible and pompous trend, a humble revolution has been taking place in the field of maintenance engineering (Tsang and Chan,2000). This revolution is today addressed under the name TPM. Before the evolution of TPM, the maintenance engineering community was exposed largely to technologically oriented approaches (Deshpande and Modak,2002, Eti.et al., 2004, Murthy,et al,2002). These approaches segregated maintenance activities from the mainstream operations of the organizations. The emanation of TPM was a strategic change in the maintenance engineering arena because, unlike the previous approaches, TPM linked maintenance engineering with human elements like operator empowerment and involvement (Nakajima, 1993).

Today in parallel with the TQM implementation, a significant number of organizations have been adopting TPM (Mc Kone et al.,1999, Cua et al., 2001, Mc Kone et al.,2001) The objective of this effort is to achieve high degree of competitiveness through the enhancement of maintenance quality. The age of TPM is little more than three decades and its adoption has resulted in various benefits including the reduction in rejections, reworks and stoppages of equipments (Chan,et al.,2005). Of late, the researchers have been trying to establish the link between TPM and TQM (Miyake and Enkawa,1999). This is presumably due to the reason that both principles dominate world-class organizational cultures and offer benefits in various forms and magnitudes (Mitchel et.al, 2002; Cua et al., 2001; McKone et al., 1999; McKone et al., 2001; Yamashina, 2000). These researchers' findings indicate the imperativeness of interlinking TQM strategies with TPM. However, the literature overview would indicate that both research and practice in the direction of interlinking specific TQM strategies with TPM have been dismally low. Particularly both TQM and TPM envisage the customer satisfaction (Jostes and Helms,1994). In TQM field, customer satisfaction is given significant thrust whereas in TPM field, the thrust on customer satisfaction has been given only indirect and minimum thrust.

In TQM field, the customer satisfaction is achieved through customer voice adoption (Hwarng and Teo, 2001). In order to achieve this strategy, the technique, QFD technique is being dominantly employed in TQM field (Fung et al., 1999,Zairi and Yousef,1996, Kathawala, and Motwani, 1994, Bouchereau, and Rownalds, 2000, Masui,et al., 2003). However, no specific technique is envisaged in TPM field to achieve customer satisfaction. Considering the power of customer satisfaction in improving quality, it is imperative that both TPM and QFD have to be interlinked.

Besides achieving higher degree of quality levels, recent researchers have been appraising the need for sustaining engineering education (Ashford, 2004, Ferrer-Balas et.al, 2004). The sustainability of engineering education is ensured by maintaining the quality of engineering education. TPM provides a way for bringing out such kind of changed scenario in engineering education. Another requirement of engineering education is to react according to its customers. In practical application, the technique QFD is found to meet this requirement. Hence the application feasibility of QFD in engineering educational scenario has to be studied. However both TPM and QFD cannot be applied in their present forms in engineering education since they are compatible with applications only in manufacturing and service organizations. In order to accomplish this process, both QFD and TPM have to be remoulded in a systematic way, so that they are made suitable for application in engineering educational scenario.

Chapter - 3

# QFD AND TPM: A SURVEY IN PRACTICING ENVIRONMENT

*Content*

# QFD AND TPM: A SURVEY IN PRACTICING ENVIRONMENT

## 3.1. Introduction

While the literature review hinted the absence of any work on the integration of QFD with TPM programs, the author developed interest to assess the status in the practical arena. In order to accomplish this task, the author conducted a survey systematically in six companies. The details of the work carried out in this direction are presented in this chapter.

## 3.2. Survey Methodology

First, the questionnaire shown in the Annexure A was designed. As shown, this questionnaire consisted of two components. The first component consisted of 10 questions and aimed to assess the level of TPM implementation in the responding company. The second component contained four questions and aimed at checking the status of QFD implementation in the responding company. With this questionnaire, the author visited five companies in the city of Coimbatore, India that were implementing TPM. The author was referred by those companies to the competent authorities from whom he could collect valuable responses through face-to-face meetings. The positions held by these competent authorities are ranging from 'Works Manager' to 'General Manager'. Besides, the questionnaire was sent through e-mail to 53 companies in India that were implementing TPM. However, one company only returned the filled-in questionnaire. This poor response might be due to the non-availability of time and expertise for completing the questionnaire. The responses gathered this way were analyzed.

## 3.3. Analysis of responses from TPM perspective

Since some of the companies were reluctant to disclose their identity, the author has preferred to refer them in this chapter as Company 1, Company 2 and so on. The question A I aimed to check whether TPM has been implemented in the company. Since all the six companies have implemented TPM, the response was affirmative. The questions AII to AIX aimed to estimate the level of implementing eight pillars of TPM. The rationales behind in designing these questions are described here. As appraised in Chapter 2, One of the methods of anchoring TPM programme is by building eight pillars (Ahmed, et al., 2005).

Hence the questions A II to IX were designed to estimate the level of implementing eight pillars of TPM. The responses gathered against these questions have been graphically depicted in Figures 3.1-3.6. The reader is advised to refer Table 3.1 for the titles of the TPM pillars against the numbers quoted in Figures 3.1-3.6. In order to facilitate the readers to have a better understanding, level of implementing TPM pillars in six companies together and the Overall percentage level of implementing TPM pillars in six companies are depicted in Figures 3.7 and 3.8 respectively.

**Table 3.1.** Eight pillars of TPM

| | |
|---|---|
| Pillar 1 | Autonomous Maintenance (Jishu- Hozen ) |
| Pillar 2 | Individual Improvement (Kobetsu Kaizen) |
| Pillar 3 | Planned Maintenance |
| Pillar 4 | Quality Maintenance |
| Pillar 5 | Office TPM |
| Pillar 6 | Education and Training |
| Pillar 7 | Safety, Health and Environment |
| Pillar 8 | Initial Control (Development Management) |

**Table 3.2. Over all percentage level of implementation of TPM pillars**

| Company | Overall percentage level of implementing TPM pillars |
|---|---|
| 1 | 55 |
| 2 | 35 |
| 3 | 32 |
| 4 | 57 |
| 5 | 37 |
| 6 | 61 |

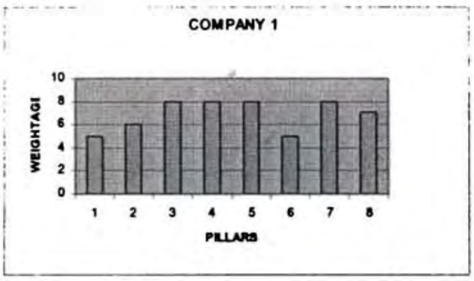



**Figure 3.1.** Implementation of TPM pillars in Company 1

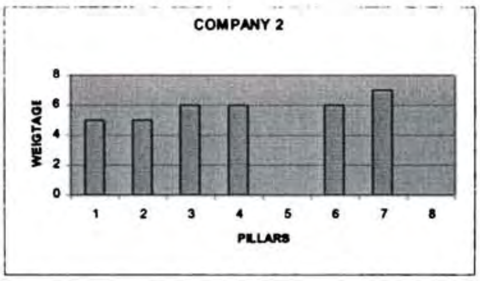



**Figure 3.2.** Implementation of TPM pillars in Company 2

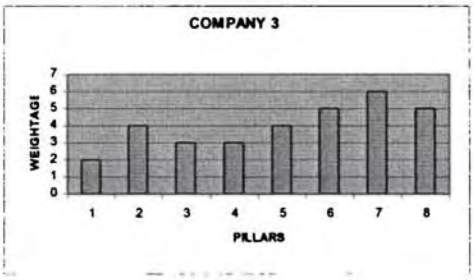



**Figure 3.3.** Implementation of TPM pillars in Company 3

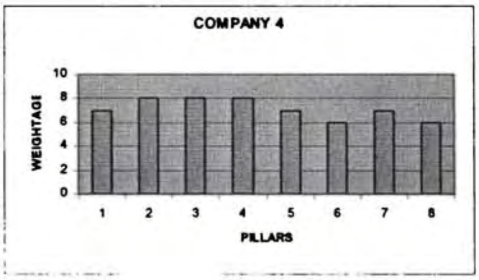



**Figure 3.4.** Implementation of TPM pillars in Company 4

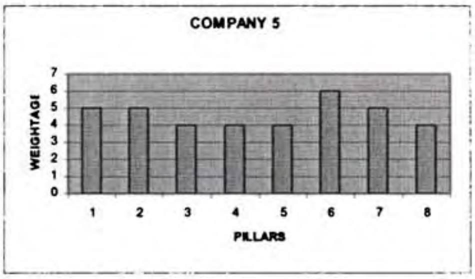



**Figure 3.5.** Implementation of TPM pillars in Company 5

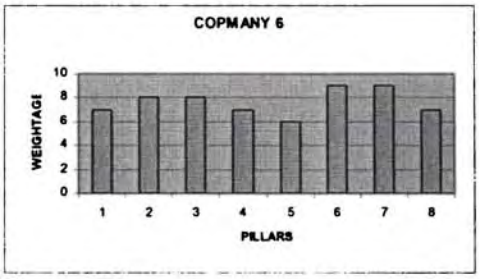



**Figure 3.6.** Implementation of TPM pillars in Company 6

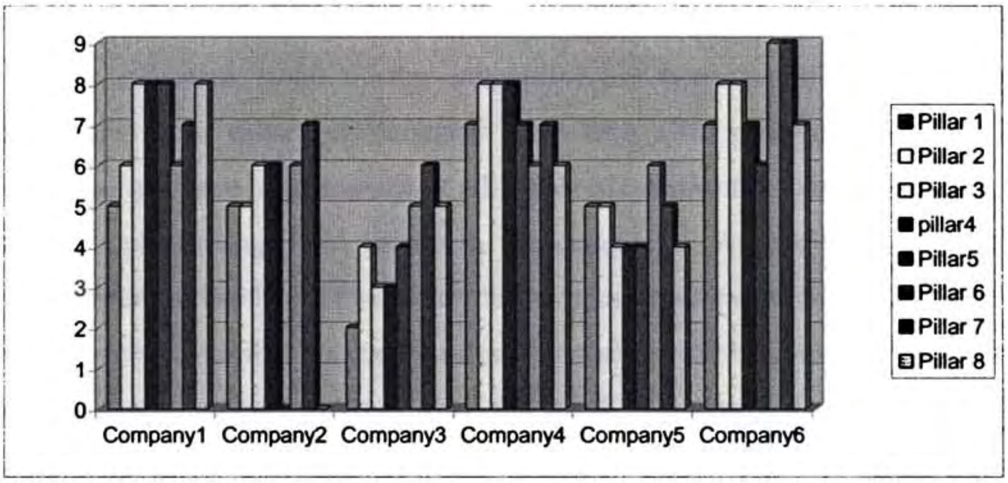



**Figure 3.7.** Level of implementing TPM pillars in six companies

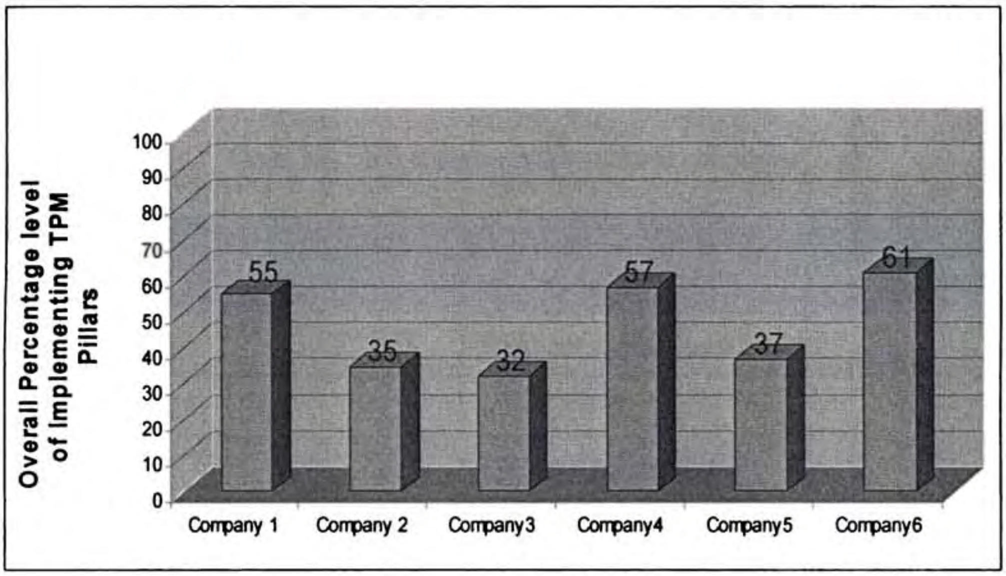



**Figure 3.8.** Overall percentage level of implementing TPM pillars in six companies

**Table 3.3** Level of using internal and external customers concept

| Company | Level of using internal and external customers concept plotted in the Likert's scale of range 0-10 |
|---|---|
| 1 | 5 |
| 2 | 2.5 |
| 3 | 0 |
| 4 | 3.5 |
| 5 | 4 |
| 6 | 8 |

As indicated, none of the companies has been found to have fully constructed TPM pillars. In company 2 the fifth TPM pillar (titled as office TPM) has not been implemented at all. Table 3.2 shows the overall percentage level of constructing TPM pillars in the companies. As shown, the overall implementation level of TPM pillars in the companies range from 32 to 61%. These levels affirm that six companies under study could be considered as TPM implementing companies. Also, that, the trend of implementing TPM pillars coincided with that of the companies situated in other parts of the world (Ireland and Dale, 2001). Hence, albeit the size of the sample was small, the inferences drawn from those companies would be representing the global scenario.

**Table 3.4.** QFD implementation status in companies

| Company | QFD Implementation status plotted in the Likert's scale of range 0-10 |
|---|---|
| Company 1 | QFD not implemented |
| Company 2 | 4 |
| Company 3 | QFD not implemented |
| Company 4 | 7 |
| Company 5 | QFD not implemented |
| Company 6 | QFD not implemented |

**Table 3.5.** Benefits achieved by companies 2 and 4 after implementing QFD

| Benefits Achieved after implementing QFD | Company 2 | Company 4 |
|---|---|---|
| Reduced design changes | Yes | Yes |
| Shorted Product Development cycles | Nil | Yes |
| Lowered costs and enhanced productivity | To some extent | Yes |
| Improved product quality and reliability | Nil | Yes |
| Increase market share | To some extent | Yes |
| Increased attention to customers perspectives | Nil | Nil |
| Any other, Please Specify | Nil | Reduce Redesign & Reworks<br>(Cost of Quality) |

## 3.4. Analysis of responses from QFD perspective

Since QFD deals with transferring customers' vague language into technical language, the proportion of utilizing internal and external customers concept while implementing TPM programs was examined using question A X.

The responses gathered are tabulated in Table 3.3 and pictorially depicted in Figure 3.9. As shown, except in the case of company 6, the level of utilizing internal and external customer concept is either nil or very small. Question BI aimed at determining whether the company ever implemented QFD. The QFD implementation status in these companies using a Likert's scale of range 0-10 is shown in Table 3.4 and Figure 3.10. Except companies 2 and 4, other companies have never implemented QFD. Hence, the data pertaining to the subsequent questions were gathered only from companies 2 and 4. As shown, the responses to question B III indicated that the implementation of QFD was confined within top and middle level management personnel. The responses gathered against question BIV are tabulated in Table 3.5. As indicated, company 2 has reaped very little benefits while company 4 has gained benefits in all aspects by implementing QFD. The QFD implementation status shown in Table 3.5 corroborates the observations indicated in Table 3.4. Therefore, the benefits gained by implementing QFD would be proportional to the level of its implementation.

## 3.5. Conclusion

On the whole, the questionnaire survey findings in the six TPM implementing companies led the author to draw the following inferences:

1. Though it is reported in literature by some authors that TPM is one of the strategies of propelling companies towards world class manufacturing (McKone, et al., 2001, Yamashina, 2000), its level of implementation in practising scenario with reference to the eight pillars is not very appreciable.

2. There exists every possibility that a company may implement TPM without installing one or more of the TPM pillars (Ahmed,et.al, 2005, Ireland and Dale, 2001).

3. TPM implementing companies possess no or very little knowledge about QFD since TPM does not stipulate the incorporation of internal and external customer concept.

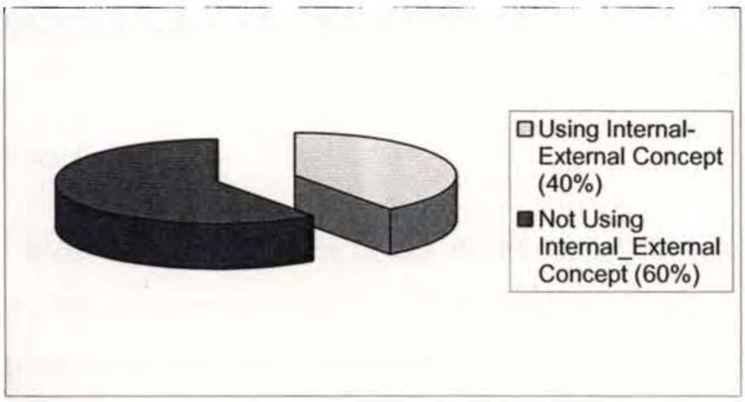



**Figure 3.9.** Proportion of internal-external customers concept in six TPM implementing companies

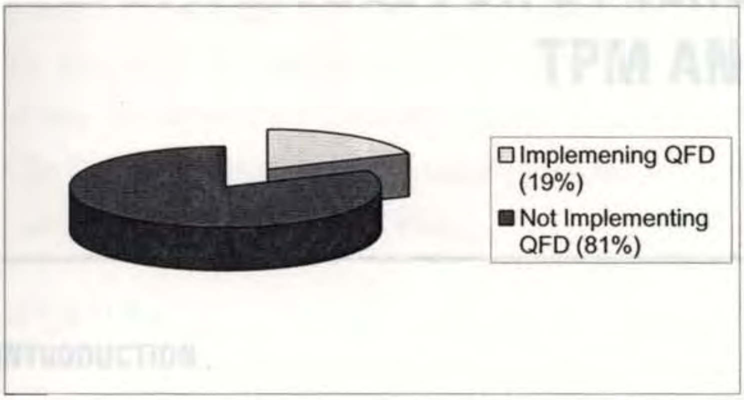



**Figure 3.10.** Proportion of QFD implementation in six companies

There was no sign of the six TPM implementing companies having applied QFD in their TPM projects. On the whole, the results of the literature review and practical survey did not reveal any appreciable difference. In other words, both literature and practical survey confirmed that no authentic model linking TPM and QFD has been adopted in both research and practice.

Chapter -4

# MQFD: A MODEL FOR SYNERGIZING TPM AND QFD

*Content*

# MQFD: A MODEL FOR SYNERGIZING TPM AND QFD

## 4.1. Introduction

While ascertaining the absence of any model linking TPM and QFD in both literature and practising arena, two methodologies of linking these two principles were examined. One methodology proposes that QFD can be introduced into TPM principles. The other methodology proposes the reverse, in the sense that TPM can be introduced into QFD projects. In both of these methodologies, there is likelihood that these two principles do not get linked, appropriately to evolve synergic benefits. To overcome this possibility, this research work was started by designing the MQFD model exclusively for linking these two principles. The conceptual features of MQFD model are described in this chapter. Next, its implementation procedure is enumerated and described by adopting a hypothetical case study.

## 4.2. Use of QFD for TPM

Both QFD and TPM have widely been in existence during last three decades (Akao and Mazur,2003, Nakajima,1993,Chan et.al., 2005). Though their objectives are about the quality improvement aspects, their perceptions and orientations are focused on attaining different objectives. In order to nourish their synergic benefits, it became necessary to examine the use of QFD for TPM. This aspect is depicted in Figure 4.1. As hinted, the objectives of QFD are largely on meeting the external customers' requirements through the involvement of managerial employees, whereas the objectives of TPM are mainly concentrated upon the enhancement of operators' capabilities towards enhancing maintenance quality of equipment. These differing objectives will lead to the division between managerial staff and the operators. If QFD is properly integrated with TPM programme, then those differing objectives can be focused towards the unified direction of achieving continuous maintenance quality improvement. However this would be a challenging task. Because, QFD professionals have not so far applied it for improving equipment's maintenance quality. Likewise TPM professionals have not been orienting towards continuous maintenance quality improvement of products produced by the organizations.

| Objectives of QFD | | Objectives of TPM | | Synergic objectives of QFD and TPM |
|---|---|---|---|---|
| 1. To translate customer's vague languages into technically understandable languages<br>2. To enable the percolation of customer's voice into practical arena.<br>3. To facilitate the customer's voice to obtain exactly what he/she wants.<br>(Sahney et.al,2004) | | 1. To achieve zero break downs<br>2. To achieve zero defects<br>3. To achieve improved throughputs. | | To gather both internal and external customer's perceptions in achieving zero break downs, zero defects and improved throughout and translate them into practically implementable and viable propositions. |
| **Benefits of QFD** | + | **Benefits of TPM** | = | **Synergic Benefits of QFD for TPM** |
| 1. Development of team work and participation culture.<br>2. Systematic development of documentation connecting all functional requirements.<br>3.Reduced field problems<br>4. Lesser design changes<br>5. Identification of strengths and weaknesses of products with reference to competitors products<br>(Lokamy and Khurana,1995) | | 1.Cultivating sense of ownership of equipment among the operators.<br>2. Development of cross functional teams to improve individual employee and employer performance.<br>3. Increase the life of equipment and plant.<br>4. Identification of reasons for equipment failures.<br>5.Increase in motivation level of employees<br>(Eti. et.al, 2004) | | Development of teams consisting of not only operators but also managers who are concerned with equipment effectiveness for providing tangible and intangible gains that would be received by both internal and external customers. |

**Figure 4.1.** Use of QFD for TPM

Hence the task of integrating QFD and TPM has to be carried out with precautions because of their inherent divergent objectives. This finding necessitated the development of MQFD model exclusively to integrate QFD and TPM principles.

## 4.3. MQFD model

The conceptual features of the MQFD model are shown in Figure 4.2. As shown, the performance of a company will be heard through the voice of customers. Those voices of customers are used to develop the HoQ (Chein and Su, 2003). This process has to be accomplished by MQFD team. The outputs of HoQ, which are in the form of technical languages (Rahim and Baksh, 2003), are submitted to the top management for making strategic decisions. This step is necessitated because researchers have established the need for applying strategic approach in both QFD (Lu and Kuei, 1995) and TPM (Murthy,et al, 2002, Hunt, and Xavier, 2003) projects for ensuring their success.

The technical languages which are concerned with enhancing maintenance quality are strategically directed by the top management towards eight TPM pillars. The TPM characteristics imbibed through the development of eight pillars are fed into the production system. Here, their implementation is focused towards increasing the values of the maintenance quality parameters, namely OEE, MTBF, MTTR, performance quality, availability and MDT.

The outputs from production system are required to be reflected in the form of business values namely improved maintenance quality, increased profit, upgraded core competence, (Miyake and Enkawa, 1999) and enhanced goodwill (Ahmed,et al, 2005). The rationale behind measuring these business oriented outputs is that, maintenance is established a business function and hence any maintenance model is required to show performance in the form of the above business metrics (Zhu,et al., 2002, Eti,et al, 2004). All the quantified values of outputs are used for developing another HoQ and comparing with set targets. At this point, the next cycle begins.

The MQFD model implementation would be a never-ending continuous improvement process. A unique feature of the MQFD model is that it is not necessary to change or dismantle the process of developing house of quality and TPM projects, which might be already in practice in the company concerned. Thus, the MQFD model enables the tactical marriage between QFD and TPM.

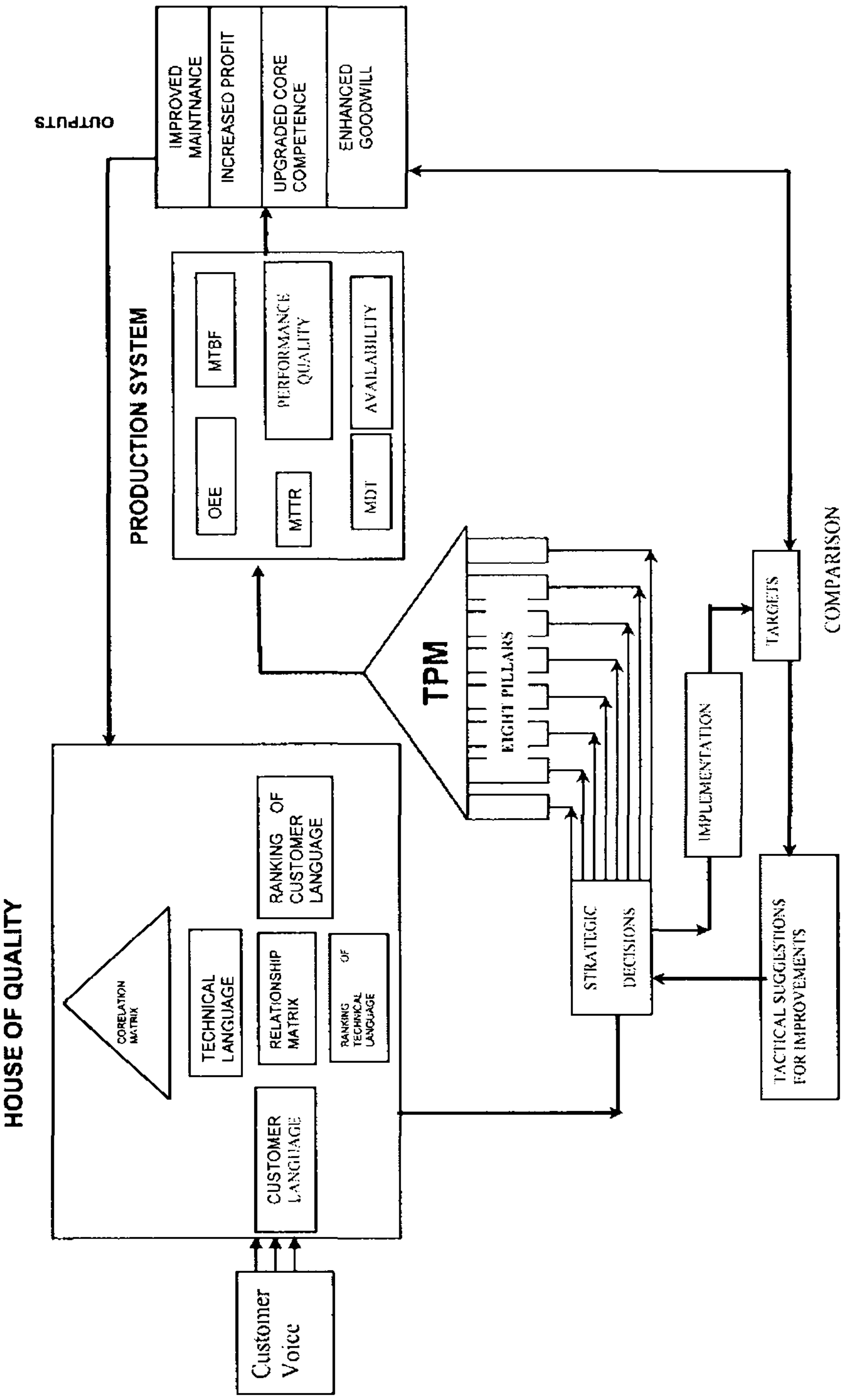



**Figure 4.2. MQFD Model**

## 4.4. Implementation aspects of MQFD

In order to illustrate the implementation aspects of MQFD, a hypothetical case study is presented here. For this purpose a company manufacturing sanitary paper products is considered. The products of this company are facial tissues, pocket tissues, lady napkins and diapers. The steps that are to be carried out to apply MQFD model are presented below. These steps have been developed as an analogy to those followed in TPM and QFD implementation case studies like those reported by Eti. et.al (2004), Ireland and Dale (2001), Chin et.al, (2001) and Pun et.al (2000).The rationale behind developing each step is also appraised.

### 4.4.1 Step 1.

MQFD experts deliver seminar to the top management personnel who subsequently agree to implement MQFD in the company.

#### 4.4.1.1 Rationale

The vitality of top management support and commitment for the successful implementation of both TPM and QFD models have been well established by the researchers (Emiliani, 2005, Kaye, and Andersen, 1999, Cooke, 2000, Kathawala and Motwani, 1994). The core requirement of the above seminar is to convince the top management about the potential value of implementing MQFD and to gain their commitment and ownership to it. Similar emphasis is made in Chan et.al (2005) while enumerating the twelve steps of a TPM implementation programme.

### 4.4.2. Step 2.

The MQFD experts and top management personnel undergo brainstorming sessions on MQFD implementation. At the end of these sessions, they decide to apply MQFD in the production process of diapers because its sales volume is the highest of all the other three products produced.

#### 4.4.2. 2. Rationale

The rationale of this step is that top management personnel are cautious while embarking any new programme. At the same time, they will be attracted to the models, which will lead to sales and revenue increase. Same approach has been reported by Ghobadian and Terry (1995) while describing the implementation of QFD in a company by name Alitalia. Similar step is envisaged under the name 'focus group brainstorming' in Pun et.al (2000) and Chin et.al (2001).

### 4.4.3. Step 3.

MQFD team consisting of eight members is formed. The constitutional structure of this team is given below.

I Works manager

II Engineer "A"

III Engineer "B"

IV Foreman "A"

V Foreman "B"

VI Quality controller

VII Factory Accountant

VIII Marketing Manager

#### 4.4.3.1 Rationale

The individual knowledge will be too narrow and self centered for adoption in real time environments. A team effort is required to make better decisions (van der Wall, and Lynn, 2002). When members from different departments join, practically compatible continuous improvement results will emerge (Chan, et al, 2005). The synergic combination of multi-disciplinary efforts will lead to very valuable decisions (Ollero, et al., 2002). Quite interestingly the formation of team is envisaged while implementing both TPM and QFD principles (Ireland and Dale, 2001, Rahim. and Baksh, 2003, Tsang and Chan, 2000). Hence the team shown above is formed while implementing MQFD which has to be done with care (Balthazard and Gargeya 1995).

### 4.4.4. Step 4.

Top management permits the MQFD team to meet once in a week in the training hall.

#### 4.4.4.1. Rationale

After formation of MQFD team, the management shall support its effective functioning by providing the required resources. One among them is the management's willingness to allot a certain time during the working hours for convening MQFD meetings. In order to fulfill this requirement, while implementing MQFD, the management shall gesture by earmarking one or two hours in a week for MQFD members' meeting. Similar appraisal has been made by Bamber et.al (1999) who has cited time allocation as one of the factors effecting successful implementation of TPM.

### 4.4.5. Step 5

MQFD experts conduct a half-a-day seminar to both management and employees.

#### 4.4.5.1. Rationale

When MQFD gains momentum, a section of management and employees may feel skeptic about its fruitful results. This feeling may emerge in the form of resistance to change. In order to mitigate these reverberations on MQFD, a seminar explaining its features and expected benefits to be reaped by the company is required to be conducted. Similar observations have been reported by Ireland and Dale (2001). Also, a step like the one said above has been suggested with regard to the implementation of TPM in a company in Tsang and Chan (2000).

### 4.4.6. Step 6.

MQFD team identifies the following four customer languages.

***Customer language 1:***" Eva tape (used for tying diapers on babies) is getting peeled off."

***Customer language 2:*** "Other companies are making T shaped diapers. Diapers produced by our company are X shaped which are difficult to handle".

***Customer language 3:*** "Packing of diapers produced by competitor companies are tri-fold which are attractive after packing whereas diapers produced by our company are bi-fold".

***Customer language 4:*** "The diapers produced by the competitor companies last longer".

#### 4.4.6.1. Rationale

Identifying customer language is a difficult exercise. The different sources and channels are to be tactically tapped and traced to gather customer languages. MQFD team has to adopt suitable methodologies to identify the above customer languages. For this purpose the MQFD team may refer to the methodologies reported in article like Chin.et.al (2001), Kumar and Midha (2001), Ghobadian and Terry .(1995) and Pun et.al (2000).

### 4.4.7. Step 7.

MQFD team ranks the customer languages according to their importance and decides to choose the 'customer language 1' for subsequent consideration.

#### 4.4.7. 1. Rationale

Prioritisation has been an accepted practice in several fields. For example Juran and Gryna (1997), recommend the use of Parato analysis to identify vital few quality problems. Likewise, the field of inventory management uses ABC analysis to prioritise the materials as A, B and C categories (Zomerdijk, and Vries, 2003). Hence, MQFD implementation would be more result oriented if customer languages are ranked and considered according to their priorities. However, the choosing of appropriate metrics and scales for ranking customer languages would be a challenging task.

### 4.4.8. Step 8.

MQFD team conducts brainstorming sessions and develops HoQ. This stage progresses through the following steps (Besterfield, et al., 2004) by conducting the eight brainstorming sessions in succession.

***Brainstorming session I:*** Customer language is subjected to discussions. Finally the customer requirements (whats) are listed.

***Brainstorming session II***: The technical features of fulfilling customers' requirements are subjected to discussions. Finally the technical descriptors with respect to the customer requirements are listed.

***Brainstorming session III***: The relationships between customer requirements and technical descriptors are discussed. Finally the relationship matrix between customer requirements and technical descriptors is developed.

***Brainstorming session IV***: The technical descriptors are subjected to discussion for establishing relationships among themselves. Finally, the inter-relationship matrix between technical descriptors is developed.

***Brainstorming session V***: The competitors' status with reference to customer requirements is discussed. Finally, the competitive assessments are quantified using numerical values.

***Brainstorming session VI:*** The customer requirements are subjected to discussions for establishing their priorities. Finally, the customer requirements are prioritized using numerical values.

***Brainstorming session VII:*** The technical descriptors are subjected to discussions for establishing their priorities. Finally, the technical descriptors are prioritized using numerical values.

***Brainstorming session VIII:*** All the outcomes of Brainstorming session I -VII are subjected to discussions from the holistic point of view. Finally these outcomes are entered into the HoQ matrix.

#### 4.4.8.1. Rationale

The need of conducting brainstorming sessions in attaining maintenance strategies is established in research (Madu, 2000). This exercise results in systematic conversion of customer languages (requirements) into technical languages (descriptors). In addition to that, HoQ matrix shows a clear picture of the ranking, relationships among customer and technical languages. In addition to that, correlation among technical languages, if any is revealed. Hence the above step utilizing these features is a core aspect of MQFD programme.

### 4.4.9. Step 9.

The highest ranked technical language brought out of HoQ is as follows. "It is found that oil used at the cutter knife flows over the tape while cutting. It causes it to get peeled off. Use of oil is to be avoided by installing artificial chiller unit".

#### 4.4.9. 1. Rationale

Vital few problems damage the systems to the maximum possible extent. Hence solving of vital few problems would overcome major malfunctioning of the systems (Logothetis, 1997). Therefore when technical language with highest priority is chosen, it would lead to solving of major deficiencies and trading off minor deficiencies (Besterfield, et al., 2004).

### 4.4.10. Step 10

MQFD team submits the results to the top management personnel.

#### 4.4.10.1. Rationale

The continuous support and leadership of management are prerequisites for the successful laying of foundation of any programme in an organization. In order to sustain its development, the management's sustained involvement is vital. Hence it is essential that MQFD team reports to the top management about the progress of MQFD. Similar thrust is made by Bamber et.al (1999) for the successful implementation of TPM.

### 4.4.11. Step 11

The top management personnel along with MQFD experts conclude that the results reported by the MQFD team are to be fed into the TPM pillars. Table

4.1 shows the action taken in this regard. The technical languages drawn from HoQ will have to be positioned to enhance maintenance quality. This task is made possible by passing through the TPM eight pillars.

**Table 4.1. Action to be taken to construct eight TPM pillars**

| | |
|---|---|
| Autonomous Maintenance (Jishu- Hozen -Pillar 1) | The operators running diaper machine are informed about the suggestions of MQFD team and are trained to maintain the artificial chiller unit on their own. The operators develop confidence to maintain artificial chiller unit |
| Individual Improvement (Kobetsu Kaizen- Pillar 2) | MQFD team members analyse different losses that emanate due to maintenance failure of artificial chiller unit and ranked the losses using risk priority numbers (R.P.N). The factors considered are severity, occurrence, and detection |
| Planned Maintenance (Pillar 3) | MQFD team identifies the maintenance requirements and their frequencies. MQFD team conducts one-point lessons to the operators who are required to run artificial chiller unit. At the end, MQFD team presents the operators with a timetable on planned maintenance of artificial chiller unit and a small sized maintenance diary with dates and check-lists containing the planned maintenance operations to be carried out. |
| Quality Maintenance (Pillar 4) | MQFD team conducts one point lesson on entering data on defects. MQFD team sets up a system to monitor defects on the basis of any duration. For this purpose, MQFD trains the operators to enter the data while operating the artificial chiller unit in maintenance diary and presents it to the MQFD experts. MQFD team members decide to conduct Why-Why analysis, poke yoke and kaizen. MQFD members decide to orient towards zero defects. |

Table Contd......

| | |
|---|---|
| Office TPM<br>(Pillar 5) | MQFD team prepares a software for personnel working in office to compute incentives for the operators who are operating artificial chiller unit. The use of this software by the office personnel ensures that the incentive computation is straightforward and free from errors. |
| Education and Training<br>(Pillar 6) | MQFD team designs and develops curriculum for providing education and training on artificial chiller unit. MQFD team prepares the list of operators and supervisors who are required to participate in these programmes and the benefits they are required to gain. |
| Safety, Health and Environment<br>(Pillar 7) | MQFD members go to the work place to demonstrate to the operators who are working on the artificial chiller unit about the safety, health and environment measures that are required to be taken care of. MQFD members conduct moke drill exercise to check the preparedness of operators working on artificial chiller unit towards safety, health and environmental aspects. |
| Initial<br>Control (Development Management-Pillar 8) | MQFD team develops the rules for rewarding the operators based upon the MTBF, OEE, MTTR, MDT, performance quality, and availability of artificial chiller unit. A reward system for calculating the tangible and intangible values of the incentives based upon the above parameters concerning the artificial chiller unit is developed. This motivates that the operators of the diaper machine to run artificial chiller unit without any resistance. |

#### 4.4.11.1. Rationale

As mentioned earlier, one of the approaches of enhancing maintenance quality is through the development of TPM pillars (Ahmed,et al, 2005, Ireland and Dale, 2001). Hence this step is necessitated. Action taken by each pillar is presented in Table 4.1.

### 4.4.12. Step 12

The construction of eight TPM pillars is completed. The results are directed towards the operation of the production system. In this regard, MQFD team computes the six TPM parameters namely OEE, MTBF, MTTR, performance quality, MDT and availability.

#### 4.4.12.1. Rationale

Many authors have claimed that OEE is the most effective measure of maintenance quality (Chan, et al., 2005), However organizations would be in need of viewing maintenance quality from different perspectives (Ahmed,et al, 2005, Juran, and Gryna, 1997, Blanchard, 1997). This is made possible by measuring the other parameters cited above. For example, the company's perspective of maintenance quality is viewed by seeing the down time of equipments and products. This is made possible by referring to MDT.

### 4.4.13. Step 13

The overall results indicate 60% increase in organisational performance. MQFD members compare this result with the set target. They find that the target set is 70%.

#### 4.4.13.1. Rationale

There is every chance that the maintenance quality of a company may be improved at the cost of its business performance. The ultimate objective of MQFD shall be the achievement of core competence. Hence, after implementing MQFD cycle, it is essential to ultimately measure its contributions towards its business success. Researchers have cited the importance of ensuring the integrity of TPM benefits with business performance (Ahmed,et al, 2005, Seth and Tripathi, 2005). Though MQFD cycle results in business performance improvement, its level has to be checked with the that of the target. This will enable the company to reap of ultimate benefits of implementing MQFD.

### 4.4.14. Step 14

MQFD members conduct brainstorming sessions among themselves and conclude that the performance quality is to be improved. Subsequently they evaluate the tactical suggestions and ideas emerged during these brainstorming sessions.

#### 4.4.14.1. Rationale

Continuous improvement is a hallmark of TPM (Blanchard, 1997). But before embarking on the next cycle of MQFD, brainstorming sessions are to be conducted among its team members. These brainstorming sessions will lead to the revealing of the effective way of promoting the next cycle of MQFD.

### 4.4.15. Step 15

Tactical suggestions of MQFD team members are submitted to the top management for taking strategic decisions. The strategic decisions lead to the approval of implementing the tactical suggestions.

#### 4.4.15.1. Rationale

The findings and results of MQFD will have to be used for company's sustained and continuous improvement. Hence, strategic decisions are required to be made for implementing the outcomes of MQFD. Since management holds the key, the task of making strategic decisions in this direction has been accomplished by the management (Madu, 2000).

### 4.4.16. Step 16

The tactical suggestions are implemented. The overall maintenance quality reaches the set target of 70%.

#### 4.4.16.1. Rationale

Since the suggestions have to yield value and results (Ireland and Dale, 2001), they have to be tactic. As the title itself hints, tactic suggestions lead to the attainment of set targets.

### 4.4.17. Step 17

On observing the favorable impact of MQFD, management revises the target for attaining maintenance quality as 80%. In this background, the MQFD members prepare themselves to work along with quality engineers to proceed towards the conduct of next cycle of MQFD, which begins by the construction of new HoQ. Thus MQFD leads to overall maintenance quality improvement with a particular reference to the voice of customers.

#### 4.4.17. 1. Rationale

It is necessary to revise the targets for facilitating the company to achieve global competitiveness (Chan, et al., 2005). Since, customers' views are changing from time to time, it is necessary to update the HoQ and carry out the subsequent steps. Now MQFD has to spread across the organization. Hence quality engineers and other competent personnel are also included in the MQFD implementation cycle. Thus MQFD is set to aid the company to achieve core competence through the threshold of enhancing maintenance quality.

## 4.5. Conclusion

In this chapter, the conceptual and implementation features of MQFD model have been presented. This model has been designed by the author by linking QFD's HoQ with TPM principles. In order to configure this model for fitting it in practical situations, the author has integrated maintenance quality with the business performance parameters namely profit, core competence and goodwill with the MQFD model. In order to direct the MQFD program along the streams of management's mission and policies, the provision for making the strategic decisions has been included. The author has presented a hypothetical case study, which illustrates MQFD's implementation steps. The MQFD model and its implementation aspects were the foundations of this research work. The subsequent activities carried out during this research work on these foundations are presented in the following chapters of this thesis.

Chapter - 5

# CUSTOMER VOICE ADOPTION FOR MAINTENANCE QUALITY IMPROVEMENT THROUGH MQFD AND ITS RECEPTIVITY ANALYSIS

*Content*

# RECEPTIVITY ANALYSIS MQFD MODEL

## 5.1. Introduction

Before implementing a new methodology, it is essential to check its receptivity among the target groups. This exercise is also necessary to foresee its failure chances (Dale and Hayward, 1984). This is a critical imperative, because numerous models and approaches surface in today's research and practical arena as the solution to face competition. However some of them are sustained while the remaining are either perishing or getting obsolete (Schneider,2000). Even the success proven TQM model has failed to work in certain conditions (Nwabueze 2001 a,b). This phenomenon inspired the author to foresee the success possibility of MQFD. In order to meet this requirement, the receptivity of this model was checked among the practising managers, academicians, and students of management and engineering fraternities. The responses of this audience were collected using questionnaires. The inferences drawn were useful to understand how well the MQFD model would work in modern organizations. The details of this work are briefly presented in this chapter.

## 5.2.Receptivity of MQFD

**Table 5.1. Questionnaire used for surveying the receptivity of MQFD model**

1.Are you familiar with TPM ? Yes/No

2. Are you familiar with QFD ? Yes/No

3. To which extent you are able to appreciate the essence and importance of MQFD?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0=Not at all 10=Full

4.To which extent you believe that MQFD could be implemented in companies?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0=Not at all 10=Full

5.To which extent you appreciate that MQFD will result in maintenance quality improvement?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0=Not at all 10=Full

6.Any other remarks that you would like to mention about MQFD

The questionnaire shown in Table 5.1 was used to explore the receptivity of MQFD during the three phases.

### 5.2.1. First phase of survey

The first phase of survey was conducted in the ninth International symposium on Logistics held at Indian Institute of Management (IIM), Bangalore, India. This international symposium was organized by the University of Notingham, UK and IIM, Bangalore during July 12 to 14, 2004. Both engineering and management professionals from different countries participated in this international symposium. Majority of them were academicians. After presenting a paper describing the salient features of MQFD in one of the sessions, the author distributed the questionnaire among the audience of this session. The filled-in questionnaires were gathered from 19 academicians.

The responses indicated that both TPM and QFD are disseminated well among academicians. This observation is depicted in Figures 5.1 and 5.2.The receptivity of MQFD was inferred from questions 3, 4, 5 and 6 under three titles namely 'Appreciation of the essence and importance of MQFD', 'Feasibility of Implementing MQFD' and 'MQFD's capability in existing maintenance quality improvement'. The average values computed from the responses are shown in Figure 5.3.As indicated the receptivity of MQFD among the participants of above international conference is just little above the value 5 in a Likert's scale of range 0-10. The reason for this average receptivity of receptivity is attributed to the lack of knowledge possessed by the respondents on QFD and TPM.

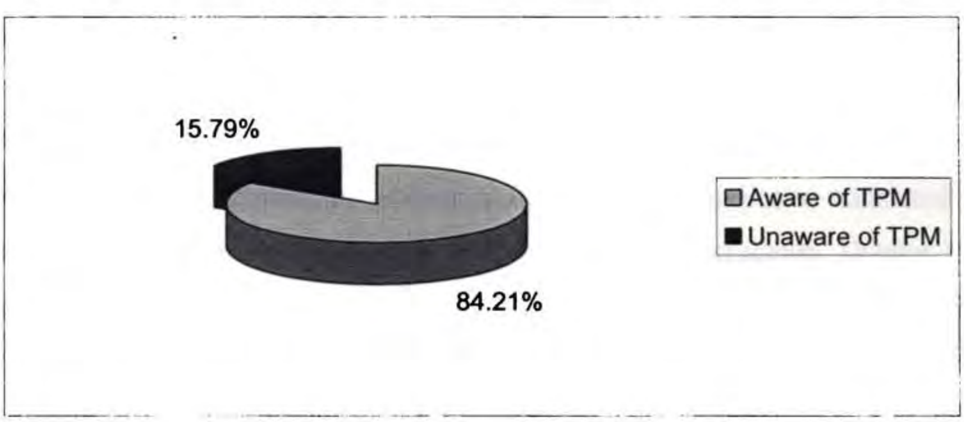



**Figure 5.1. Awareness of TPM among international participants**

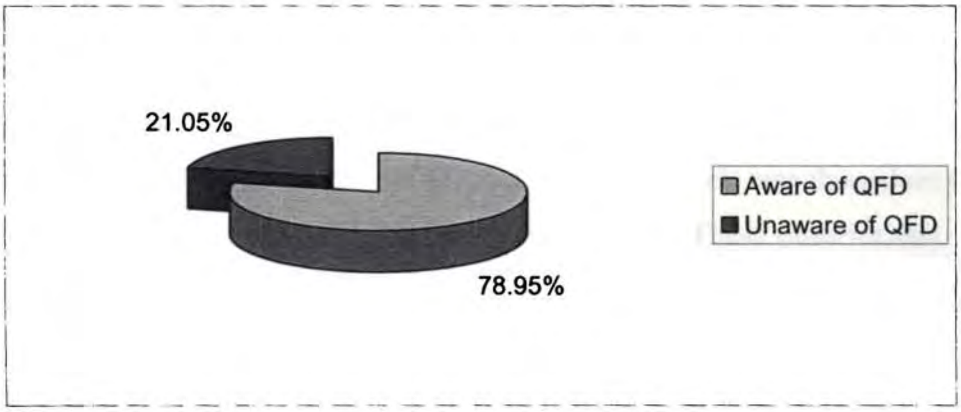



**Figure 5.2. Awareness of QFD among international participants**

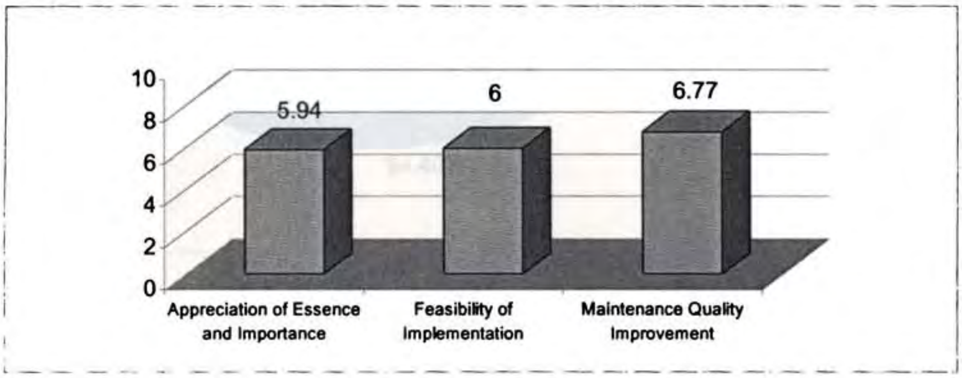



**Figure 5.3. MQFD receptivity among the participants of international conference**

## 5.2.2. Second phase of survey

The second phase of the survey was conducted at "Palghat Management Association" (PMA), Kerala state, India. As the title implies, the objective of this association is to serve as the podium for the management professionals residing in and around Palakkad district' Kerala state, India. The author presented the features of MQFD in a monthly meeting of PMA on August 10, 2005. After the meeting, the same questionnaire shown in Table 5.1 was distributed to two classes of audience. One class of audience consisted of practising managers and the other consisted of, MBA students. During this phase, the responses were gathered from 18 practising managers. The awareness level of TPM and QFD among both category of audience are shown in Figures 5.4, 5.5, 5.6 and 5.7.An overview of these Figures would indicate that awareness on TPM is widespread among both practicing managers and

MBA students while it is not so in the case of QFD. The receptivity of MQFD among practising managers is fairly well. That is, the average value of MQFD receptivity under the three aspects is more than 6 in the Likert's scale of range 0-10. But it is not so in the case of MBA students in which case the values are only little above 5 in the Likert's scale of range 0-10. These observations are shown in Figures 5.8 and 5.9, which imply that the degree of practical experience influences the receptivity of MQFD.

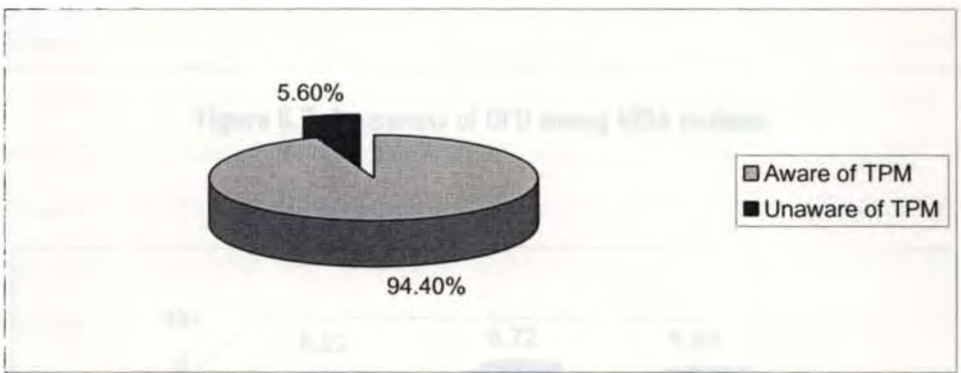



**Figure 5.4. Awareness of TPM among Practising Managers**

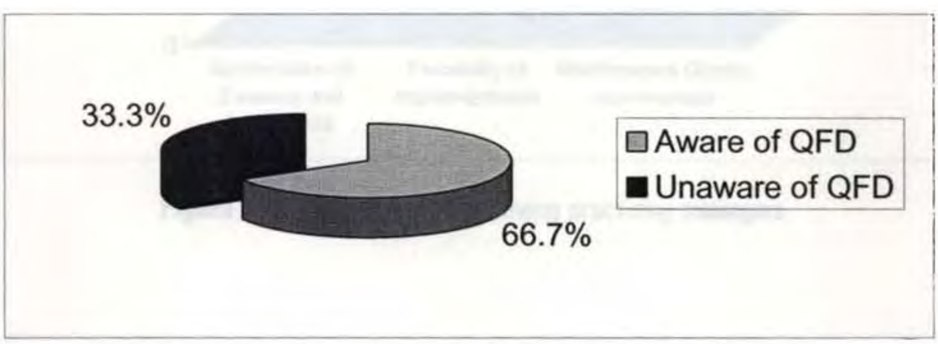



**Figure 5.5. Awareness of QFD among Practising Managers**

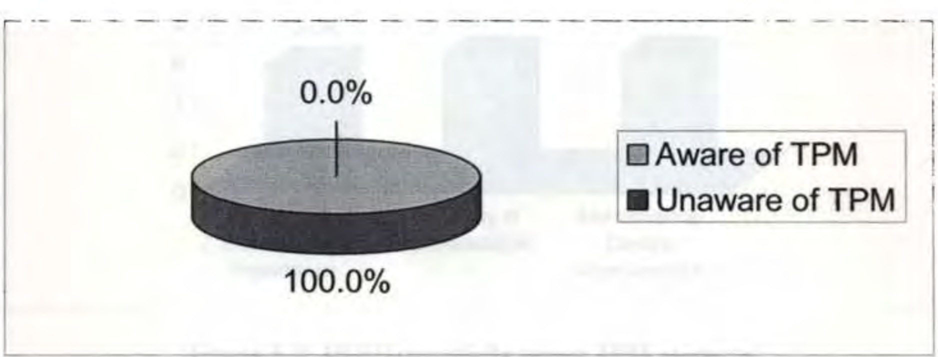



**Figure 5.6. Awareness of TPM among MBA students**

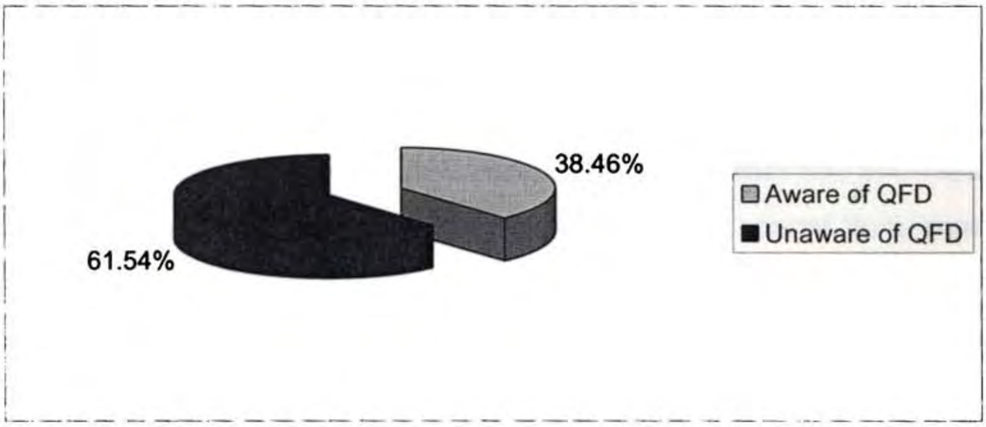



**Figure 5.7** Awareness of QFD among MBA students

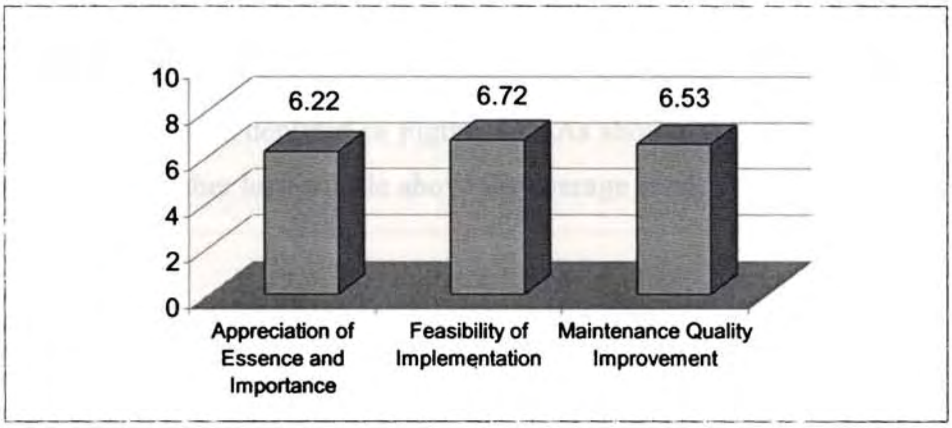



**Figure 5.8. MQFD receptivity among practising managers**

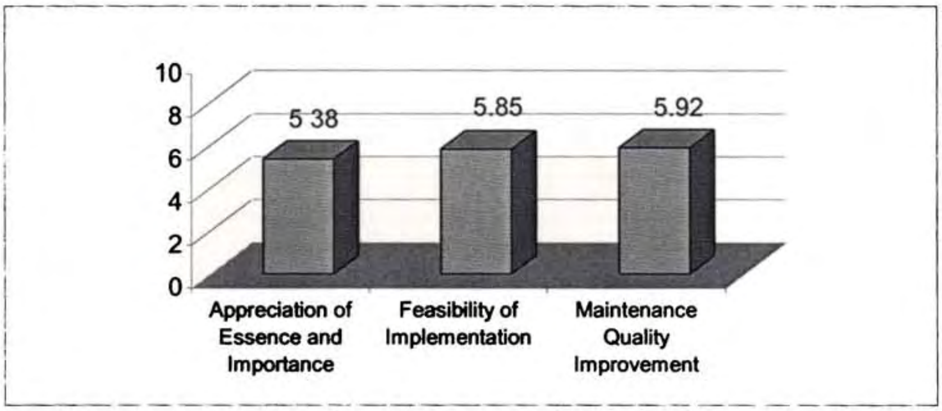



**Figure 5.9** MQFD receptivity among MBA students

### 5.2.3. Third phase of survey

The third phase of the survey was conducted in the national conference on Innovated TQM held at PSG College of Technology, Coimbatore, India (Hereafter referred to as ITQM conference). ITQM conference was held during February 25-26,2005. The author got an opportunity to present three papers dealing with MQFD in ITQM conference. The participants consisted of research scholars, graduate and postgraduate students, one engineering college teacher and one practitioner. After presenting the paper, the author distributed the questionnaire to the audience and collected their responses. During this phase, the responses were gathered from 12 conference participants. The responses indicated that the concepts of TPM are well known to the respondents while QFD principles are known to them only to an average extent. These findings are depicted in Figures 5.10 and 5.11. The MQFD receptivity among ITQM participants is depicted in Figure 5.12.As shown, the MQFD receptivity among them is either less or little above the average level.

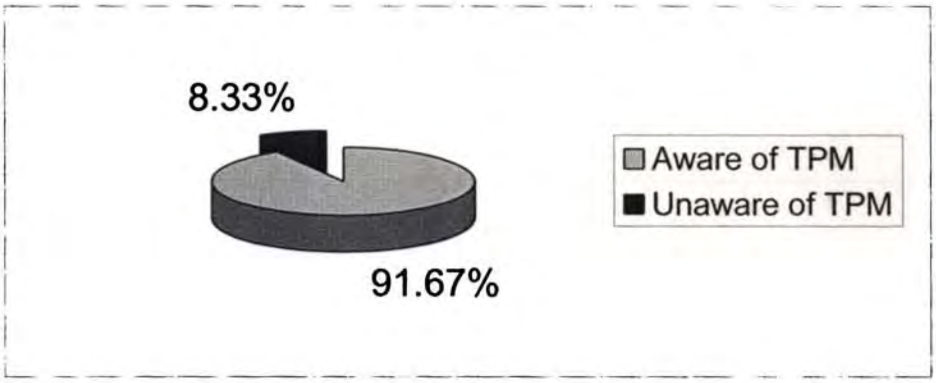



**Figure 5.10. Awareness of TPM among ITQM conference Participants**

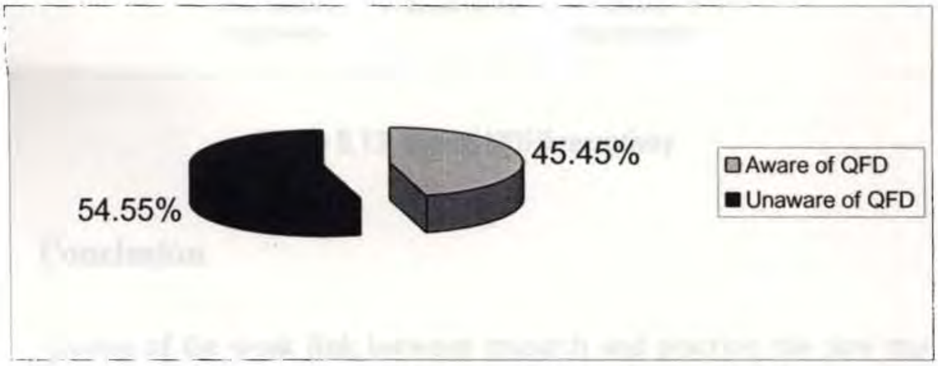



**Figure 5.11. Awareness of QFD among ITQM conference Participants**

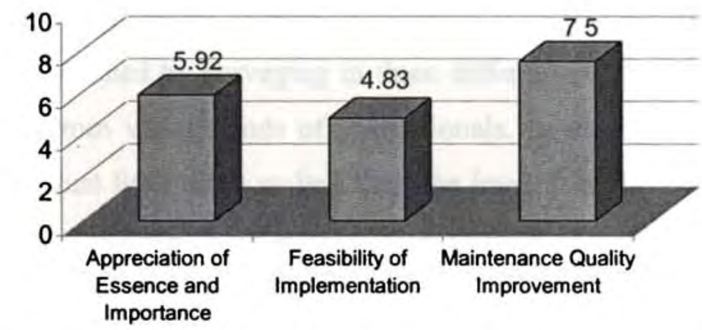



**Figure 5.12. MQFD receptivity among ITQM participants**

## 5.2.4. Interpretation from MQFD receptivity survey

Despite the reasonable exposure to QFD and TPM, the MQFD receptivity among the respondents against the questionnaire shown in Table 5.1 is little above the average level. The overall MQFD receptivity is indicated in Figure 5.13.This finding indicates that preliminary exposure to MQFD is vital for its successful implementation. Hence it is necessary that before embarking on MQFD, a company has to conduct a number of exposure and orientation programmes on MQFD.

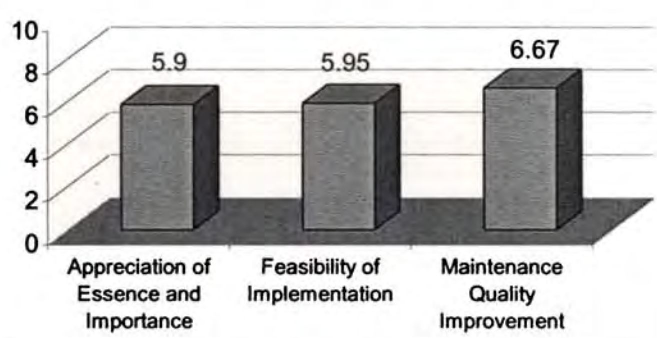



**Figure 5.13. Overall MQFD receptivity**

## 5.3. Conclusion

Because of the weak link between research and practice, the new models like MQFD cannot be transferred from research environment to the practicing field within a quick span of time. In order to explore in this direction, the levels of MQFD receptivity among various professional communities were examined. This was accomplished by surveying in three different podiums and responses were collected from varied kinds of professionals. In most cases, the MQFD receptivity was just little more or less than the level 5 in the Likert's scale of range 0-10.This state reveals the conservative mindset of professionals who are not willing to mix techniques and approaches which would emanate for attaining different strategies. Hence the results of MQFD receptivity indicated that the implementation of MQFD was not going to be an easy task.

Chapter - 6

# IMPLEMENTATION OF MQFD IN A VEHICLE SERVICE STATION: A CASE STUDY

*Content*

# IMPLEMENTATION OF MQFD IN A VEHICLE SERVICE STATION: A CASE STUDY

## 6.1. Introduction

In order to examine the working of MQFD in real time situation, its implementation study was conducted in an Indian state government run public sector automobile service station. The details of this work are presented in this chapter.

## 6.2. About the company

The case study on MQFD being reported in this chapter was carried out in a maintenance intensive automobile service station. This service station is located at Coimbatore city of India. This service station is run by the Tamil Nadu state Government of India. This service station is required to cater for the maintenance requirements of Tamil Nadu state Government's vehicles. This service station was chosen for the study because of the intense maintenance engineering activities being carried out in it.

## 6.3. Implementation study

To begin with, the customer reaction was obtained using a questionnaire as shown in Annexure B. Ten vehicles were considered for study. The details of the vehicles are depicted in Table 6.1. The drivers of the vehicles are the customers of this service station. By making use of the long experience of the automobile engineer, the list containing the maintenance quality aspects was prepared. The drivers were asked to mark their reactions against those aspects. In total, the reactions from 14 drivers were collected pertaining to 20 maintenance quality aspects. The data collected through this questionnaire based survey is tabulated in Table 6.2. As an example, the details of the data presented against serial number 1 in Table 6.2 are illustrated here. This question aimed to gather the reaction of each driver about the condition of the driver's seat of the vehicle. Out of the 14 drivers, three of them have mentioned 'excellent', while 5 and 6 of them have mentioned that it is 'good' and 'average' respectively. None of them have felt that the driver's seat of the vehicle that they drive is in bad condition. The selection of maintenance quality aspect was prioritised on the basis of drivers' reactions in the order ranging from 'Bad' to 'Excellent'. That is, the maintenance quality aspects in which 'Bad' reactions dominate are given the highest priority in choosing for subsequent study. It is gradually decreased from average to excellent reactions. The priorities were quantified by assigning weightages 1,2,3, and 4 for the reactions 'Excellent', 'Good', 'Average' and 'Bad' respectively. The priority scores thus computed have been entered in the last column of Table 6.2. As a sample, the computation of the priority score against the condition of the driver's seat is presented below.

**Table 6.1. Details of the vehicles considered for study**

| NO. | REG. NO. | Make | Year Of Manufacture |
|---|---|---|---|
| 1 | TN 07 G- 223 | Bajaj Trax | 1995 |
| 2 | TN 38 G- 111 | Mahindra and Mahindra 540 | 1997 |
| 3 | TN 38 G- 139 | Mahindra and Mahindra 540 | 1998 |
| 4 | TN 38 G- 182 | Mahindra and Mahindra 540 | 1998 |
| 5 | TDI 129 | Mahindra and Mahindra 540 | 1984 |
| 6 | TDI 130 | Mahindra and Mahindra 540 | 1984 |
| 7 | TAN 150 | Mahindra and Mahindra 540 | 1988 |
| 8 | TN 38 G- 107 | Mahindra and Mahindra 540 | 1997 |
| 9 | TN 38 G- 253 | Mahindra and Mahindra 540 | 1998 |
| 10 | TN 38 G- 110 | Mahindra and Mahindra 540 | 1997 |

"Number of 'Excellent' reactions × 1+ Number of 'Good' reactions × 2+ Number of 'Average' reactions × 3+ Number of 'Bad' reactions × 4"= $(3 \times 1+5 \times 2+ 6 \times 3 +3 \times 0) = 31$.

As shown in the last column of Table 6.2, the 'ride comfort' and 'condition of the head light' shall be the highest priorities for choosing subsequent study since their score is 37. This score is the highest among all. These details were input into HoQ (Besterfield et.al 2004). The HoQ thus developed is shown in Figure 6.1. After this, the technical languages numbering 32 was prepared by the Automobile engineer. The driver's reactions (which are referred to as customer voices in QFD terminology) and the technical languages were entered in rows and columns of the correlation matrix. The correlation between the customers' voice and technical languages were entered using the following three symbols, which are shown below.

Table 6.2. Data on Customers' voice

| Sl.No. | Customers' voice | Number of drivers' response | | | | Priority Scores |
|---|---|---|---|---|---|---|
| | | Excellent priority | Good priority | Average priority | Bad priority | |
| 1 | Condition of driver's seat | 3 | 5 | 6 | - | 31 |
| 2 | Condition of rear-view mirror | 1 | 11 | 1 | 1 | 30 |
| 3 | Condition of headlights | 1 | 6 | 4 | 3 | 37 |
| 4 | Engine condition | 4 | 6 | 3 | 1 | 31 |
| 5 | Condition of gearbox | 2 | 7 | 4 | 1 | 32 |
| 6 | Condition of transmission | 1 | 8 | 4 | 1 | 34 |
| 7 | Condition of suspension/springs | 1 | 6 | 6 | 1 | 36 |
| 8 | Condition of tyres | 2 | 7 | 3 | 2 | 33 |
| 9 | Condition of steering | 1 | 6 | 5 | 2 | 36 |
| 10 | Condition of brakes | - | 11 | 3 | - | 34 |
| 11 | Condition of clutches | - | 12 | 2 | - | 33 |
| 12 | Ride comfort | - | 6 | 7 | 1 | 37 |
| 13 | Handling characteristics | 1 | 11 | 1 | 1 | 30 |
| 14 | Oil leaks, if any | - | 10 | 4 | - | 32 |
| 15 | Fuel efficiency | - | 9 | 4 | 1 | 34 |
| 16 | Periodic maintenance | 1 | 11 | 2 | - | 29 |
| 17 | Response from maintenance department against problems | 1 | 8 | 5 | - | 32 |
| 18 | Control of repeated breakdowns | 1 | 9 | 4 | - | 31 |
| 19 | Consideration of drivers' suggestions by maintenance personnel | - | 9 | 4 | 1 | 34 |
| 20 | Skill of maintenance workers | 1 | 9 | 3 | 1 | 32 |

Strong Relation ship = ■

Medium relation ship = Δ

Weak Relation ship = ●

In case of no relationship, the corresponding cell is left blank. These data were entered into the HoQ matrix shown in Figure 6.1. Followed by that the correlation matrix was developed using the same symbols used for constructing relationship matrix to bring out the correlation among technical languages.

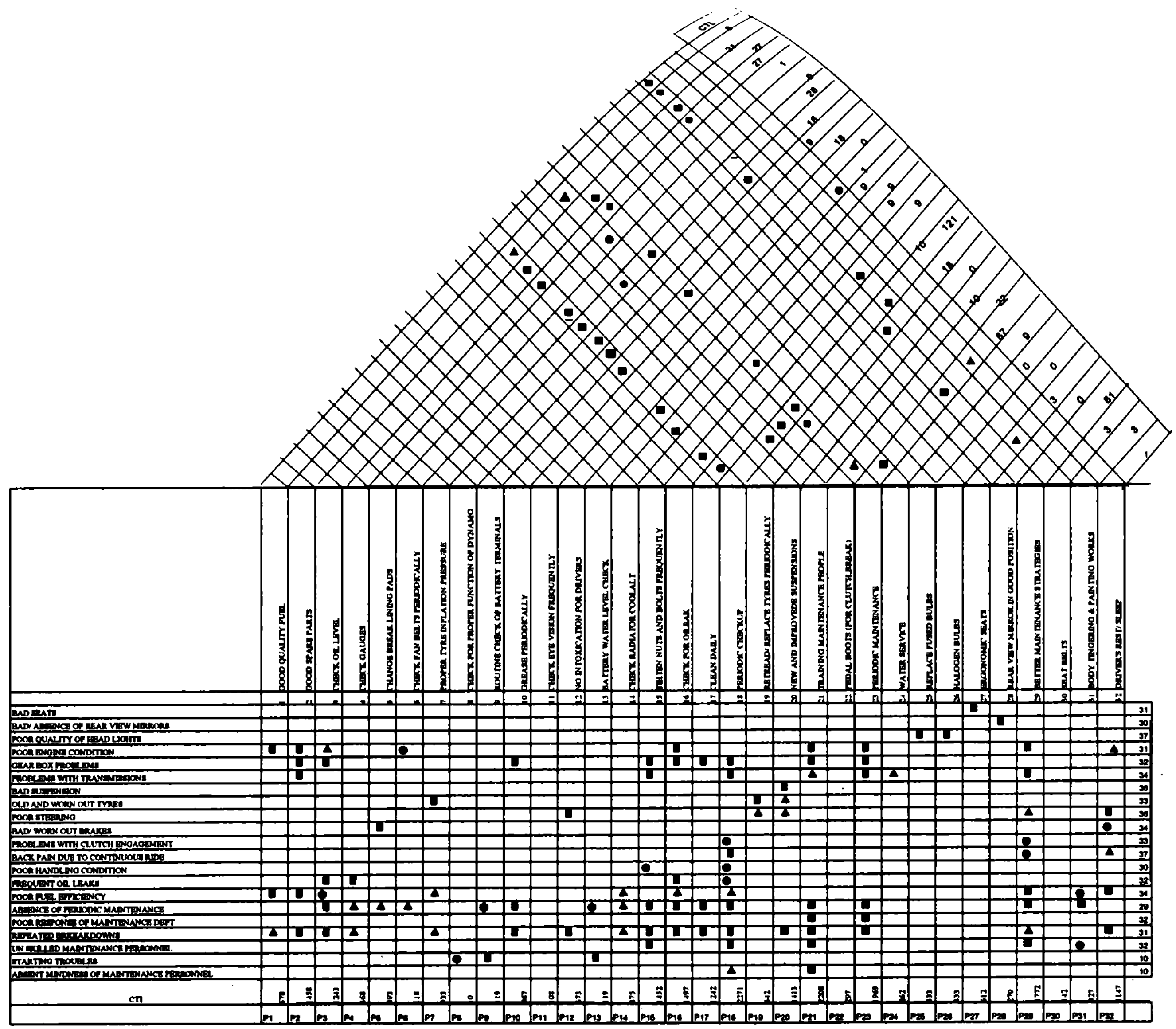



Figure 6.1 House of Quality matrix

CTI=Customer technical interactive score

CTL=Correlated weightage of the technical language

In order to quantify the relationships and correlate using numerical values, the pattern followed by Lu and Kuei (1999) for quantifying the relationships was used. Accordingly, the values 9, 3 and 1 were assigned to strong relationship/ correlation, medium relationship/ correlation, and weak relationship/ correlation respectively. No values were assigned against blank cells. These values were used to compute Customer-technical interactive scores and weighted correlated values. As a sample, the method of calculating Customer-technical interactive score is illustrated here by considering the technical language "Good Quality Fuel". The relationship of customer voices (that is, drivers' reactions) namely 'poor engine condition' and 'poor fuel efficiency' against 'good quality fuel' is indicated by the symbol ,whose value is 9. While the relationship of repeated breakdown with 'good quality fuel' is denoted by the symbol Δ, whose value is 3.The Customer technical interactive scores in this case was calculated as follows:

Formula:

$$\text{Customer technical interactive score} = \sum_{i=1}^{n} \text{Relationship values between customer voice and technical languages} \times \text{Expected value of customer voice}$$

Where n refers to the number of customer voices.

Example: Customer technical interactive score for 'good quality fuel'

$$=9\times13 +9\times34+3\times31 =678$$

In order to visualize the relative weightages, the percentage normalized value of customers technical interactive scores were computed as follows.

Formula used: Percentage normalized value of customers technical interactive

$$\text{score} = \frac{\text{Customer technical interactive score}}{\text{Sum of Customer Technical interactive score}} \times 100$$

Example: Percentage normalized score of customers technical interactive score against the technical voice "good quality fuel"

$$= (678/ 25551) \times 100 = 2.65$$

These computed scores are displayed in Table 6.3. The weighted correlated value is calculated by summing the values of correlations. As shown in Table 6.3, the weighted correlated value against the technical parameter "good quality fuel" is 9.

**Table 6.3. Technical descriptors and their computed scores**

| Sl No. | Technical descriptors | Customer technical interactive score (1) | Percentage normalized value of customers technical interactive score (2) | Correlated weightage of the technical language (3) | Percentage normalized value of correlated weightage (4) | Sum of (2)+(4) |
|---|---|---|---|---|---|---|
| 1 | Good quality fuel | 678 | 2.65 | 9 | 1.57 | 4.22 |
| 2 | Good spare parts | 1458 | 5.71 | 21 | 3.67 | 9.38 |
| 3 | Check oil level | 1243 | 4.86 | 27 | 4.72 | 9.58 |
| 4 | Check gauges | 468 | 1.83 | 27 | 4.72 | 6.55 |
| 5 | Change brake lining pads | 393 | 1.54 | 1 | 0.16 | 1.70 |
| 6 | Check fan belts periodically | 118 | 0.46 | 9 | 1.57 | 2.03 |
| 7 | Proper tyre inflation pressure | 933 | 3.65 | 28 | 4.89 | 8.54 |
| 8 | Check for proper function of alternator/dynamo | 10 | 0.04 | 18 | 3.15 | 3.19 |
| 9 | Routine checkup of battery terminals | 119 | 0.47 | 9 | 1.57 | 2.04 |
| 10 | Grease periodically | 867 | 3.39 | 18 | 3.15 | 6.54 |
| 11 | Check eye vision frequently | 108 | 0.42 | 0 | 0.00 | 0.42 |
| 12 | No intoxication for drivers | 673 | 2.63 | 1 | 0.18 | 2.81 |
| 13 | Battery water level check | 119 | 0.46 | 9 | 1.57 | 2.03 |
| 14 | Check radiator coolant | 375 | 1.47 | 9 | 1.57 | 3.04 |
| 15 | Tighten nuts and bolts frequently | 1452 | 5.68 | 9 | 1.57 | 7.25 |
| 16 | Check for oil leak | 1497 | 5.86 | 9 | 1.57 | 7.43 |
| 17 | Clean daily | 1242 | 4.86 | 10 | 1.75 | 6.61 |
| 18 | Periodic checkup | 2271 | 8.88 | 121 | 21.15 | 30.03 |
| 19 | Retread/replace tyres as needed | 442 | 1.73 | 18 | 3.15 | 4.88 |
| 20 | New and improved suspensions | 1413 | 5.53 | 0 | 0.00 | 5.53 |
| 21 | Training maintenance personnel | 2208 | 8.64 | 10 | 1.75 | 10.39 |
| 22 | Pedal boots (for clutch, brake, gas pedal) | 297 | 1.16 | 22 | 3.85 | 5.01 |
| 23 | Periodic maintenance | 1969 | 7.71 | 87 | 15.20 | 22.91 |
| 24 | Water service | 262 | 1.03 | 9 | 1.57 | 2.60 |
| 25 | Replace fused bulbs | 333 | 1.30 | 0 | 0.00 | 1.30 |
| 26 | Halogen bulbs | 333 | 1.30 | 0 | 0.00 | 1.30 |
| 27 | Ergonomic seats | 612 | 2.39 | 3 | 0.52 | 2.91 |
| 28 | Rear-view mirror in good position | 270 | 1.06 | 0 | 0.00 | 1.06 |
| 29 | Better maintenance strategies | 1772 | 6.94 | 81 | 14.16 | 21.10 |
| 30 | Seat belts | 142 | 0.56 | 3 | 0.52 | 1.08 |
| 31 | Body tinkering and painting works | 327 | 1.28 | 3 | 0.52 | 1.80 |
| 32 | Drivers' rest/sleep | 1147 | 4.48 | 1 | 0.18 | 4.66 |

**Table 6.4. Technical languages which are not required to pass through the TPM pillars**

| Technical languages | Actions to be taken |
|---|---|
| Periodical Check up | Conduct once in every six months |
| Good spare parts | Always buy spare parts from Original equipment manufacturers. |
| Good quality fuel | Fuel should be purchased from government owned depots only |
| Proper Tyre inflation pressure | Tyre inflation pressure has to be checked periodically for each vehicle. The frequency of checking has to be decided as per the recommendation of the manufacturers. |
| Check Gauges | Gauges are to be checked by both drivers and maintenance personnel immediately after the engine is started. |
| Check fan belts periodically | Fan belt should not be loose. This has to be checked when the alternator/dynamo is not functioning. Due to this, battery will not get charged. This will result in engine starting troubles. |
| Routine checkup of battery terminals | This has to done once in a week. This is to remove any scale formation. |
| Grease periodically | Greasing has to be done at specified points. This has to be done after every 1500 kilometers of ride. The purpose of greasing is to prevent wear and tear of machinery parts and severe vibrations. |
| Battery water level check. | This can help to enhance the life of the battery. |
| Check radiator coolant | This avoids the corrosion of aluminum parts and hence the life of the waterpump and cylinder head assembly can be improved. The frequency of checking is once in every week. |
| Retread/ replace tyres as needed | Tyres have to be replaced for every 55,000 to 60,000 kilometers. Rethreading has to be done after 25,000 kilomters or when tyre is worn out which ever is early. |
| Replace fused bulbs | Replacement of fused bulbs and other electrical accessories has to be done when they fail. |
| Body tinkering and painting works | This has to be done according to the decision of the competent authority, which will be based up on the situation or body condition. |
| Pedal boots (for clutch, brake and gas pedal) | This has to be done as a routine maintenance practice. |
| Check for proper function of alternator/dynamo | Fan belt should not be loose. This has to be checked when the alternator/dynamo is not functioning. Due to this, battery will not get charged. This will result in engine starting troubles. |
| Halogen bulbs | It is used for visible lighting. Replacement has to be done as and when bulbs fail. |

**Table 6.5** Technical languages, which are required to pass through TPM pillars.

| Technical languages | Actions to be taken |
|---|---|
| Training maintenance people | When a new vehicle is purchased, training should be imparted to drivers/ maintenance personnel. They should be deputed to attend those training sessions which will be conducted by the authorize dealers. This is achieved by the pillar 'Education and Training'. |
| Check for oil leak | This has to be checked daily before the vehicle is being put into use. This has to be bone through the pillar 'Education and Training'. |
| Tighten nuts and bolts frequently | Everyday before starting the vehicle, nuts and bolts are to be checked and if found any looseness they are to be tightened. This has to be done by the implementation of the pillar 'Autonomous Maintenance'. |
| Check oil level | This has to be implemented by the pillar 'Autonomous Maintenance'. |
| Change brake lining pads | Checking of brakes has to de done when there are complaints from the drivers. In addition to that, break lining pads are to be replaced once in every 20000 kilometers of running. It has to be done by implementation of the pillar 'Planned Maintenance'. |
| Check eye vision of the drivers frequently | Drivers have to ensure that their eye vision is good. They have to do the checkup every year. In addition to that drivers of age above 40 are needed to do complete health checkups every year. This has to be done by implementation of the pillar 'Safety, Health and Environment' |
| Ergonomic seats | The seat designs of drivers are to be changed as per the ergonomics requirements. In addition to that drivers should be instructed to use seat belts. This has to be implemented by the pillar, 'Safety, Health and Environment' |
| Drivers' rest/sleep | Drivers are advised to avoid night driving as far as possible, especially during peak sleeping hours. This has to be implemented by the pillar, 'Safety, Health and Environment' |
| Rear-view mirror in good position | This has to be adjusted by the drivers before starting the engine. This has to be implemented by the pillar, 'Autonomous Maintenance'. |
| No intoxication for drivers | Drivers are instructed to avoid alcohol. This has to be implemented by the pillar 'Education and Training' |
| Clean daily | Vehicles have to be maintained always clean. For that daily cleaning is essential .Cleaning has to be done by drivers. Extreme care has to be taken in the conditions of wind screen and glasses. |

Table Contd

| | |
|---|---|
| Periodic maintenance | This has to be executed in the interval of every three months. This is very important in the case of vehicles which are used in hilly terrains. This has to be implemented by the pillar, 'Planned Maintenance'. |
| Seat belts | Drivers are instructed to use seat belts. This has to be implemented by the pillar, 'Education and Training'. |
| Better maintenance strategies | Maintenance personnel should be imparted training once in every six months. They should be trained about fuel economy, economic speed, conducting of special classes by Indian oil corporation adds a lot in this regard. Their theme includes economic usage of fuel and lubricants. People are deputed for the course in every six months. This has to be implemented by the pillar, 'Education and Training'. |
| Water service | It has to be done in every 1600 Kilometers. This has to be implemented by the pillar, 'Planned Maintenance'. |
| New & improved suspensions | This has used for good cushioned effect for both drivers as well as passengers. This has to be implemented by the pillar, 'Safety, Health and Environment. |

In order to visualize the relative weightages of technical correlation, the percentage normalized value of correlated weights were calculated using the following formula.

Percentage normalized value of correlated weightage =

$$\frac{\text{Correlated weightage of the technical language}}{\text{Sum of Correlated weightages}} \times 100$$

Example: Percentage normalized value of correlated weightage against the technical parameter 'good quality fuel'= 9/572 × 100 =1.57

Both percentage normalized score of customers technical interactive score and percentage normalized value of correlated weightage have been added and entered in the side of correlation matrix of HoQ and are termed as total normalized values.

The Automobile engineer was interviewed to spell out the technical descriptors. These are given code numbers P1, P2, P3,........P32. Though his intension was to prioritise the implication of technical requirements based on percentage normalized value of correlated weightage, he expressed the feasibility of implementing all the technical requirements. According to the MQFD model the Automobile engineer was asked to make strategic decisions to either direct the technical requirements towards the TPM eight pillars implementation or an immediate and direct implementation. Such decisions taken by him are portrayed in Tables 6.4 and 6.5. However these technical requirements could not be implemented in this service station because it is an Indian state government run public sector, which requires decision making by the top level committee by following long democratic procedures. Hence the Automobile engineer was asked to anticipate the result of implementing the MQFD by considering six of its maintenance quality parameters of MQFD model. In order to compare the present and future performance, the past data of ten vehicles serviced by the service station were collected. They are shown in Table 6.6. The sample calculations of maintenance quality parameters (Chan et.al, 2005,Juran and Gryna,1997) are presented in the subsequent subsections.

### 6.3.1. Computation of Availability

Availability is a measure of what percentage of the total time the vehicle is available for use. It is calculated using the following formula

Availability = (Scheduled running time – Down time) / (Scheduled running time)

For example, for vehicle 1 during the year 2003,

Availability = [365 days – (1 + 18 + 1) days] / 365 days

= 94.98%

### 6.3.2. Computation of MDT

MDT is the average down time of the vehicle. That is, the average time a vehicle would be out of service during a specified year once it breaks down or is brought for service. It is the sum of down time and idle time.

MDT = Total down time / Number of breakdowns or service entries

= Σ (Down times) / (Number of down times)

For vehicle 1 in 2003,

MDT = (1 + 18 + 1) days / 3

= 6.6 days = 7 days

### 6.3.3. Computation of MTBF

MTBF is the average time a vehicle would run trouble-free before experiencing any sort of failure. In our situation, information was available only regarding the cases of failure where the vehicle was brought into the workshop for maintenance. Hence, this was assumed accordingly.

$$MTBF = \Sigma(TBF) / (N_f + 1)$$

where

TBF = Time between failures

$N_f$ = Number of failures

For vehicle 1 in 2003,

MTBF = (80 + 72 + 39 + 173) days / (3 + 1)

= 92 days

### 6.3.4. Computation of MTTR

MTTR is the average time taken to repair a vehicle once it is brought into service.

It is given by the following formula

MTTR = Total repair time / Number of workshop visits

In this workshop, it was not possible to gather data required to find total repair time. Hence, it was decided to take the time to repair as the amount of time the vehicle is laid back inside the workshop. This made MTTR equal to MDT.

### 6.3.5. Computation of OEE

OEE is an effective way of analyzing any vehicle. It is a product of availability, performance rate and quality rate, which are measures of equipment losses (Jonsson and Lesshammar,1999). Thus, overall effectiveness of the vehicle was considered the ultimate tool in the measuring the success of TPM implementation in the company. It is given by the following formula,

OEE = Availability × Performance rate × Quality rate

Here, Performance Rate was given an assumed constant value of 0.90 and Quality Rate was given a value of 0.95.

Using these values, OEE for vehicle 1 in the year 2003 was calculated as follows

OEE = 94.98 × 0.90 × 0.95

= 85.48%

**Table 6.6.** Vehicle maintenance data

| Serial Number of the Vehicle | Date of Arrival | Date of Release | Downtime (Days) |
|---|---|---|---|
| 1 | **2003** | | |
| | March 20,2003 | March 20,2003 | 1 |
| | June 02,2003 | June 19,2003 | 18 |
| | July 28,2003 | July 28, 2003 | 1 |
| | **2004** | | |
| | January 20,2004 | February13,2004 | 24 |
| | April 19,2004 | May 04,2004 | 16 |
| | July 22,2004 | August 04,2004 | 13 |
| | September 01,2004 | September 08,2004 | 8 |
| | November 29,2004 | November 30,2004 | 1 |
| | December 28,2004 | December 28,2004 | 1 |
| 2 | **2003** | | |
| | February 02,2003 | February 18,2003 | 13 |
| | November 11,2003 | November 11,2003 | 1 |
| | **2004** | | |
| | February 13,2004 | February 13,2004 | 1 |
| | May 18,2004 | May18,2004 | 1 |
| | July 17 2004 | July 17 2004 | 1 |
| | August 27 2004 | August 27 2004 | 1 |
| | September 29 2004 | November 17 2004 | 49 |
| 3 | **2003** | | |
| | January 21 2003 | January 23, 2003 | 2 |
| | February 04 2003 | February 04, 2003 | 1 |
| | April 11 2003 | April 11, 2003 | 1 |
| | August 11 2003 | August 11, 2003 | 1 |
| | December 29 2003 | December 29, 2003 | 1 |
| | **2004** | | |
| | May 6,2004 | May 6,2004 | 1 |
| | July 14, 2004 | July 14, 2004 | 1 |
| | September 7,2004 | September 14,2004 | 8 |

Table Contd

| | | | |
|---|---|---|---|
| 4 | **2003** | | |
| | February 17, 2003 | February 17, 2003 | 1 |
| | April 09, 2003 | April 09, 2003 | 1 |
| | July 25, 2003 | September 10,2003 | 46 |
| | September 29, 2003 | September 30, 2003 | 1 |
| | **2004** | | |
| | February 27, 2004 | February 27, 2004 | 1 |
| | May 17, 2004 | June15, 2004 | 28 |
| | August 13, 2004 | August 13, 2004 | 1 |
| 5 | **2003** | | |
| | March19 2003 | March19, 2003 | 1 |
| | April 22 2003 | May14, 2003 | 24 |
| | June 19, 2003 | June 24, 2003 | 5 |
| | November 27, 2003 | December12, 2004 | 76 |
| | **2004** | | |
| | May 16, 2004 | June 23, 2004 | 39 |
| 6 | **2003** | | |
| | June 02, 2003 | June 10, 2003 | 9 |
| | October 07, 2003 | October 07, 2003 | 1 |
| | **2004** | | |
| | March 25, 2004 | March 29, 2004 | 3 |
| 7 | **2003** | | |
| | March 04 2003 | March 04 2003 | 1 |
| | March 12 2003 | March 12 2003 | 1 |
| | May 26, 2003 | June 11,2003 | 16 |
| | October 08, 2003 | October 08, 2003 | 1 |
| | November 08 2003 | November 08, 2003 | 1 |
| | November 20, 2003 | December 11, 2003 | 21 |
| | **2004** | | |
| | April 14, 2004 | April 14, 2004 | 1 |
| | September 10, 2004 | September 10, 2004 | 1 |
| 8 | **2003** | | |
| | March 07, 2003 | March 07, 2003 | 1 |
| | March 17, 2003 | March 26, 2003 | 9 |
| | April 07, 2003 | April 07, 2003 | 1 |
| | September 19, 2003 | September 19, 2003 | 1 |
| | November 14, 2003 | November 14, 2003 | 1 |
| | December 15, 2003 | February 03, 2004 | 48 |
| | **2004** | | |
| | April 12, 2004 | April 12, 2004 | 1 |
| | May, 31, 2004 | May, 31, 2004 | 1 |
| | August 13, 2004 | August 13, 2004 | 1 |
| | October 29, 2004 | October 29, 2004 | 1 |
| 9 | **2003** | | |
| | November 14, 2003 | November 14, 2003 | 1 |
| | **2004** | | |
| | January 19, 2004 | January 19, 2004 | 1 |
| | February 20, 2004 | February 20, 2004 | 1 |
| | March 02, 2004 | March 02, 2004 | 1 |
| | June 18, 2004 | June 18, 2004 | 1 |
| | September 27, 2004 | September 27, 2004 | 1 |
| | November 16, 2004 | December16, 2004 | 30 |

Table Contd.

| | | | |
|---|---|---|---|
| 10 | **2003**<br>February 11, 2003<br>March 21, 2003<br>May, 26, 2003<br>December 01, 2003<br>**2004**<br>January 22, 2004<br>May 03, 2004<br>September 16, 2004<br>October 14, 2004 | <br>February 11, 2003<br>March 21, 2003<br>June 03, 2003<br>December 30, 2003<br><br>February 06, 2004<br>May 03, 2004<br>September 16, 2004<br>October 14, 2004 | <br>1<br>1<br>7<br>29<br><br>14<br>1<br>1<br>1 |

Like the above, the values of maintenance quality parameters concerning the remaining nine vehicles were also computed. The computed values of maintenance quality parameters were shown to the automobile engineer of the service station . Then he was asked to imagine that MQFD was implemented and forecast the values for the year 2005. Those values (both computed and forecast) are shown in Table 6.7. As indicated, he anticipates improvement in maintenance quality of vehicles 1-5. He expects the retainment of maintenance quality values for vehicles 6-10. The reason he cites is that these vehicles are new and retaining the previous year's maintenance quality itself is a major achievement. Finally he was asked to declare the anticipated outputs of MQFD implementation. According to his forecast, there will be 5% improvement in maintenance quality and 20% increase in profit (due to less expenditure on maintenance activities). He is also confident that core competence will get upgraded from the current level of 2 in the Likert's scale of range 0-10 to the level of 7. Further he expects that the goodwill of the service station will enhance from the current level of 4 in the Likert's scale of range 0-10 to the level of 8. According to him, the core competence will be revealed through enhanced skill level of both maintenance staff and drivers, increased awareness over new maintenance methods and reduced number of breakdowns. The goodwill will be revealed through increased owner satisfaction, reduced delivery time of vehicles, drivers' satisfaction and saving in fuel cost. These benefits closely coincide with the theoretical drawn predictions shown in Figure 4.2.

Table 6.7. Tangible parameters to measure the success of MQFD

| Serial Number of the Vehicle | Year | Availability In percentage | MDT (Days) | MTBF (Days) | OEE In percentage | Remarks |
|---|---|---|---|---|---|---|
| 1 | 2003 | 94.98 | 6 | 92 | 85.48 | Slightly old |
| | 2004 | 82.97 | 10 | 50 | 74.67 | |
| | 2005(Anticipated) | 96 | 5 | 110 | 90 | |
| 2 | 2003 | 96.16 | 7 | 97 | 86.54 | Slightly old |
| | 2004 | 86.39 | 10 | 59 | 77.75 | |
| | 2005(Anticipated) | 98 | 5 | 120 | 92 | |
| 3 | 2003 | 99.27 | 1 | 72 | 89.34 | Slightly old |
| | 2004 | 97.72 | 3 | 89 | 87.95 | |
| | 2005 (Anticipated) | 99.27 | 1 | 72 | 89.34 | |
| 4 | 2003 | 87.26 | 12 | 74 | 78.53 | Slightly old |
| | 2004 | 92.24 | 10 | 93 | 83.02 | |
| | 2005(Anticipated) | 95 | 5 | 95 | 88 | |
| 5 | 2003 | 82.42 | 16 | 75 | 74.18 | Old |
| | 2004 | 77.81 | 41 | 142 | 70.03 | |
| | 2005(Anticipated) | 82.42 | 16 | 75 | 74.18 | |
| 6 | 2003 | 97.49 | 5 | 147 | 87.74 | Old |
| | 2004 | 99.18 | 3 | 222 | 89.26 | |
| | 2005(Anticipated) | 99.18 | 3 | 222 | 89.26 | |
| 7 | 2003 | 89.68 | 6 | 54 | 80.71 | New |
| | 2004 | 99.91 | 1 | 121 | 89.92 | |
| | 2005(Anticipated) | 99.91 | 1 | 121 | 89.92 | |
| 8 | 2003 | 97.35 | 2 | 75 | 87.62 | Very New |
| | 2004 | 99.82 | 1 | 82 | 89.84 | |
| | 2005(Anticipated) | 99.82 | 1 | 82 | 89.84 | |
| 9 | 2003 | 99.95 | 1 | 190 | 89.96 | New |
| | 2004 | 91.55 | 5 | 53 | 82.40 | |
| | 2005(Anticipated) | 91.55 | 5 | 53 | 82.40 | |
| 10 | 2003 | 89.50 | 10 | 81 | 80.55 | New |
| | 2004 | 95.75 | 4 | 69 | 86.18 | |
| | 2005(Anticipated) | 95.75 | 4 | 69 | 86.18 | |

## 6.4. Conclusion

The implementation possibility of MQFD was checked in an Indian state government run Public sector service station. The successful development of MQFD documents and the reactions of the Automobile engineer were very encouraging to infer that MQFD would be a feasible model for successfully implementing it and nourishing the synergic benefits of QFD and TPM.

Chapter - 7

# IMPLEMENTATION OF MQFD IN TYRE MANUFACTURING: AN IMPLEMENTATION STUDY

*Content*

# IMPLEMENTATION OF MQFD IN TYRE MANUFACTURING: AN IMPLEMENTATION STUDY

## 7.1. Introduction

The mankind has been sensing the need of transportation. During the contemporary days, transportation has become a part of many activities of the organization. Hence the smooth running of transportation system improves the performance of the organization. Since majority of the transportation occurs through road, the world communities' dependence on tyres keeps increasing. The tyres are made up of rubber which provides cushioning effect to the wheels and thereby increases the speed and comfort of the transportation systems. This situation reveals that any contribution on increasing the quality of manufacturing tyres would benefit the entire human race. In this context, the study on MQFD implementation was conducted in a tyre building section in a unit of an Indian company. The details of this work are presented in this chapter.

## 7.2. About the Tyre manufacturing unit

The tyre-manufacturing unit in which MQFD implementation was conducted is located at the village called Perambra of Thrichur district of India. This tyre manufacturing unit was chosen for the study because TPM is being implemented in it. This company's tyres have created a niche for itself in the Indian tyre market. After three decades of consistent growth, today, it has become India's premier tyre manufacturing company. The commercial production of this company began in 1977 with an installed capacity of 420,000 tyres and tubes. On November 17, 2003 the company entered into a strategic alliance with Michelin, a French based company for setting up a joint venture company for producing dual branded truck and bus radial tyres in India. Michelin will also provide technical assistance for manufacturing of passenger radial tyres. The company is ISO 9001 certified in 1994. It has also got QS 9000: 1998 certifications for quality management systems.

## 7.3. Data Collection

To begin with, the customer complaints received during the months from July to December 2005 were analyzed. The tyre building section supplies green (uncured ) tyres to the curing section. One of the machines used in tyre building section is shown Figure 7.1. Since the green tyres are subsequently cured by the employees of the curing section, they were considered as the internal customers of the tyre building section. Relevant data were gathered by referring to the data sheet called quality matrix which was maintained in the technical department. A sample portion of the quality sheet referred is shown in Figure 7.2. The complaints of internal customers in the curing department are regularly collected and maintained by the technical department. Those data were collected and were analyzed. The complaints with maximum frequency were considered for implementation study and expressed as a percentage of total number of tyres produced in each month. Those data are shown in Table 7.1.

**Table 7.1. Major Customer Complaints from July to December2005**

| Customer Complaints | Bead off | | Turn up wrinkle | | Loose turn up | | Air under tread | |
|---|---|---|---|---|---|---|---|---|
| Month | Number | Percentage | Number | Percentage | Number | Percentage | Number | Percentage |
| July 2005 | 73 | 0.06 | 29 | 0.024 | 10 | 0.008 | 10 | 0.008 |
| August 2005 | 100 | 0.076 | 27 | 0.020 | 6 | 0.005 | 7 | 0.005 |
| September 2005 | 56 | 0.05 | 18 | 0.016 | 7 | 0.006 | 13 | 0.012 |
| October 2005 | 69 | 0.061 | 26 | 0.023 | 9 | 0.008 | 13 | 0.012 |
| November 2005 | 68 | 0.056 | 21 | 0.017 | 9 | 0.008 | 7 | 0.006 |
| December 2005 | 95 | 0.078 | 16 | 0.013 | 10 | 0.008 | 5 | 0.004 |

## 7.4. Construction of HoQ

Ranking of customer complaints was done based on the discussion with technical managers. Those complaints were entered as the customer voices in the HoQ matrix. Customer voices were converted into appropriate technical languages by discussing with the technical and quality managers. The relationships of customer voices with technical languages were established by discussing with technical and quality managers and were assigned weight factors for the purpose of quantifying them. The HoQ thus constructed during this implementation study is shown in Figure 7.3. The methodology explained in chapter 6 was adopted to construct this HoQ.The calculated CTI, CWTL and other related terms are given in Table 7.2.

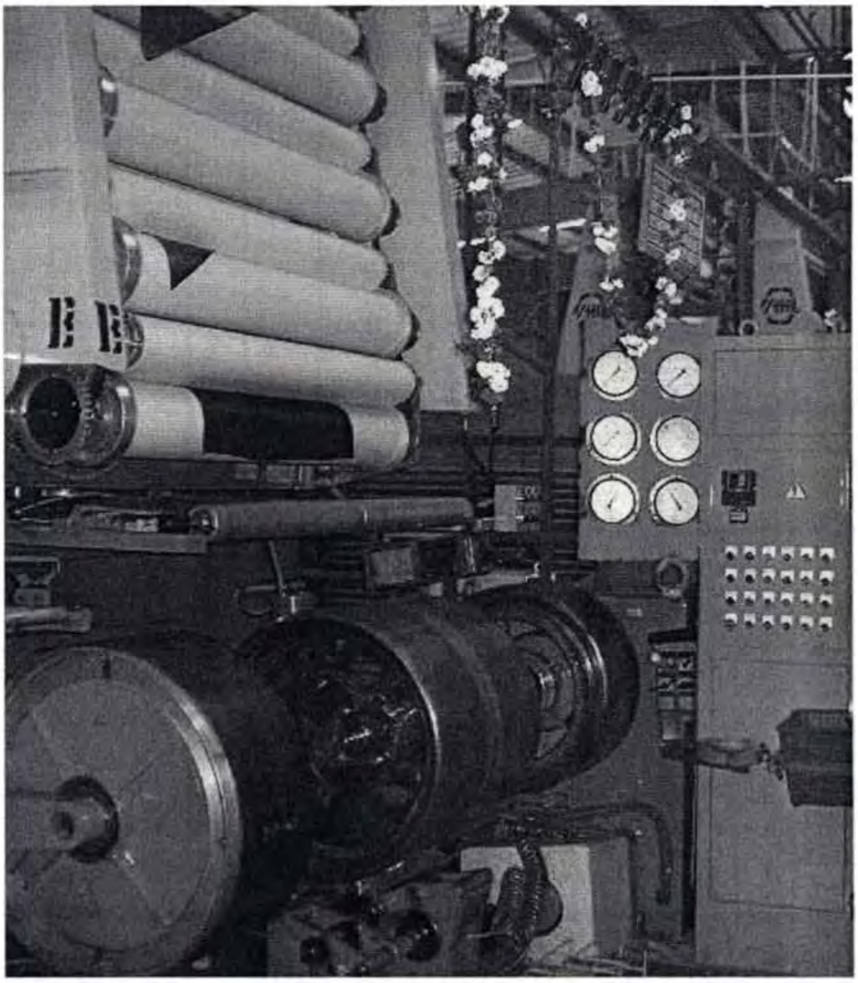
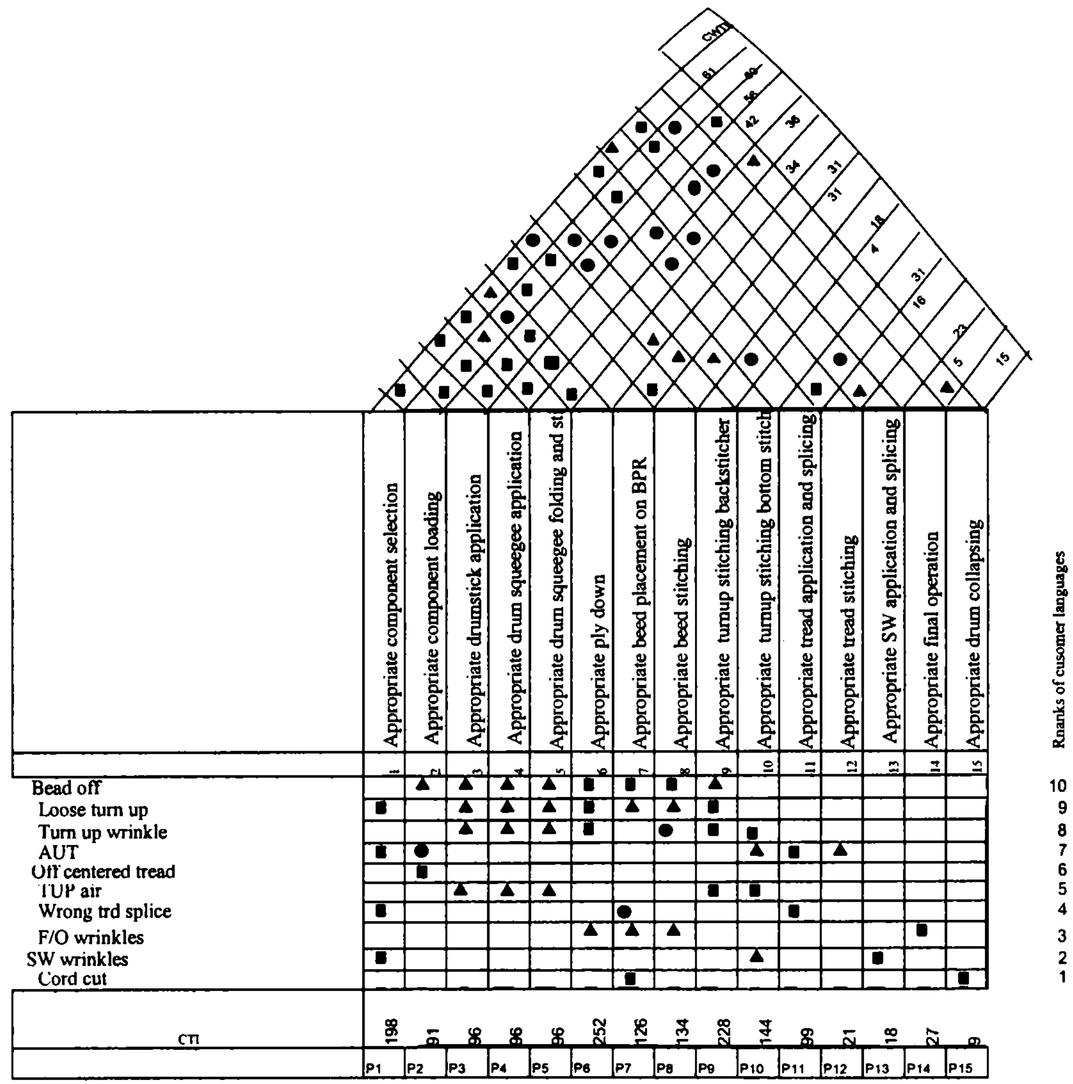


**Figure 7.1** Tyre building machine

| Technical Requirements | Appropriate component selection | Appropriate component loading | Appropriate drum stick application | Appropriate drum squeegee application | Appropriate drum squeegee folding and stitching | Appropriate ply down | Appropriate bead placement on BPR | Appropriate bead stitching | Appropriate turn up stitching back stitcher | Appropriate turn up stitching bottom stitcher | Appropriate tread application and splicing | Appropriate tread stitching | Appropriate SW application and splicing | Appropriate final operation | Appropriate drum collapsing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bead off | | √ | √ | √ | √ | √ | √ | √ | √ | | | | | | |
| Loose turn up | √ | | √ | √ | √ | √ | √ | √ | √ | | | | | | |
| Turn up wrinkle | | | √ | √ | √ | √ | | √ | √ | √ | | | | | |
| AUT | √ | √ | | | | | | | | √ | √ | √ | | | |
| Off cent. Tread | | √ | | | | | | | | | | | | | |
| TUP air | | | √ | √ | √ | | | | √ | √ | | | | | |
| Wrong trd splice | √ | | | | | | | | | | √ | | | | |
| F/O wrinkles | | | | | | √ | √ | √ | | | | | | √ | |
| SW wrinkles | √ | | | | | | | | | √ | | | √ | | |
| Cord cut | | | | | | | | | | | | | | | √ |

**Figure 7.2. A sample quality sheet**




CTI=Customer technical interactive score

CWTL=Correlated weightage of the technical language

Figure 7.3 HoQ Matrix

**Table 7.2. Percentage normalized value of customer technical interactive score and correlated weight factors of technical language.**

| Technical language | CTI | Percentage normalized value of CTI (a) | CWTL | Percentage normalized value of CWTL (b) | Sum of (a) and (b) |
|---|---|---|---|---|---|
| Appropriate component selection | 198 | 12.11 | 61 | 13.20 | 25.31 |
| Appropriate component loading | 91 | 5.56 | 60 | 12.99 | 18.55 |
| Appropriate drum stick application | 96 | 5.87 | 56 | 12.12 | 17.99 |
| Appropriate drum squeegee application | 96 | 5.87 | 42 | 9.09 | 14.96 |
| Appropriate drum squeegee folding and stitching | 96 | 5.87 | 36 | 7.79 | 13.66 |
| Appropriate ply down | 252 | 15.41 | 34 | 7.36 | 22.77 |
| Appropriate bead placement on BPR | 126 | 7.71 | 30 | 6.49 | 14.2 |
| Appropriate bead stitching | 134 | 8.19 | 31 | 6.71 | 14.9 |
| Appropriate Turn up stitching back stitcher | 228 | 13.94 | 18 | 3.90 | 17.84 |
| Appropriate Turn up stitching bottom stitcher | 144 | 8.80 | 4 | 0.86 | 9.66 |
| Appropriate tread application and splicing | 99 | 6.05 | 31 | 6.71 | 12.76 |
| Appropriate tread stitching | 21 | 1.28 | 16 | 3.46 | 4.74 |
| Appropriate SW application and splicing | 18 | 1.10 | 23 | 4.98 | 6.08 |
| Appropriate final operation | 27 | 1.65 | 5 | 1.08 | 2.73 |
| Appropriate drum collapsing | 9 | 0.55 | 15 | 3.25 | 3.8 |
| Total | 1635 | 100 | 462 | 100 | 200 |

From the Table 7.2, it can be observed that appropriate component selection, component loading and ply down are the most critical technical requirements to ensure good quality green tyre. These are the technical requirements having very high sum of CTI and CWTL. By discussing with the assistant manager-production, who is also in charge of TPM implementation, it is found out that these technical requirements can be implemented using some of the TPM pillars. Hence actions have been recommended for implementation through each TPM pillar against each technical language. These recommendations are narrated in the following subsections.

### 7.4.1. Appropriate Components Selection

Appropriate components selection is vital for maintaining the components like tread, bead and sidewall in good condition. There should not be any damage to these components, as use of defective components will affect the quality of green tyre. Appropriate component selection can be implemented by applying certain TPM pillars which are indicated with recommended actions in Table 7.3.

**Table 7.3.** TPM Pillars and actions recommended for implementing TPM pillars for appropriate component selection

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | Operators should inspect all the components and make sure that they are in good condition. Actions have to be taken to prevent any damages to the components. |
| Education and training | All employees should be trained to use good components and taught the methods of handling them appropriately so that they are not damaged during handling. |
| Quality maintenance | All the actions needed to assure quality should be strictly followed. The components should have specified dimensions |
| Individual improvement | All the machines used for component preparation should be in good condition and all the employees should have knowledge about the activities of the machine and specifications of components. |

### 7.4.2. Appropriate Component Loading

Component centering and placement are important for loading. This can be by applying certain TPM pillars which are indicated with recommended actions in Table 7.4.

**Table 7.4.** TPM Pillars and actions recommended for implementing TPM pillars for appropriate Component Loading

| TPM Pillars | Actions recommended |
|---|---|
| Individual improvement | Loading of each component should be given sufficient care to ensure that appropriate placement and centering occur. |
| Education and training | Employees should be trained in appropriate component loading and taught how to do it appropriately. |
| Quality maintenance | All activities needed to ensure appropriate loading and splicing of components should be strictly followed. |

### 7.4.3. Appropriate Drumstick Application

The quantity of drumstick should be optimum. The area applied also should be exact. This can be ensured by applying certain TPM pillars which are indicated with recommended actions in Table 7.5.

**Table 7.5.** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Drumstick Application

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | Employees should be trained in drumstick application and its quantity to be applied. They should know the exact area where the drum stick has to be applied. |

### 7.4.4. Appropriate Drum Squeegee Application

Drum Squeegee should stick appropriately. Centering and placement have also to be correct. This can be implemented by applying certain TPM pillars which are indicated with recommended actions in Table 7.6.

**Table 7.6.** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Drum Squeegee Application

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | Employees should be trained how to place and center the drum squeegee appropriately and about its importance in assuring the quality of green tyre. |
| Quality maintenance | All activities needed to ensure quality of green tyres should be undertaken. Employees should make sure that drum squeegee sticks appropriately. |

## 7.4.5. Appropriate Drum Squeegee Folding and Stitching

Appropriate Drum Squeegee Folding and Stitching have to be ensured so that while folding and stitching drum squeegee, there will be no wrinkles. In order to achieve this, the tools should be in good condition. This can be implemented by applying certain TPM pillars which are indicated with recommended actions in Table 7.7

**Table 7.7** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Drum Squeegee Folding and Stitching.

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | The stitching tool should be in good condition. This is achieved by regular cleaning, lubricating and tightening of bolts. |
| Planned maintenance | All the maintenance activities should be planned in advance and scheduled as per the plans to ensure good quality products. |
| Education and training | Employees should be made aware of the importance of this operation and how to do it appropriately. |
| Quality maintenance | All the activities needed to ensure quality has to be done. The stitching tool should be kept in good condition. |

## 7.4.6. Appropriate Ply Down

Ply is the most critical component of a tyre. There should not be any wrinkles or open end. In order to achieve this level of quality, the tools should be maintained in good condition. This can be implemented by applying certain TPM pillars which are indicated with recommended actions in Table 7.8.

**Table 7.8** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Ply Down.

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | This is done to keep the stitching tool in good condition. Regular cleaning, lubricating and tightening of bolts are to be done. |
| Planned maintenance | All the maintenance activities should be planned in advance and scheduled as per the plans to ensure optimum ply down. |
| Education and training | Employees should be educated on manufacturing aspects of ply. |
| Quality maintenance | All the activities needed to ensure the quality of ply should be undertaken. The stitching tool should be kept in good condition. |

### 7.4.7. Appropriate Bead Placement on Roller

Selection of good beads and its appropriate placement on the roller are very important to produce a good tyre. Bead should be placed squarely and concentrically. This can be implemented by applying certain TPM pillars which are indicated with recommended actions in Table 7.9.

**Table 7.9.** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Bead Placement on BPR

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | The employees should be trained about the importance of appropriate bead placement and the methods of placing it squarely and concentrically. |
| Quality maintenance | All activities needed to ensure quality of centering of bead should be carriedout. The bead should be in good condition and should have specified dimensions. |

### 7.4.8. Appropriate Bead Stitching

Appropriate Bead Stitching can be achieved by maintaining the stitching tool in appropriate condition. This can be implemented by applying certain TPM pillars, which are indicated with recommended actions in Table 7.10.

Table 7.10. TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Bead Stitching

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | This is done to keep bead stitching tool in good condition by regular cleaning, lubricating and tightening of bolts. |
| Planned maintenance | All the maintenance activities should be planned in advance and scheduled according to the plans to ensure good quality products. |
| Education and training | Employees should be made aware of the importance of this operation and the method of doing it appropriately. |
| Quality maintenance | All the activities needed to ensure quality of bead stitching should be carriedout. The bead stitching tool should be kept in good condition. |

## 7.4.9. Appropriate Turn up Stitching Back Stitcher

Appropriate Turn up Stitching Back Stitcher can be achieved by maintaining the back stitching tool in appropriate condition. This can be implemented by applying certain TPM pillars, which are indicated with recommended actions in Table 7.11.

Table 7.11 TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Turn up Stitching Back Stitcher.

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | This is done to keep the back stitching tool in good condition. Regular cleaning, lubricating and tightening of bolts are to be carried out. |
| Planned maintenance | All the maintenance activities should be planned in advance and scheduled according to the plans to ensure the quality of backstitching. |
| Education and training | Employees should be educated on the importance of back stitching operation and the method of carrying out it appropriately. |
| Quality maintenance | All the activities needed to ensure quality of back stitching should be carried out. The back stitching tool should be kept in good condition. |

### 7.4.10. Appropriate Turn up Stitching Bottom Stitcher

Appropriate Turn up Stitching Bottom Stitcher can be achieved by maintaining the stitching tool in appropriate condition. This can be implemented by applying certain TPM pillars, which are indicated with recommended actions in Table 7.12.

**Table 7.12.** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Turn up Stitching Bottom Stitcher

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | This is done to keep the bottom-stitching tool in good condition. Regular cleaning, lubricating and tightening of bolts are to be done. |
| Planned maintenance | All the maintenance activities should be planned in advance and scheduled according to the plans to ensure the quality of bottom stitching. |
| Education and training | Employees should be educate4d on the importance of bottom-stitching operation and the method of doing it appropriately. |
| Quality maintenance | All the activities needed to ensure quality of bottom stitching should be done. The bottom stitching tool should be kept in good condition |

### 7.4.11. Appropriate Tread Application and Splicing

Appropriate placement, centering and splicing of tread are essential for ensuring quality of green tyre. Usage of fresh tread paint is also necessary to avoid foreign particles going inside the space between the ply and the tread. This can be implemented by applying certain TPM pillars, which are indicated with recommended actions in Table 7.13.

**Table 7.13.** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Tread Application and Splicing.

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | Workers should inspect the tread and paint to ensure their quality. If any abnormality is found, it should be corrected immediately |
| Education and training | Employees should be trained to splice the tread appropriately. They should be educated on the importance of appropriate tread application and splicing. |

### 7.4.12. Appropriate Tread Stitching

Appropriate tread stitching can be achieved by maintaining the tread stitching tool in appropriate condition. This can be implemented by applying certain TPM pillars, which are indicated with recommended actions in Table 7.14

**Table 7.14** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Tread stitching

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | This is done to keep the tread stitching tool in good condition. Regular cleaning, lubricating and tightening of bolts are to be done. |
| Planned maintenance | All the maintenance activities should be planned in advance and scheduled according to the plans to ensure the quality of tread stitching. |
| Education and training | Employees should be educated on the importance of bead stitching operation and trained to do tread stitching appropriately. |
| Quality maintenance | All the activities needed to ensure quality of tread stitching should be done. The tread stitching tool should be kept in good condition. |

### 7.4.13. Appropriate Sidewall Application and splicing

Appropriate centering, placement and splicing of sidewall can be ensured by by applying certain TPM pillars, which are indicated with recommended actions in Table 7.15.

**Table 7.15.** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Sidewall Application and splicing.

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | Employees should inspect to ensure quality of side wall of the tyres and if any abnormality is found out it should be corrected immediately |
| Quality maintenance | All activities to ensure quality of side wall of the tyres should be undertaken. Side wall should be in good condition and should have specified dimensions |
| Education and training | Employees should be trained on the method of splicing sidewall appropriately and should be made educated on its importance. |

### 7.4.14. Appropriate Final Operation

Appropriate Final Operation can be carried out by maintaining the tool to be checked in appropriate condition. This can be implemented by applying certain TPM pillars, which are indicated with recommended actions in Table 7.16.

**Table 7.16.** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Final operation

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | This is done to keep the tool in good condition. Regular cleaning, lubricating and tightening of bolts are to be done. |
| Planned maintenance | All the maintenance activities should be planned in advance and scheduled according to the plans to ensure good quality of tyres. |
| Education and training | Employees should be educated on the importance of tread operation and trained to do it appropriately. |
| Quality maintenance | All the activities needed to ensure quality of tyres should be done. The tool should be kept in good condition. |

### 7.4.15. Appropriate Drum Collapsing

Appropriate Drum Collapsing can be achieved by maintaining the tool in appropriate condition. This can be implemented by applying certain TPM pillars, which are indicated with recommended actions in Table 7.17.

**Table 7.17** TPM Pillars and actions recommended for implementing TPM pillars for Appropriate Drum Collapsing

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | This is done to keep drum and its components in good condition. Regular cleaning, lubricating and tightening of bolts are to be done. |
| Planned maintenance | All the maintenance activities should be planned in advance and scheduled according to the plans to ensure the quality of green tyres. |
| Education and training | Employees should be educated on the importance of tyre drum collapsing operation and trained to do it appropriately. |
| Quality maintenance | All the activities needed to ensure quality of tyres should be done. The drum and its components should be kept in good condition and the cord used should be of good quality. Otherwise drum collapsing may result in cord cut. |

## 7.5. Root Cause Analysis

In addition to the spelling out of maintenance quality characteristics and application of TPM pillars, a root cause analysis of bead off using Why-Why technique was conducted. The block diagram indicating this exercise is shown in Figure 7.4.

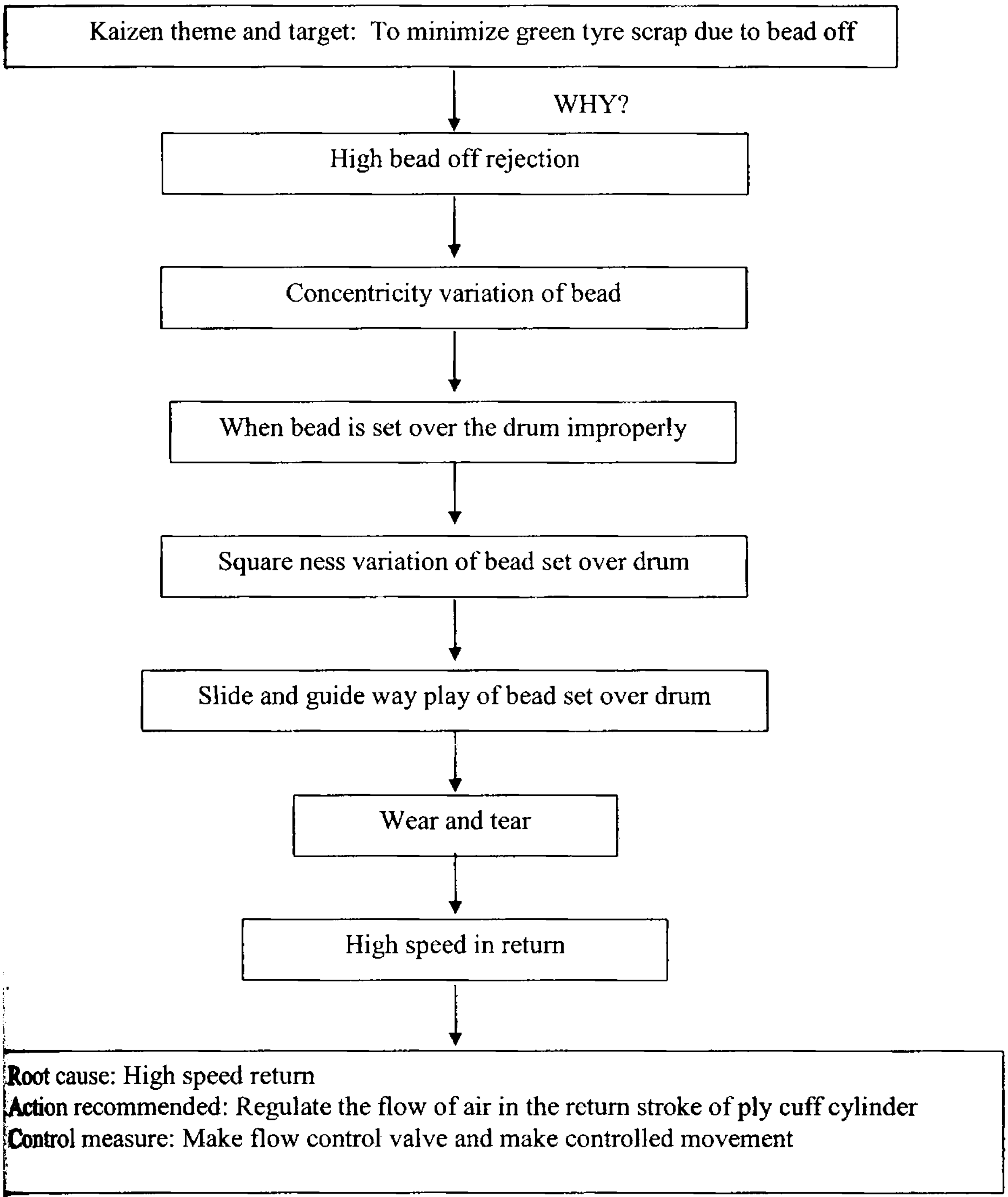



**Figure 7.4** Root cause analysis to minimize scrap

## 7.6. Analysis Of Maintenance Parameters

The ultimate aim of this implementation study was to achieve optimum equipment utilization by eliminating losses due to breakdowns, defects, idle time, etc. Therefore, an analysis of maintenance quality parameters was carried out to understand the effectiveness of implementing MQFD in the company.

**Table 7.18.** Data Used for Calculation of Maintenance Quality Parameters.

| Months | July (2005) | August (2005) | September (2005) | October (2005) | November (2005) | December (2005) |
|---|---|---|---|---|---|---|
| Scheduled time (minutes) | 44640 | 44640 | 43200 | 44640 | 43200 | 44640 |
| Cycle time (minutes) | 12.3 | 12.3 | 12.3 | 12.3 | 12.3 | 12.3 |
| Mechanical Break down (minutes) | 865 | 2275 | 2210 | 280 | 945 | 1610 |
| Electrical break down (minutes) | 650 | 775 | 1515 | 505 | 530 | 1047 |
| Instrumentation breakdown (minutes) | 90 | 190 | 0 | 0 | 0 | 0 |
| Set up and adjustment loss (minutes) | 0 | 0 | 40 | 0 | 0 | 220 |
| Scheduled break down (minutes) | 480 | 160 | 0 | 0 | 0 | 0 |
| Tool change loss (minutes) | 30 | 0 | 50 | 0 | 0 | 0 |
| Number of break downs | 30 | 35 | 38 | 12 | 18 | 27 |
| Actual output (Number of tyres) | 2885 | 1997 | 1922 | 2558 | 1346 | 1464 |
| Scrap (Number. of tyres) | 0 | 2 | 6 | 1 | 10 | 0 |
| Material waiting loss (minutes) | 2235 | 4470 | 2830 | 1025 | 1095 | 2400 |
| Manpower loss (minutes) | 1545 | 4700 | 3080 | 6720 | 11130 | 815 |
| Power loss (minutes) | 0 | 0 | 0 | 0 | 0 | 0 |
| Number of down times | 63 | 69 | 77 | 41 | 52 | 65 |

These parameters are Availability, Performance efficiency, Rate of quality, OEE, MTBF, MTTR, and MDT. Through this analysis, the factors to be prioritized to improve the performance of machines were found out. This analysis was done with respect to the parameters of tyre building machine which was selected for MQFD implementation. Various data used for calculating maintenance quality parameters are shown in Table 7.18.

### 7.6.1 Computation of Availability

Availability is a measure of what percentage of the total time the equipment is available for use. It is calculated using the following formula

**Table 7.19. Data Used for Calculating Availability**

| Month | July (2005) | August (2005) | September (2005) | October (2005) | November (2005) | December (2005) |
|---|---|---|---|---|---|---|
| Scheduled time (Minutes) | 44640 | 44640 | 43200 | 44640 | 43200 | 44640 |
| OEE loss (Minutes) | 2115 | 3400 | 3765 | 785 | 1475 | 2877 |
| Availability (%) | 95.3 | 92.4 | 91.3 | 98.2 | 96.6 | 93.6 |

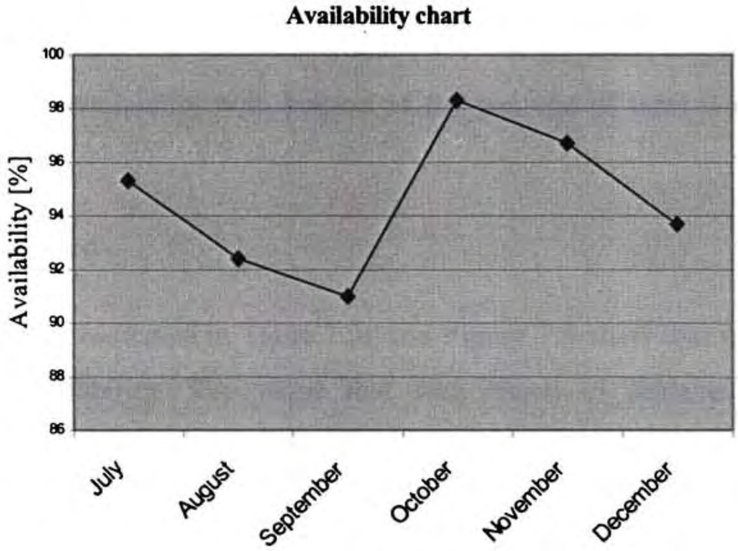



**Figure. 7.5 Graphical representation of the variations in availability**

Availability = (Scheduled running time – Down time) / (Scheduled running time)

In other words it is the total time a machine is available for operation, expressed as the percentage of scheduled time.

Availability = [(Scheduled time – OEE loss)/ Scheduled time] $\times$100

For example, the availability of machine during July 2005 is found out as follows.

Scheduled time = 24$\times$ 31 hours = 24$\times$ 31$\times$ 60 minutes = 44640 minutes

OEE loss = mechanical break down + electrical break down + instrumentation break down + set up and adjustment loss + scheduled break down + tool change loss

OEE loss = 865+650+90+0+480+30 = 2115 minutes

Availability = [(Scheduled time – OEE loss)/ Scheduled time] $\times$100

= [(44640- 2115)/44640]$\times$ 100 = 95.3%

The values of availability for the months from July 2005 to December 2005 were calculated and entered in Table 7.19. The graphical representation of the changes in availability with respect to the passage of time is depicted in Figure 7.5.

### 7.6.1.1. Inference

The values indicated in Table 7.21 and Figure 7.5 show that machine has very good availability. The value that was aimed to achieve was 90%. Throughout the months under study, availability has been higher than 90%. During October 2005 availability of 98% was observed indicating very good performance of tyre building machine. The reason for high availability is due to low OEE loss. The factors causing OEE loss are mechanical, electrical and instrumentation breakdowns, tool change loss, set up and adjustment loss and scheduled breakdown. Among these, the main reason was found to be the mechanical breakdown of the machine.

### 7.6.2 Computation of MDT

MDT was calculated during this study using the formula given below.

MDT = Total down time / Number of breakdowns or service entries

= Total down time/ Number of down times

The values of MDT calculated using the above formula are presented in Table 7.20 and depicted graphically in Figure 7.6. The sample calculation of MDT during **July 2005** is presented below.

OEE loss = 2115 minutes, Material waiting loss = 2235 minutes

Manpower loss = 1545 minutes, Power loss = 0 minutes

Total down time = 5895 minutes, Number of downtimes = 63

MDT = 5895/ 63 = 93.6 minutes

**Table 7.20.** Data Used for Calculation of MDT

| Month | July (2005) | August (2005) | September (2005) | October (2005) | November (2005) | December (2005) |
|---|---|---|---|---|---|---|
| OEE loss (minutes) | 2115 | 3400 | 3765 | 785 | 1475 | 2877 |
| Material waiting loss (minutes) | 2235 | 4470 | 2830 | 1025 | 1095 | 2400 |
| Manpower loss (minutes) | 1545 | 4700 | 3080 | 6720 | 11130 | 815 |
| Power loss (minutes) | 0 | 0 | 0 | 0 | 0 | 0 |
| Total downtime (minutes) | 5895 | 12570 | 9675 | 8530 | 13700 | 6092 |
| Number of downtimes | 63 | 69 | 77 | 41 | 52 | 65 |
| MDT (minutes) | 93.6 | 182.2 | 125.6 | 208.0 | 263.5 | 93.7 |

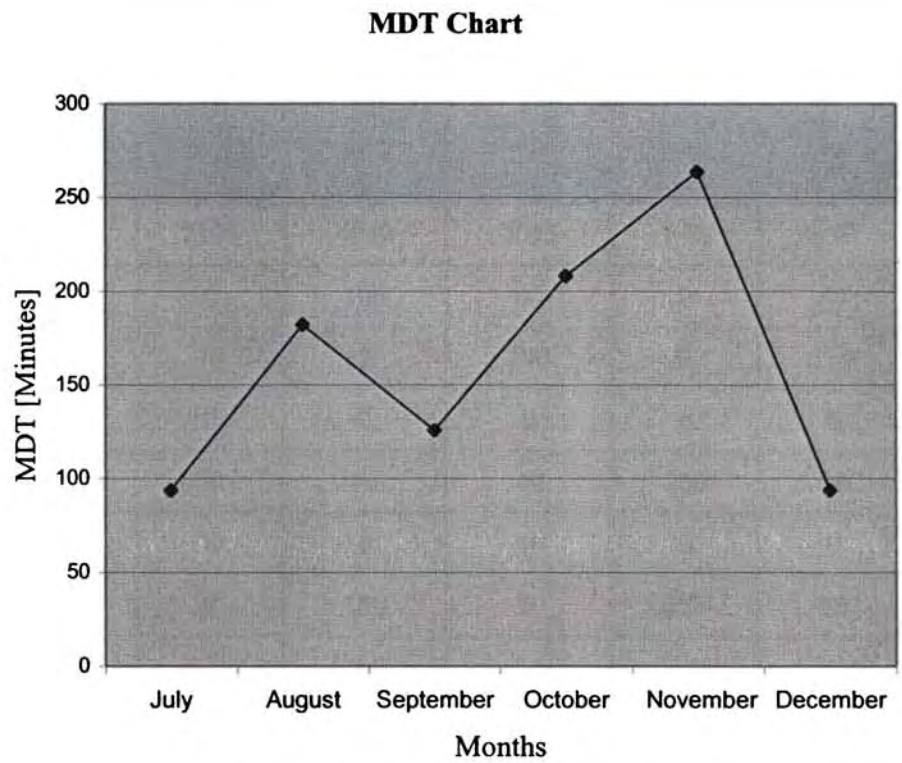



**Figure 7.6** Graphical representation of the variations in MDT

### 7.6.2.1. Inference

As shown in Table 7.20 and Figure 7.6, MDT is lowest during July 2005. During November 2005 and October 2005, MDT values are high indicating poor performance of the machine. This is mainly due to high manpower loss.

## 7.6.3 Computation of Material waiting loss

The data on material waiting loss gathered are presented in Table 7.21. The last row of this table shows the trial material loss during the month under study.

**Table 7.21.** Data Used for Calculation of Material waiting loss

| Materials | July 2005 (Minutes) | August 2005 (Minutes) | September 2005 (Minutes) | October 2005 (Minutes) | November 2005 (Minutes) | December 2005 (Minutes) |
|---|---|---|---|---|---|---|
| Ply | 2195 | 4010 | 2055 | 640 | 870 | 1125 |
| Squeegee | 0 | 100 | 80 | 0 | 40 | 165 |
| Side wall | 70 | 120 | 290 | 0 | 120 | 0 |
| Tread | 0 | 0 | 0 | 0 | 0 | 835 |
| Bead | 70 | 90 | 40 | 130 | 40 | 135 |
| Chafer | 60 | 0 | 0 | 0 | 0 | 0 |
| Breaker | 0 | 150 | 0 | 255 | 25 | 140 |
| Total material waiting loss | 2235 | 4470 | 2830 | 1025 | 1095 | 2400 |

### 7.6.3.1. Inference

As shown in Table 7.21, material-waiting loss is high during the month of August 2005 and it is low during November 2005. The main reason of material waiting loss is the time lost waiting for ply. So importance should be given in making the ply available at the required time.

## 7.6.4. Computation of MTBF

MTBF is the average time between failures.

MTBF = $[\sum TBF]/[Nf + 1]$

$\sum TBF$ = Sum of time between failures = Total scheduled time – Total failure time

Nf = Number of failures

As a sample, the calculation of MTBF during July 2005is presented below.

Mechanical break down = 865 minutes, Electrical break down = 650 minutes

Instrumentation breakdown = 90 minutes, Total failure time = 1605 minutes

Scheduled time = 44640 minutes, No. of failures = 29

**Table 7.22 Data Used for Calculation of MTBF**

| Months | July (2005) | August (2005) | September (2005) | October (2005) | November (2005) | December (2005) |
|---|---|---|---|---|---|---|
| Mechanical break down (Minutes) | 865 | 2275 | 2210 | 280 | 945 | 1610 |
| Electrical break down (Minutes) | 650 | 775 | 1515 | 505 | 530 | 1047 |
| Instrumentation break down (Minutes) | 90 | 190 | 0 | 0 | 0 | 0 |
| Total failure time (Minutes) | 1605 | 3240 | 3725 | 785 | 1475 | 2657 |
| Scheduled time (Minutes) | 44640 | 44640 | 43200 | 44640 | 43200 | 44640 |
| No. of failures | 29 | 34 | 38 | 12 | 18 | 27 |
| MTBF (Minutes) | 1434.5 | 1182.9 | 1012.2 | 3373.5 | 2196.1 | 1499.4 |

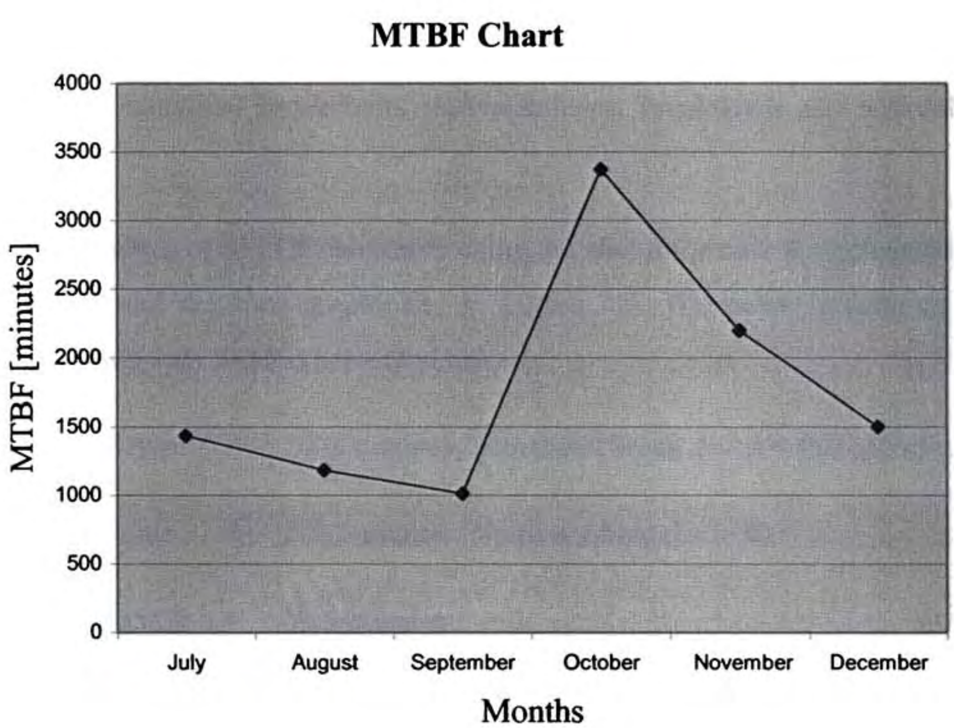



**Figure 7.7. Graphical representation of the variations in MTBF**

MTBF = [44640-1605]/29 = 1434.5 minutes.

Similarly the MTBF values for the months from July to December 2005 were calculated and displayed in Table 7.22 and Figure 7.7.

#### 7.6.4.1. Inference

As shown in table 7.22 and Figure 7.7, there is high MTBF during October and November 2005 indicating good performance of the machine. This implies that during that period, failure time and number of failures were comparatively lower. During July 2005 though the failure time was small, the number of failures was high making MTBF lower.

### 7.6.5. Computation of MTTR

Mean time to repair is the average time taken to repair a machine once it is in the breakdown condition. It is given by the following formula

MTTR = Total repair time/ Number of repairs

In the study being reported, time taken to repair was not available. So total break down time was taken as total repair time. This includes mechanical breakdown, electrical breakdown, instrumentation breakdown and scheduled breakdown.

The values of MTTR calculated using the above formula are presented in Table 7.23 and depicted graphically in Figure 7.8. The same calculation of MTTR during **July 2005** is presented below.

Total failure time = 1605 minutes, Scheduled break down = 480 minutes

Total repair time = 2085 minutes, Number of repairs = 30

MTTR = 2085/30 = 60.5 minutes

Similarly the MTTR values for the months from July to December 2005 were computed and displayed in Table 7.23 and Figure 7.9.

### 7.6.5.1. Inference

As shown in Table 7.23 and Figure 7.8, during October and November, 2005, MTTR was high. This implies that it took longer time to repair. During July,2005, repair was faster. Reduction in repair time implies either that the management is highly responsive to failures or that the failures were not so critical that they could be solved in a small duration of time.

**Table 7.23. Data Used for Calculation of MTTR**

| Month | July (2005) | August (2005) | September (2005) | October (2005) | November (2005) | December (2005) |
|---|---|---|---|---|---|---|
| Total failure time (Minutes) | 1605 | 3240 | 3725 | 785 | 1475 | 2657 |
| Scheduled break down (Minutes) | 480 | 160 | 0 | 0 | 0 | 0 |
| Total repair time (Minutes) | 2085 | 3400 | 9485 | 7505 | 10595 | 2657 |
| No. of repairs | 30 | 35 | 38 | 12 | 18 | 27 |
| MTTR (Minutes) | 69.5 | 97.1 | 249.6 | 625.4 | 588.6 | 98.4 |

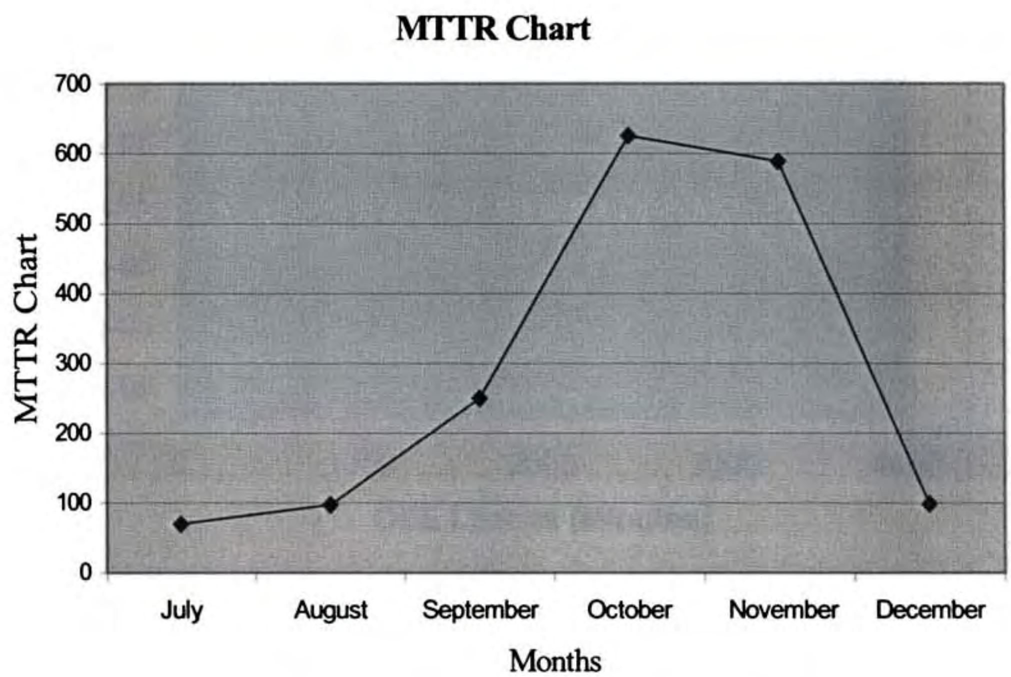



**Figure 7.8** Graphical representation of the variations in MTTR

### 7.6.6. Computation of OEE losses

**Table 7.24.** Data Used for Calculation of OEE Losses

| Months | July (2005) | August (2005) | September (2005) | October (2005) | November (2005) | December (2005) |
|---|---|---|---|---|---|---|
| Mechanical Break down (Minutes) | 865 | 2275 | 2210 | 280 | 945 | 1610 |
| Electrical break down (Minutes) | 650 | 775 | 1515 | 505 | 530 | 1047 |
| Instrumentation break down (Minutes) | 90 | 190 | 0 | 0 | 0 | 0 |
| Set up and adjustment loss (Minutes) | 0 | 0 | 40 | 0 | 0 | 220 |
| Scheduled break down (Minutes) | 480 | 160 | 0 | 0 | 0 | 0 |
| Tool change loss (Minutes) | 30 | 0 | 50 | 0 | 0 | 0 |
| OEE Loss (Minutes) | 2115 | 3400 | 3765 | 785 | 1475 | 2877 |

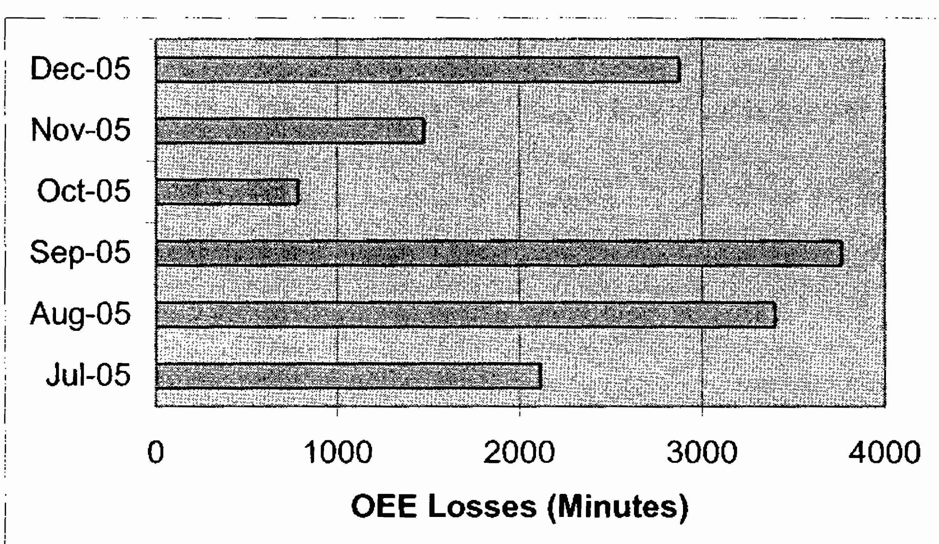



**Figure 7.9** Graphical representation of the variations in OEE Losses

In order to categorize the intensity of losses due to various failure modes ,OEE losses were calculated. OEE loss table for the months from July to December 2005 are shown in Table 7.26 and Figure 7.9.

#### 7.6.6.1. Inference

OEE losses were found to be higher during August and September 2005. This is due to losses caused by mechanical breakdowns. During August and September 2005, electrical breakdowns were also high. During October OEE loss was very low indicating very good performance of the machine. After calculating OEE losses, OEE was calculated.

### 7.6.7. Computation of OEE

OEE is the product of Availability, Performance efficiency and Rate of quality

OEE = Availability X Performance efficiency X Rate of quality

The values of OEE calculated using the above formula are presented in Table 7.25 and depicted graphically in Figure 7.10. The same calculation of OEE during **July 2005** is presented below.

Availability = 95.3%, Performance efficiency = 83.4%

Rate of quality = 100%, OEE = $[95.3 \times 83.4 \times 100/1000000] \times 100 = 79.5\%$

The OEE for the months from July to December 2005 were calculated and displayed in Table 7.25 and Figure 7.11.

**Table 7.25. OEE from July to December 2005**

| **Month** | **July (2005)** | **August (2005)** | **September (2005)** | **October (2005)** | **November (2005)** | **December (2005)** |
|---|---|---|---|---|---|---|
| Availability [%] | 95.3 | 92.4 | 91.3 | 98.2 | 96.6 | 93.6 |
| Performance efficiency [%] | 83.4 | 59.6 | 59.9 | 71.7 | 39.7 | 43.1 |
| Rate of quality [%] | 100.0 | 99.9 | 99.7 | 99.9 | 99.3 | 100 |
| OEE [%] | 79.5 | 55.0 | 54.5 | 70.4 | 38.1 | 40.3 |

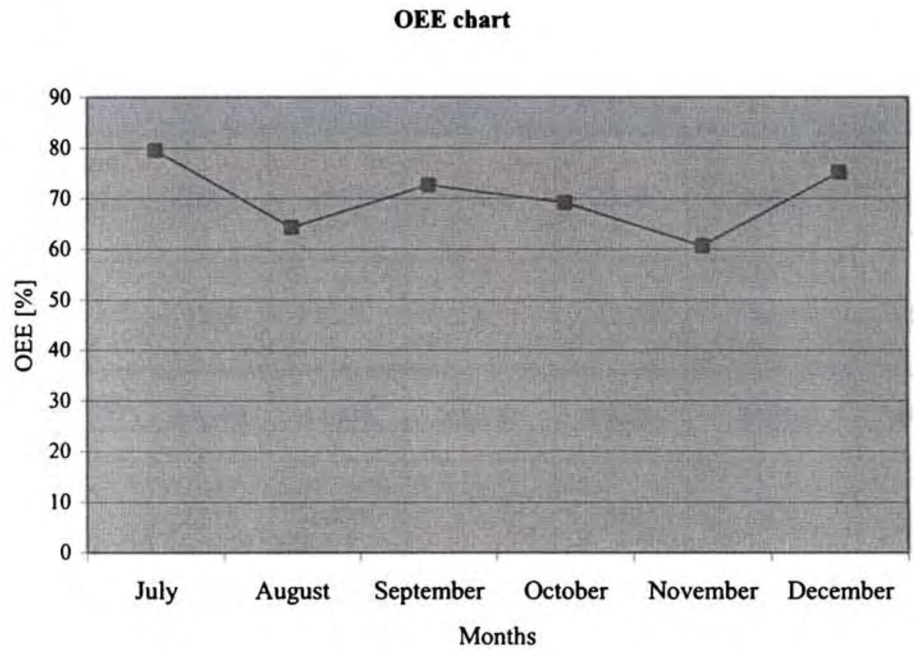



**Figure 7.10.** Graphical representation of the variations in OEE

### 7.6.7.1. Inference

As shown in Table 7.25 and Figure 7.10, Though an OEE of 85% was aimed to achieve, it was never achieved due to low performance efficiency. Because of comparatively higher performance efficiency value, an OEE of 79.5% was obtained in the month of July.

## 7.6.8. Computation of Performance Efficiency

Performance efficiency is total time during which actual production takes place. This is expressed as a percentage of the total time the machine is available.

Performance efficiency = [(Actual output × Cycle time)/(Scheduled time – OEE loss)]×100

**Table 7.26. Data Used for Calculation of Performance efficiency**

| Month | July (2005) | August (2005) | September (2005) | October (2005) | November (2005) | December (2005) |
|---|---|---|---|---|---|---|
| Actual output (Number of tyres) | 2885 | 1997 | 1922 | 2558 | 1346 | 1464 |
| Cycle time (Minutes) | 12.3 | 12.3 | 12.3 | 12.3 | 12.3 | 12.3 |
| Scheduled time (Minutes) | 44640 | 44640 | 43200 | 44640 | 43200 | 44640 |
| OEE Loss (Minutes) | 2115 | 3400 | 3765 | 785 | 1475 | 2877 |
| Performance efficiency [%] | 83.4 | 59.6 | 59.9 | 71.7 | 39.7 | 43.1 |

**Performance efficiency chart**

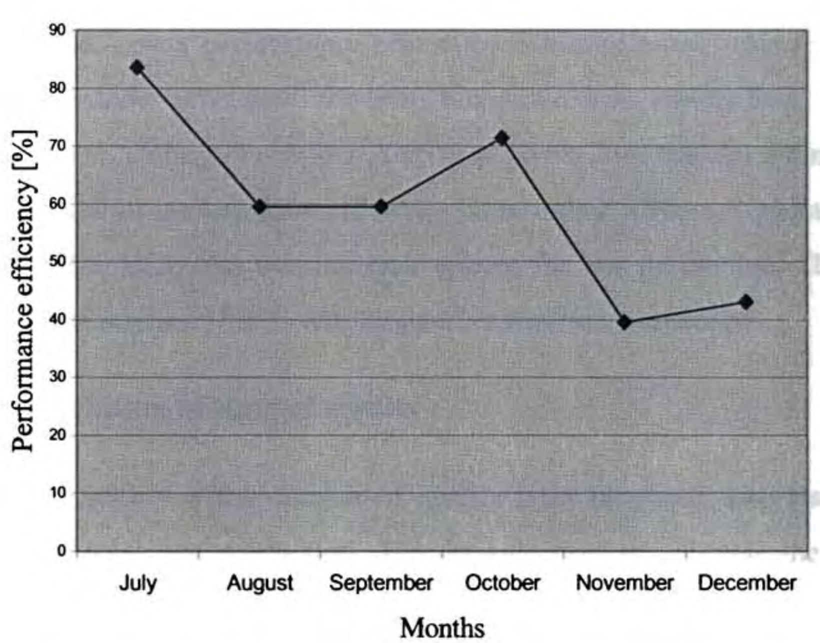



**Figure 7.11. Graphical representation of the variations in Performance efficiency**

The values of performance efficiency calculated using the above formula are presented in Table 7.26 and depicted graphically in Figure 7.11. The same calculation of performance efficiency during **July 2005** is presented below.

Similarly the Performance efficiency for the months from July to December 2005 were calculated and displayed in Table 7.26 and Figure 7.12

Actual output = 2885

Cycle time = 12.3 minutes

Scheduled time = 44640 minutes OEE loss = 2115 minutes

Performance efficiency = [(2885×12.3)/(44640 – 2115)] × 100 = 83.4%

Cycle time is the time needed to build a tyre and it is 12.3 minutes.

### 7.6.8.1. Inference

As shown in Table 7.26 and Figure 7.11, During July 2005 and October 2005 performance efficiency values are comparatively higher than that during the other months. During the other months it was lower because of the low production rate. Lower performance efficiency indicates losses other than OEE losses. This includes scheduled idle time, manpower loss, energy loss, material waiting loss, etc. During November 2005 man power loss was the main reason for a sudden fall of performance efficiency. But during August, September and December 2005, OEE loss was the main reason for low production. Though a performance efficiency of 95% was targeted, it was never achieved.

### 7.6.9. Computation of Rate of quality

Rate of quality is the number of quality tyres produced, expressed as a percentage of total tyre production. The formula used to compute the rate of quality is given below.

Rate of quality = [(Actual output-Scrap)/ Actual output]×100

The values of rate of quality calculated using the above formula are presented in Table 7.27 and depicted graphically in Figure 7.12. The same calculation of rate of quality during July 2005 is presented below.

Actual output = 2885 tyres Scrap = 0

Rate of quality = (2885-0)/2885 = 100%

Similarly the rate of quality for the months from July to December 2005 were calculated and displayed in Table 7.27 and Figure 7.12.

**Table 7.27. Data Used for Calculation of Rate of quality**

| Month | July (2005) | August (2005) | September (2005) | October (2005) | November (2005) | December (2005) |
|---|---|---|---|---|---|---|
| Actual output (Number of tyres) | 2885 | 1997 | 1922 | 2558 | 1346 | 1464 |
| Scrap (Number of tyres) | 0 | 2 | 6 | 1 | 10 | 0 |
| Rate of quality | 100.0 | 99.9 | 99.7 | 99.9 | 99.3 | 100 |

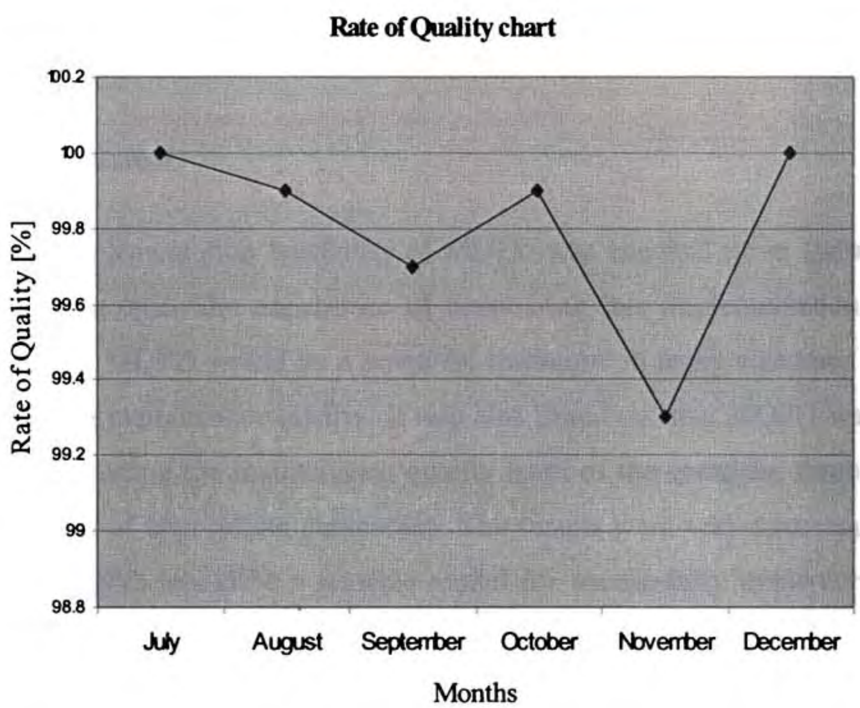



**Figure 7.12. Graphical representation of the variations in Rate of quality**

### 7.6.9.1 Inference

As shown in Table 7.27 and Figure 7.13, Very high performance quality was maintained in the tyre building section. Scrap produced was very low.

Quality of 100% was targeted which was nearly or fully achieved during all months.

### 7.7. Interpretation of the results

Analysis of maintenance parameters shows that very high values of machine availability and rate of quality were achieved. But performance efficiency has not achieved to the expectation. Therefore, OEE has not been achieved as aimed. This is mainly because of the manpower and ply waiting losses. In order to reduce the manpower loss, it is necessary to reduce absenteeism by enhancing the employee morale and commitment to work. For this purpose, the top and middle management should have good knowledge about TPM and should be actively involved in it. Only then they will encourage the workers to participate in TPM. Assigning the responsibility of implementing TPM solely to the facilitators will affect the effectiveness of its implementation.

## 7.8. Conclusion

The implementation feasibility of MQFD was checked in an Indian tyre manufacturing unit. The experience of conducting this implementation study indicated that MQFD would be a powerful technique in using customer voices for enhancing maintenance quality. It was also found out that MQFD was very useful in indicating the maintenance quality level of the company through the quantification of appropriate parameters. The results were very encouraging to infer that MQFD would be a feasible model for successfully implementing it and nourishing the synergic benefits of QFD and TPM.

Chapter - 8

# IMPLEMENTATION OF MQFD IN THE MINES OF A CEMENT PLANT

*Content*

# IMPLEMENTATION OF MQFD IN THE MINES OF A CEMENT PLANT

## 8.1. Introduction

In order to examine the implementation aspects of MQFD in a mining organization, an implementation study was carried out in a maintenance intensive mine located at Palakkad district of India. This mine is known as Pandarath mine and run by the Kerala state Government of India. This mine is required to cater to the lime requirements of Malabar Cement Limited (MCL) , which is situated in Palakkad district. This mine was chosen for the study because of the intensive maintenance engineering activities being carried out in it and the admirable cooperation extended by the General Manager, Deputy Chief Engineer and Plant Engineer towards the pursuance of the module of this research work being reported in this chapter. These professionals were present during the lecture on MQFD delivered on 10$^{th}$ August 2005 by the author in the monthly meeting of Palakkad Management Association. This meeting was chaired by the General Manager of MCL. He granted permission to pursue the implementation study in the mine section. The details of conducting this study are presented in this chapter.

## 8.2. About the Company

MCL is the only company, which manufactures Portland cement manufacturer in Kerala. MCL was incorporated in April 1978. MCL commenced commercial production in 1984, with the capital outlay of Indian Rupees (INR) 680 million and paid up equity capital of INR 260 million. MCL is owned fully by the Government of Kerala, India. The 1200 ton per day (TPD) plant at Walayar (a place near Palakkad) is continuously running in profit. The factory is rated to produce 4.2 lakh tones cements per annum. The company meets about 10 percent of total cement consumption in Kerala. The company moves with a work force of over 1000 dedicated and highly skilled personnel. MCL is incorporated with the state of art dry process technology for manufacturing of super quality cement whose, quality is much above the level specified by the national standard.

MCL is incorporated with the following infrastructure:

- Limestone reserve of about 10 million tones.
- Modern dry process manufacturing technology with four-stage suspension pre-heater system.
- Modern 110 TPD Closed Circuit Cement Mill.
- Most modern Instrumentation and Control system for efficient process engineering.
- Stringent Quality Control system to ensure quality of the product.
- Elaborate pollution control system to meet pollution control standards.

### 8.2.1. Credentials

Following are the credentials of MCL:

- The only integrated gray cement company in Kerala State of India.
- The first public sector cement company in the country to receive ISO 9000 certification.
- The first Public sector cement company to win the National Award for the best achievements in Energy Conservation.
- MCL's Accumulated net profit is INR 479 million as on March 31,2005.
- There has been no loss of production due to labor unrest or strike since inception.

### 8.2.2. ISO 9000 Certification

- MCL obtained IS/ISO 9002: 1994 certification in November 1996.
- The revised standard ISO 9001: 2000 in August 2003.

### 8.2.3. Quality Policy

Every employee of MCL commits to comply with all requirements to continually improve the effectiveness of the Quality Managements System and strives:

- To identify various group of customers.
- To understand their respective needs and desires either stated or not stated.
- To ensure best possible quality in products and services.
- To meet and exceed their expectations.

The company maintains capacity utilization of more than 100% for the past two financial years. That is 109.51% in the financial year 2003-2004 and a utilization of 105.39% in the year 2004-2005. This is an achievement that commands respect on considering the fact that the national average is well below 70%.

### 8.2.4. Mines Department

Malabar cements mines department, known as Pandarath Mines is located 9 kilometers away from the main plant at Walayar located at Palakkad district of Kerala state. The mine is the chief supplier of limestone to the MCL plant. The Pandarath Mines is an open pit mine where the extraction of limestone is accomplished by blasting of limestone rocks using explosives. The cost of maintenance of mining equipments lies in the range of 40-55 percent of the total mines operating cost. In Pandarathu mines, the average cost of maintenance of mining equipments is around 30 percent of total mines operating costs. The figure is much lower than industrial average. This achievement is made possible through systematic maintenance practice. It is also a result of teamwork right from the top-level executives to the bottom level workers. The team now strives to achieve better performance and any change in this regard will be accepted positively. The organizational commitment, employee involvement, and attitude towards change are highly positive.

### 8.2.5.Operations carried out at the mines

The operations carried out at Pandarath mines are enumerated below.

1. Identification of area where limestone deposit is present (based on topographical survey)
2. Drilling of the rocks to lay the heavy explosives
3. Blasting of the rocks
4. The broken rocks are then loaded by the hydraulic shovels
5. These rocks are then carried away to the crushers using dumpers
6. Crushing of these rocks is carried out by the primary and secondary crushers
7. The crushed limestone is then carried away to the plant by the aerial ropeway.

## 8.3. Implementation study

This implementation study of this module of research work was conducted in four phases. Phase 1 consisted of categorizing various failure modes of the critical equipments. During Phase 2, the HoQ was prepared and subjected to analysis. During Phase 3, the suggestions to implement TPM Pillars for each output of HoQ were developed. The calculation of maintenance quality parameters were carried out during Phase 4. The activities carried out during these phases are described in the following subsections.

### 8.3.1. Identification of critical equipments

As a beginning, the author tried to locate the critical machines in the mines. Critical machines are those machines whose failure can lead to the stoppage of the entire unit. Through careful reviewing of the previous records and subsequent discussions with the department engineers, the author came to a conclusion that the most important or rather critical machines in the mines were the loading machines and dumpers. After that the author analyzed the present condition of the critical machines and then decided to apply the MQFD with respect to the heavy equipments. The details of the heavy equipments considered for the study are presented in Tables.8.1, 8. 2 and 8.3.

**Table 8.1** List of heavy equipments considered for study

| Serial Number | Equipment Name | Manufacturer | Type |
|---|---|---|---|
| 1 | PC2 | BEML | Excavator |
| 2 | PC3 | BEML | Excavator |
| 3 | EX400 | TATA Hitachi | Excavator |
| 4 | H1 | BEML | Dumper |
| 5 | H2 | BEML | Dumper |
| 6 | H3 | BEML | Dumper |
| 7 | H4 | BEML | Dumper |
| 8 | H5 | BEML | Dumper |
| 9 | H6 | BEML | Dumper |
| 10 | H7 | BEML | Dumper |
| 11 | H8 | BEML | Dumper |
| BEML: Bharath Earth movers Limited | | | |

**Table 8.2.** Specifications of Excavators

| Excavators | Manufacturer | Power | Tonnage |
|---|---|---|---|
| PC 650 | Bharath Earth Movers Limited (BEML) | 404 BHP | 600 Tones per hour (Tph) |
| EX 400 | Tata Hitachi | 350 BHP | 450 Tph |

**Table 8.3.** Specifications of Dumpers

| Dumpers (Haulpak) | Manufacturer | Type | Engine | Power | Pay load |
|---|---|---|---|---|---|
| H1 - H7 | BEML | Rear dump | Kirloskar Cummins | 380 BHP | 32 Tonnes |
| H8 | BEML | Rear dump | Kirloskar Komatsu | 380 BHP | 32 Tonnes |

### 8.3.2. Failure analysis of equipments

The failures occurring in the equipments were closely studied. Researchers have reported that the maintenance is consuming one third of the total costs of a firm (Chan et al, 2005). This fact motivated the author to analyze the failures and categorize them. Here pie chart was used to represent the intensity of failures. The total failures occurring in a machine during the years 2004 and 2005 were categorized and depicted in pie charts. These are shown in Figures 8.1 to 8.20. The meaning of failure codes can be seen in Table 8.4. This gave a clear idea of which types of failures are predominant in each machine. Based on that, the author was able to recommend action plans for each equipment.

### 8.3.3. Failure index

Performance of the machines was observed and a few major problems were identified. Those problems that are recurring frequently and those which can cause the stoppage of the machines were sorted out. The constantly recurring failure modes and the codes adopted to represent them are presented in Table 8.4.

**Table 8.4.** Codes used for representing various failure modes

| Serial Number | Failure Code | Failure |
|---|---|---|
| 1 | ENG 1 | Engine oil leak |
| 2 | ENG 2 | Less pulling |
| 3 | ENG 3 | Turbocharge problem |
| 4 | ENG 4 | Overheat |
| 5 | ENG 5 | Over smoke |
| 6 | ENG 6 | Radiator water leak |
| 7 | ENG 7 | Air lock |
| 8 | ENG 8 | Fuel line filter problem |
| 9 | ENG 9 | Injector trouble |
| 10 | ENG 10 | V Belt's problem |
| 11 | ENG 11 | Component failure |
| 12 | ENG 12 | Engine seizure |
| 13 | ENG 13 | Diesel dilution |
| 14 | ENG 14 | Fuel contamination |
| 15 | ENG 15 | Engine mounting failure |
| 16 | ENG 16 | Compressor problems |
| 17 | ENG 17 | Overheating |
| 18 | ENG 18 | Silencer problem |
| 19 | ENG 19 | Maintenance |
| 20 | ENG 20 | Cooler failure |
| 21 | ELT 1 | Low battery charge |
| 22 | ELT 2 | Starting trouble |
| 23 | ELT 3 | Alternator problem |
| 24 | ELT 4 | Head light problem |
| 25 | ELT 5 | Equipment electrical trouble |

Table Contd....

| | | |
|---|---|---|
| 26 | ELT 6 | Short circuit |
| 27 | MNT 1 | Planned maintenance |
| 28 | MNT 2 | Over hauling |
| 29 | MNT 3 | Major repairs |
| 30 | PTO 1 | PTO trouble |
| 31 | OIL 1 | Oil filling |
| 32 | HYD1 | Oil leak |
| 33 | HYD 2 | Hose/ pipe failure |
| 34 | HYD 3 | Cylinder seal changing |
| 35 | HYD4 | Hydraulic component trouble |
| 36 | HYD 5 | System trouble |
| 37 | HYD 6 | Pin locks/Connecting link failure |
| 38 | HYD 7 | Hydraulic coolant failure |
| 39 | STR 1 | Structural failure |
| 40 | STR 2 | Fastener problem |
| 41 | UDC 1 | Track out |
| 42 | UDC 2 | Track link cut |
| 43 | UDC 3 | Track shoe changing/Bolt tightening |
| 44 | UDC 4 | Track loose |
| 45 | UDC 5 | Track pin out |
| 46 | UDC 6 | Track roller/ sprocket problem |
| 47 | UDC 7 | Idler problem |
| 48 | UDC 8 | Final drive trouble |
| 49 | BKT 1 | Bucket welding |
| 50 | BKT 2 | Bucket repair |
| 51 | BKT 3 | Bucket tooth trouble |

Table Contd…

| | | |
|---|---|---|
| 52 | CAB 1 | Cabin vibration |
| 53 | CAB 2 | Operator seat trouble |
| 54 | CAB 3 | Windshield/glass failure |
| 55 | BRK1 | Break Trouble |
| 56 | TRS 8 | Oil From Transmission |
| 57 | TRS 4 | Transmission Trouble |
| 58 | TRS 5 | Steering Trouble |
| 59 | TRE 3 | Tube Cut |
| 60 | TRE 2 | Clutch Problem |
| 61 | PNE 1 | Air Leak |
| 62 | TRS 7 | Final Drive Problem |
| 63 | PNE 3 | Break Fluid Leak |
| 64 | MNT 2 | Major Overhauling |
| 65 | UDC 9 | Other Usual Under Carriage Trouble S |
| 66 | UDC 10 | Unknown under carriage troubles |
| 67 | HYD 8 | Abnormal hydralic function |
| 68 | BKT 4 | Bucket Collar Failure |
| 69 | TRE 4 | Tyre O ring failure |
| 70 | TRS 1 | Transmission linkage problem |
| 71 | HYD 9 | Hydraulic filter chock |
| 72 | CAB 4 | Cabin fan failure |
| 73 | TRE 5 | Wheel bolt cut |

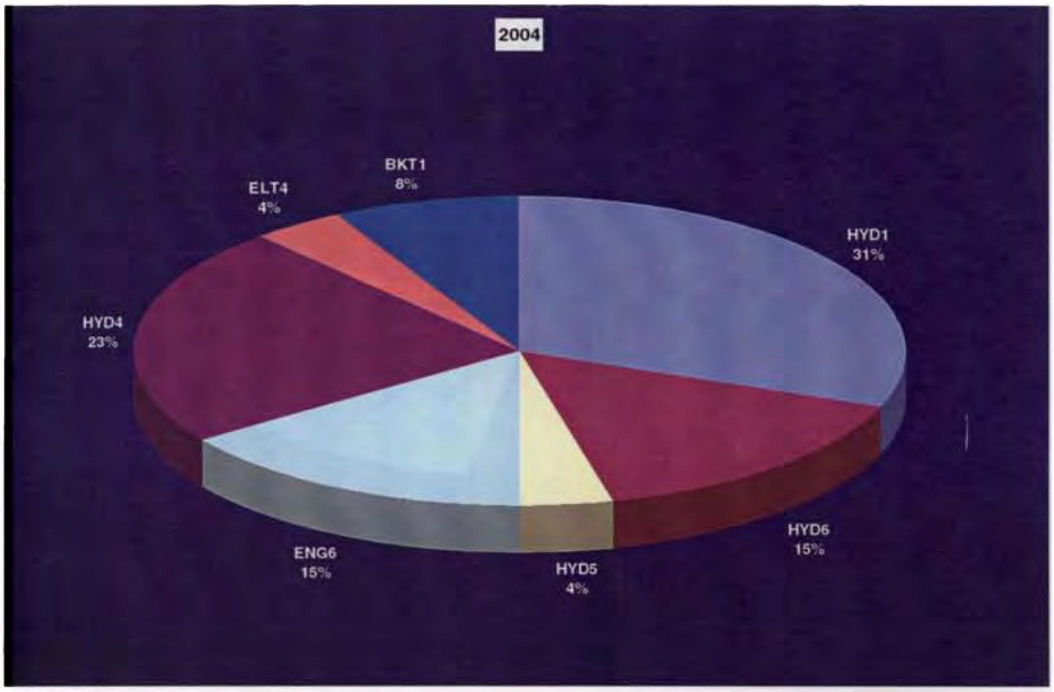



**Figure 8.1.** Pie chart on the failure of excavator EX 400 during the year 2004

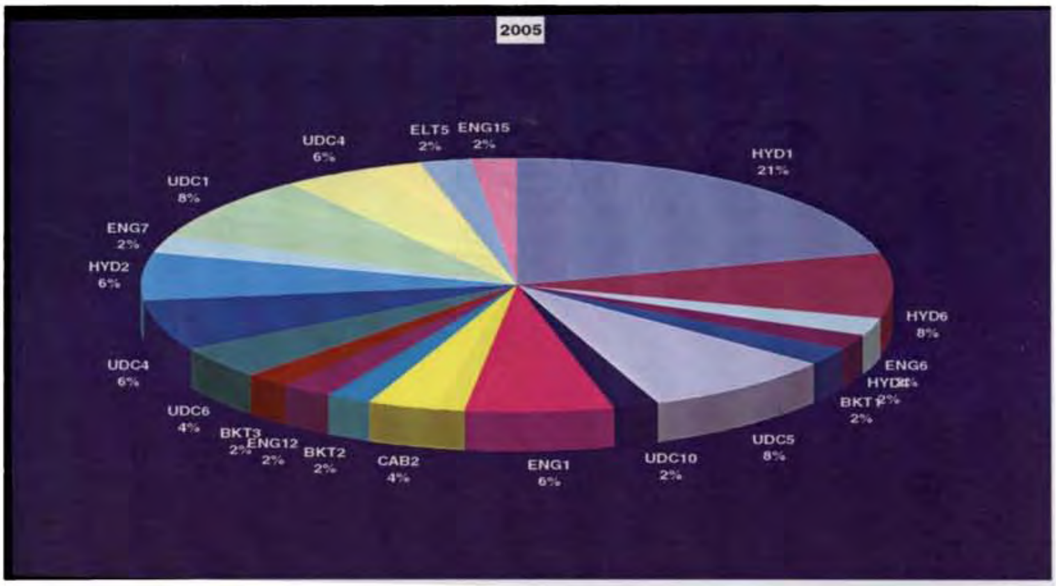



**Figure 8.2.** Pie chart on the failure of excavator EX 400 during the year 2005

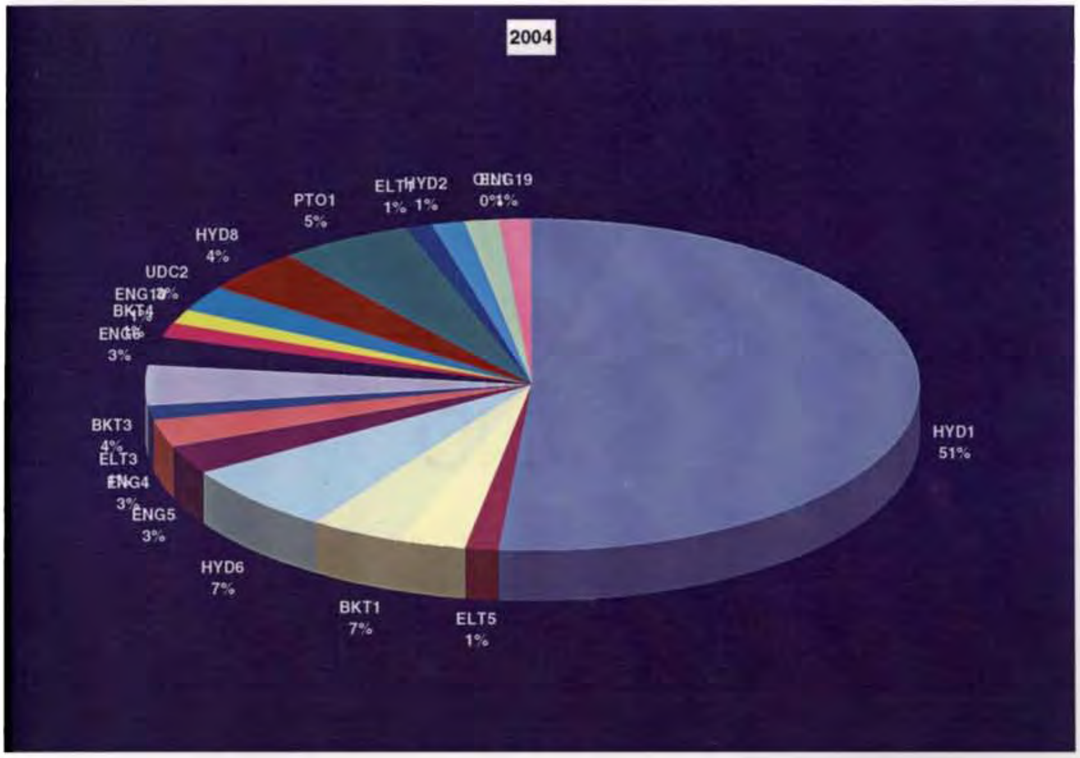



**Figure 8.3.** Pie chart on the failure of excavator PC2 during the year 2004

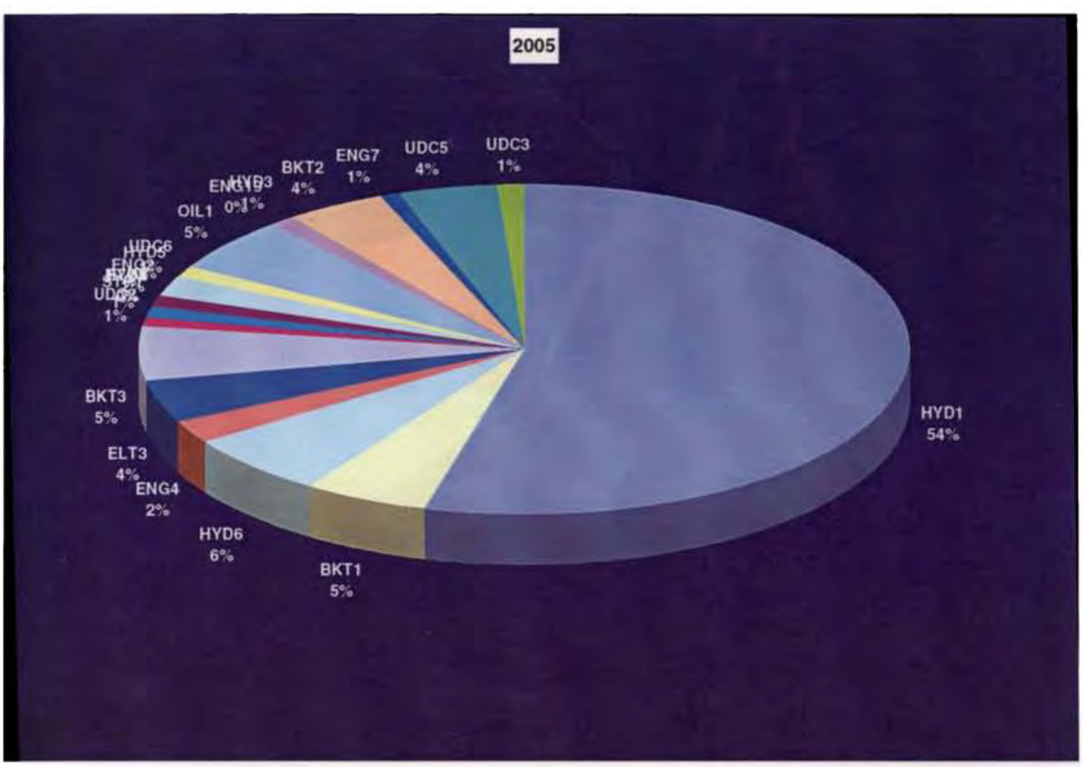



**Figure 8.4**. Pie chart on the failure of excavator PC2 during the year 2005

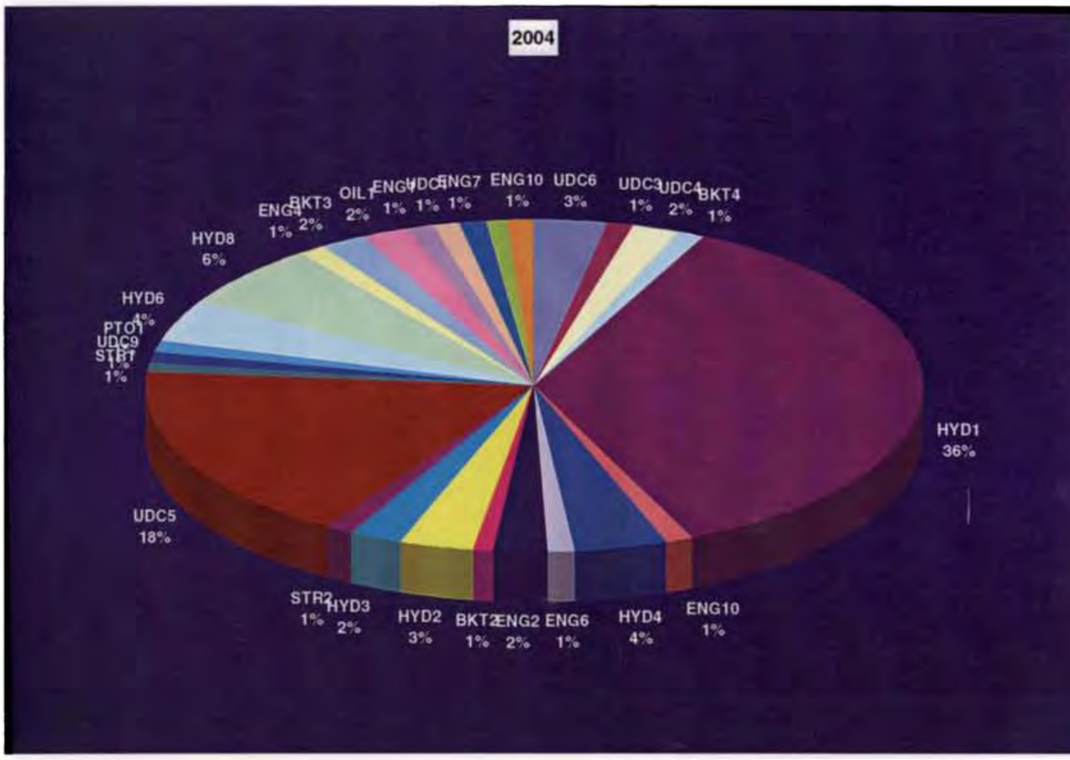



**Figure 8.5.** Pie chart on the failure of excavator PC3 during the year 2004

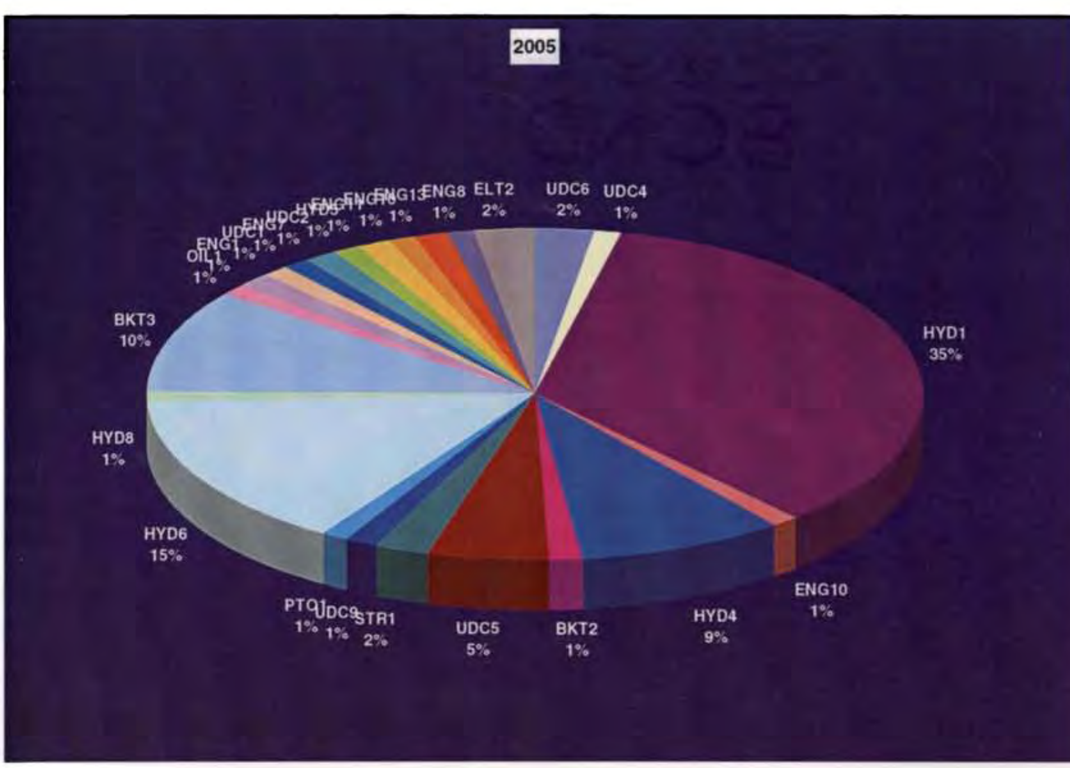



**Figure 8.6.** Pie chart on the failure of excavator PC3 during the year 2005

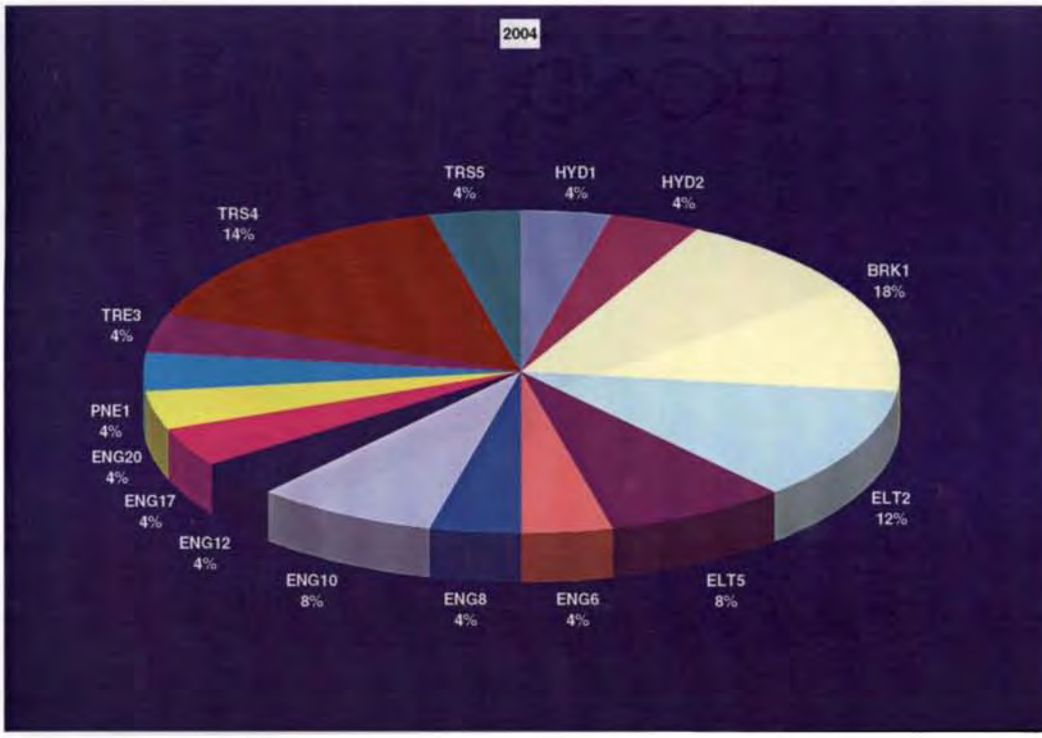



**Figure 8.7.** Pie chart on the failure of Dumper H1 during the year 2004

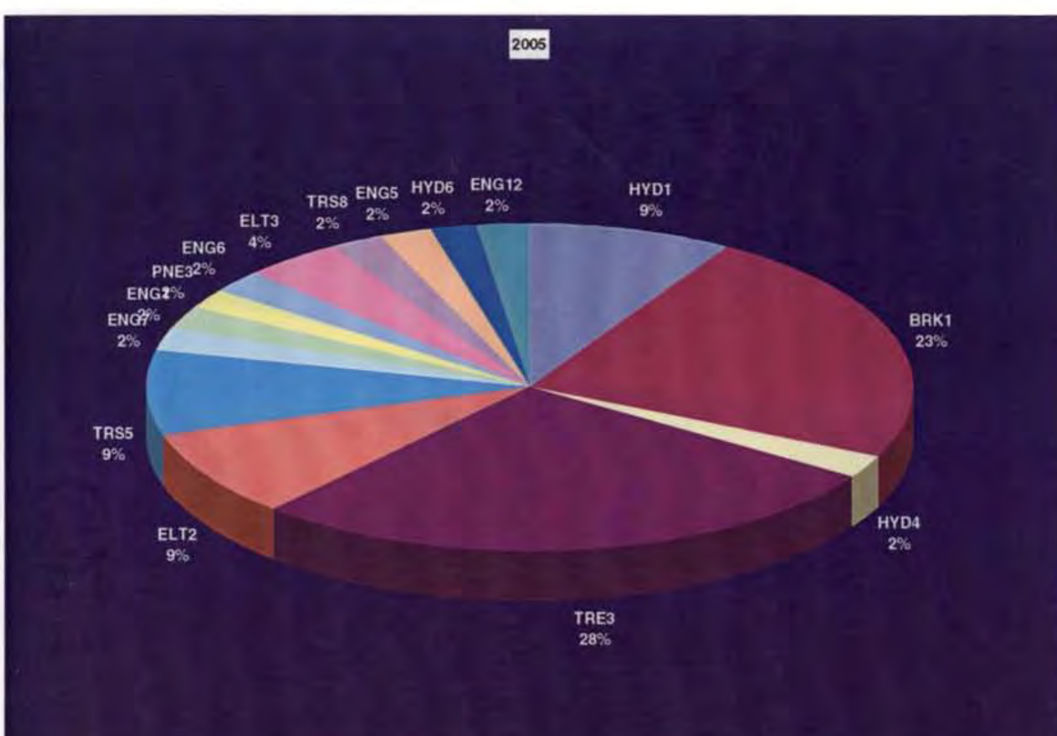



**Figure 8.8**. Pie chart on the failure of Dumper H2 during the year 2005

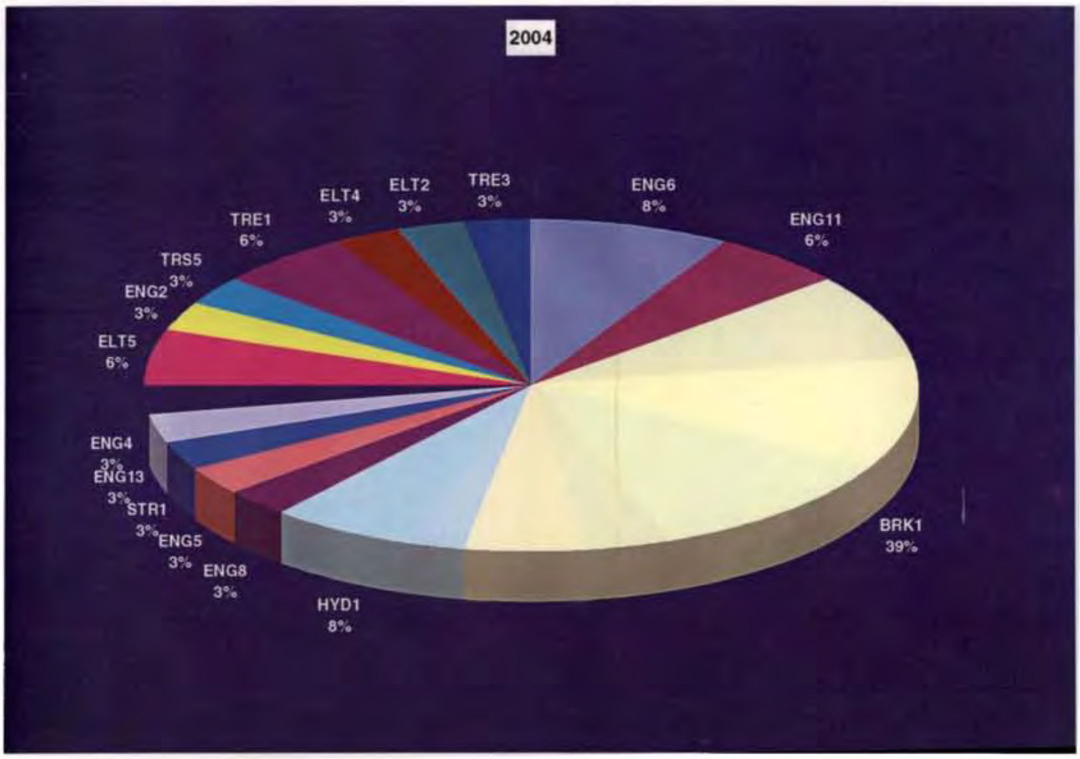



**Figure 8.9.** Pie chart on the failure of Dumper H3 during the year 2004

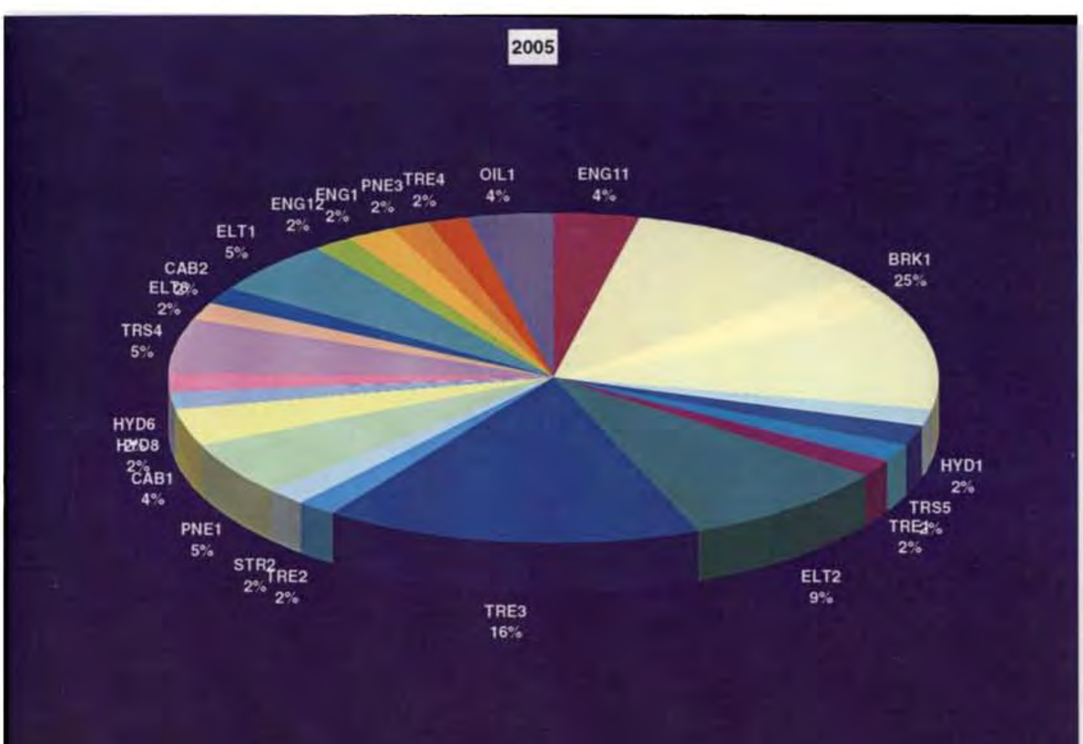



**Figure 8.10.** Pie chart on the failure of Dumper H3 during the year 2005

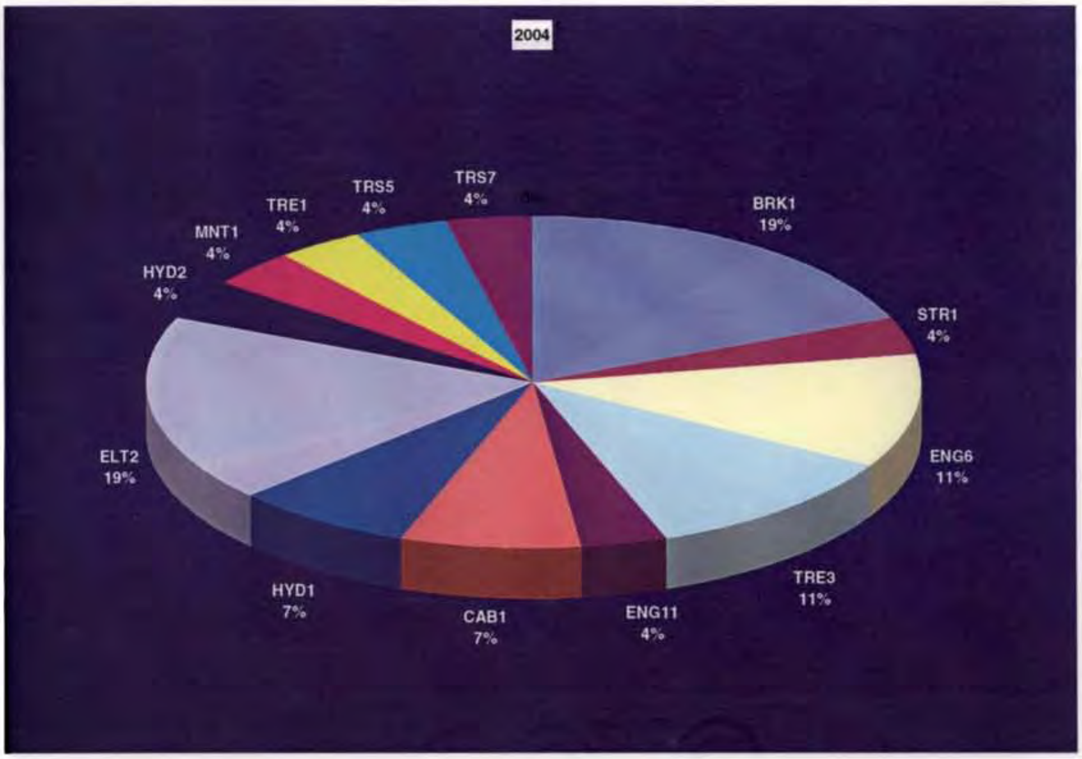



**Figure 8.11.** Pie chart on the failure of Dumper H4 during the year 2004

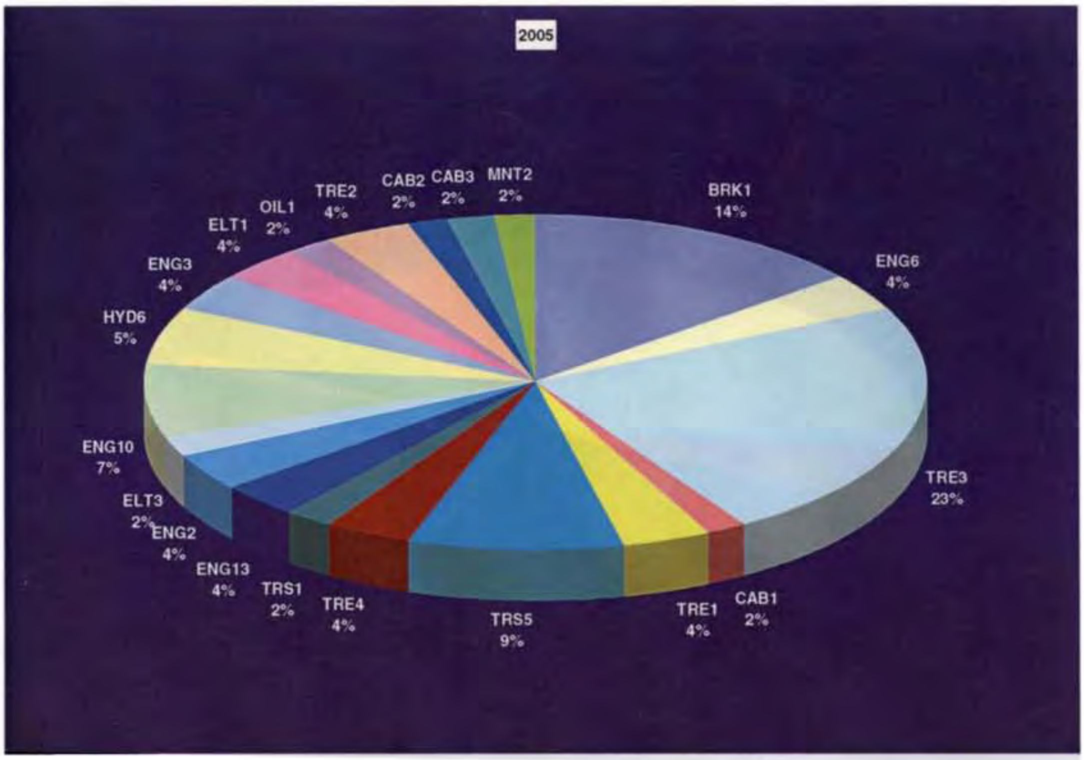



**Figure 8.12.** Pie chart on the failure of Dumper H4 during the year 2005

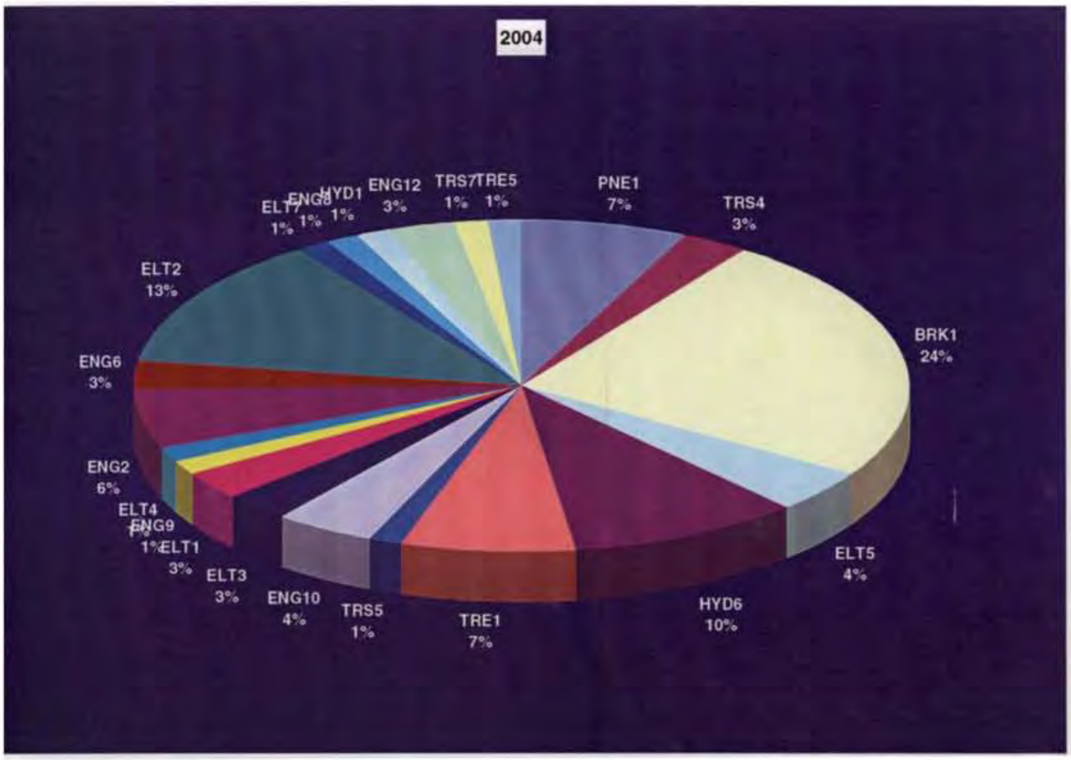



**Figure 8.13**. Pie chart on the failure of Dumper H5 during the year 2004

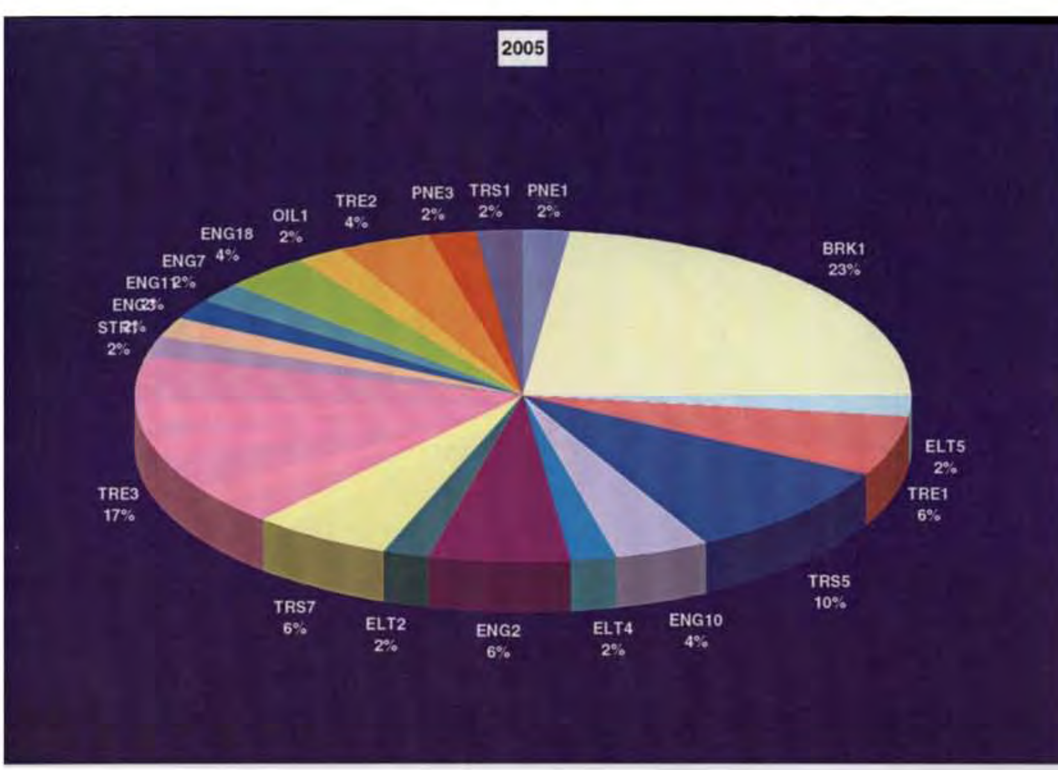



**Figure 8.14.** Pie chart on the failure of Dumper H5 during the year 2005

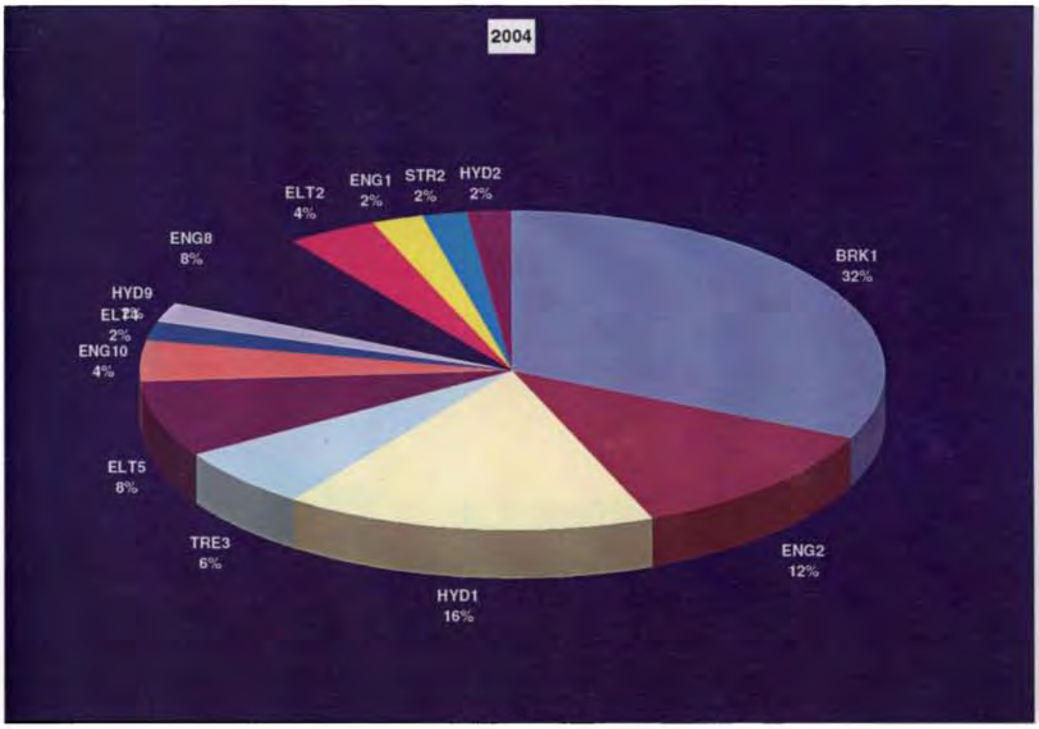



**Figure 8.15.** Pie chart on the failure of Dumper H6 during the year 2004

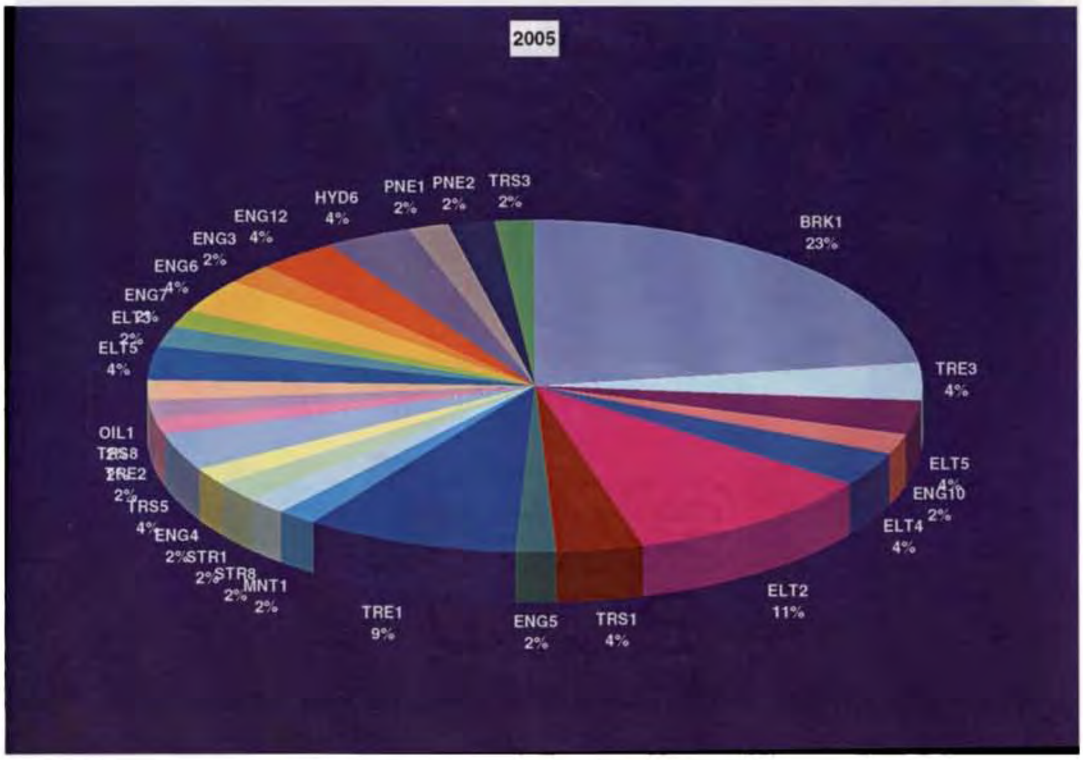



**Figure 8.16.** Pie chart on the failure of Dumper H6 during the year 2005

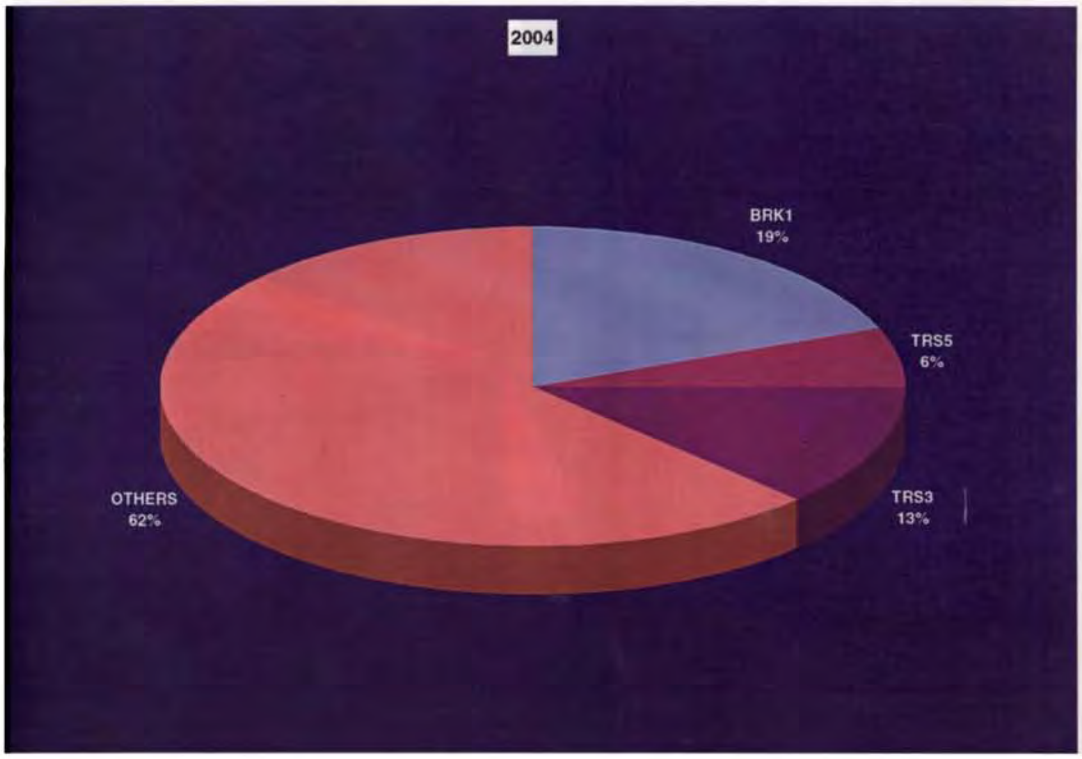



**Figure 8.17**. Pie chart on the failure of Dumper H7 during the year 2004

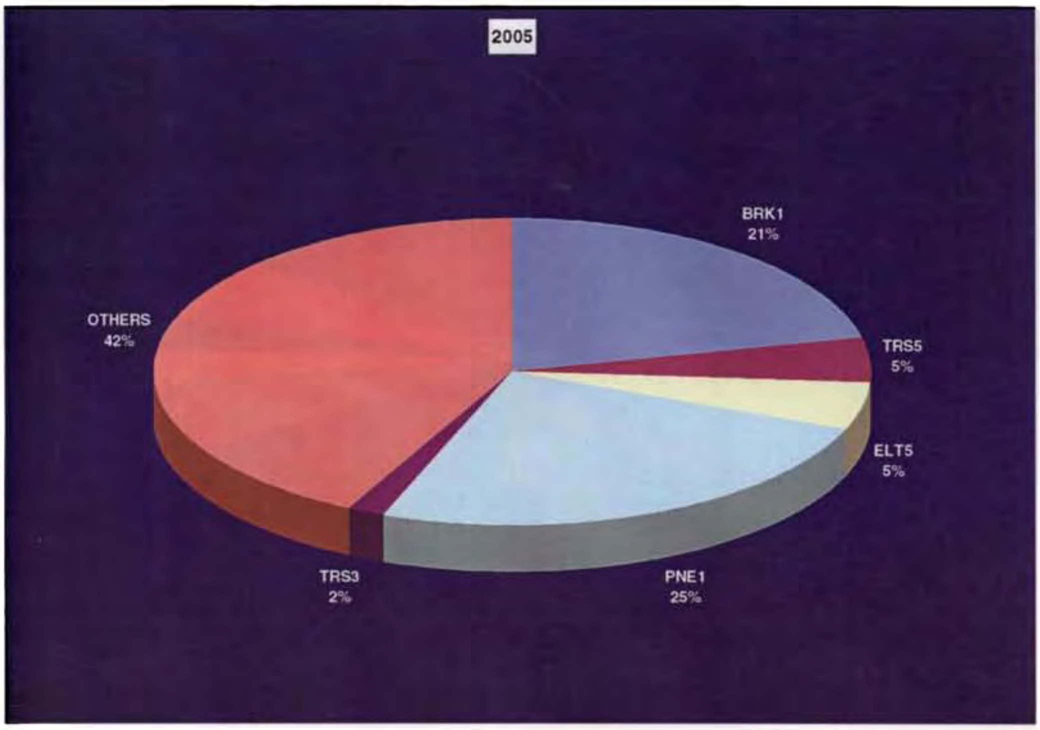



**Figure 8.18**. Pie chart on the failure of Dumper H7 during the year 2005

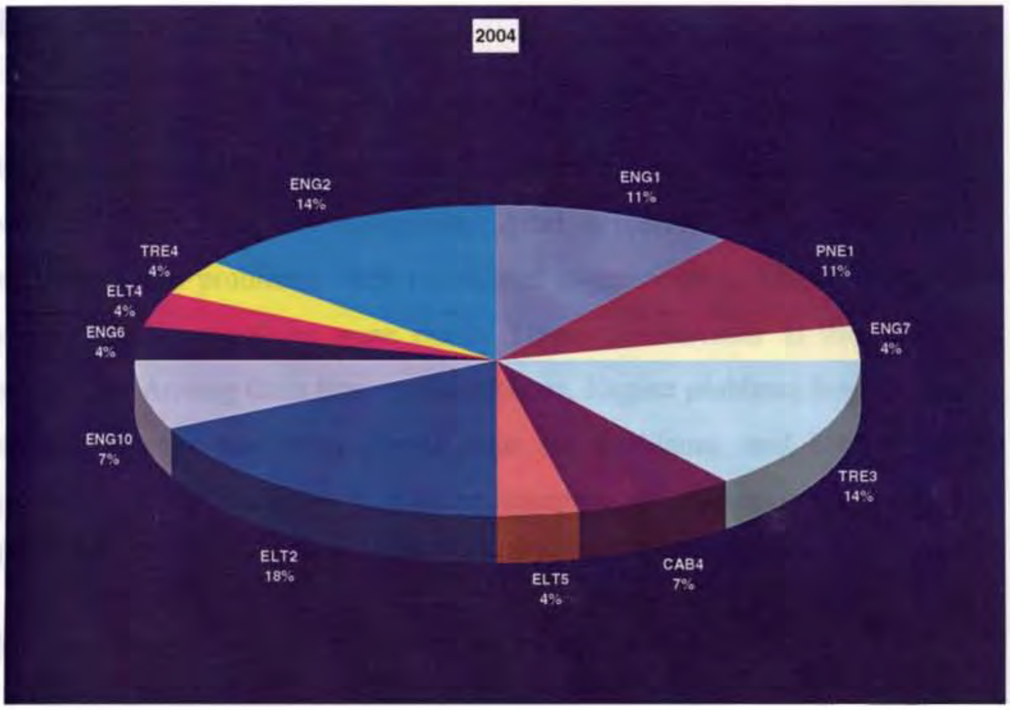



**Figure 8.19.** Pie chart on the failure of Dumper H8 during the year 2004

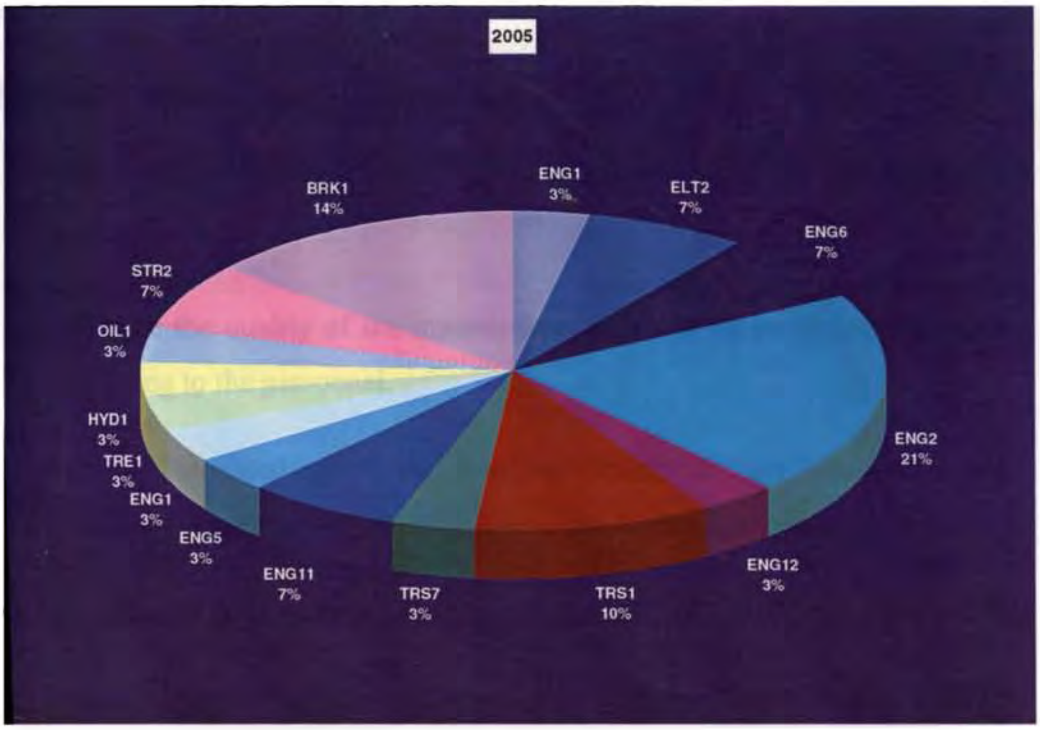



**Figure 8.20.** Pie chart on the failure of Dumper H8 during the year 2005

### 8. 3.4. Interpretations

Representation of the failures using pie charts gave a clear indication of the intensiveness of their occurrence. The problems occurring in the equipments were classified into ten catogories. After a careful analysis of all the equipments, the problems, their cause, and suggestions to eliminate or rather minimize these problems ware made. Those are narrated in the following subsections. Among them Structural problems, Engine problems (mainly engine seizure), Bucket problems, Power take off problems, and Under-carriage problems are the problems that cause stoppage of machines. Hydraulic and Electrical problems are the most frequently occurring problems.

#### 8.3.4 .1. Hydraulic problems (designated as Hyd1-Hyd8)

Hydraulic problems contribute towards the major share of total problems. In other words, more than 50% of the total failures belong to this category of problems. These problems are usually identified by leakages and pressure drops. They are caused due to O-ring failure, leakage in hoses, improper fitting and overheating due to overload.

Suggestions to minimize the problems are

1. Use O-rings and hoses supplied by Original Equipment Manufacturers (OEM).
2. Assure the quality of the maintenance activities by providing intensive training to the personnel.
3. Avoid overloading of the machine which in turn can cause the overheating of parts. This may lead to the failure of machines.

#### 8.3.4 .2. Electrical problems (designated as ELT1-ELT10)

Major electrical failures experienced in machines were starting trouble and generator problems. The electrical problems vary from severe generator problems to minor lighting problems. These problems though do not cause machine stoppage, but can occur frequently. Majority of these problems can be rectified by the operator himself. However, in order to rectify the generator problems, contacting the manufacturer is recommended. In order to ensure long life of battery, water level should be checked frequently.

#### 8.3.4.3. Structural problems ( designated as STR1-STR10)

These failures are mainly caused due to overloading, improper lubrication and poor quality components. It includes the failure of boom, boom cylinder, arms and linkages.

Suggestions to minimize these problems are as follows:

1. Avoid overloading of machines.
2. Ensure that the lubrication is done according to the manufacturer's instructions.
3. Ensure proper linkage between the components must be ensured

#### 8.3.4.4. Engine problems (designated as ENG1-ENG10)

These are the few major problems that can lead to the stoppage of machines. Out of these problems, engine seizure is the most severe of all. This problem can cause the equipment to stay for several months. Another problem found in engines is oil leakage. It can be reduced to some extent by using good quality oil seals and their proper installation.

#### 8.3.4.5. Power Take off Problems (PTO)

Frequency of these problems is lesser when compared to other problems. But the time for repair may be extending up to three to four shifts. Hence it affects MTTR. Periodic inspection and replacement if required on PTO bearings are suggested to minimize these problems.

#### 8.3.4.6. Under-carriage Problems (UDC)

The undercarriage is the track on which the machine moves. This warrants high degree of training at operator's level. For example, if the equipment is deployed on unleveled ground, the load distribution on track rollers of excavators will be very high. The PC 650 excavator weighs about 65 tonnes and is supported by 16 track rollers. On a level ground, the load distribution will be uniform but as stated above when the equipment is operated in unleveled ground, a single-track roller may be subjected to a load of 65 tonnes.

#### 8.3.4.7. Bucket Problems (BKT)

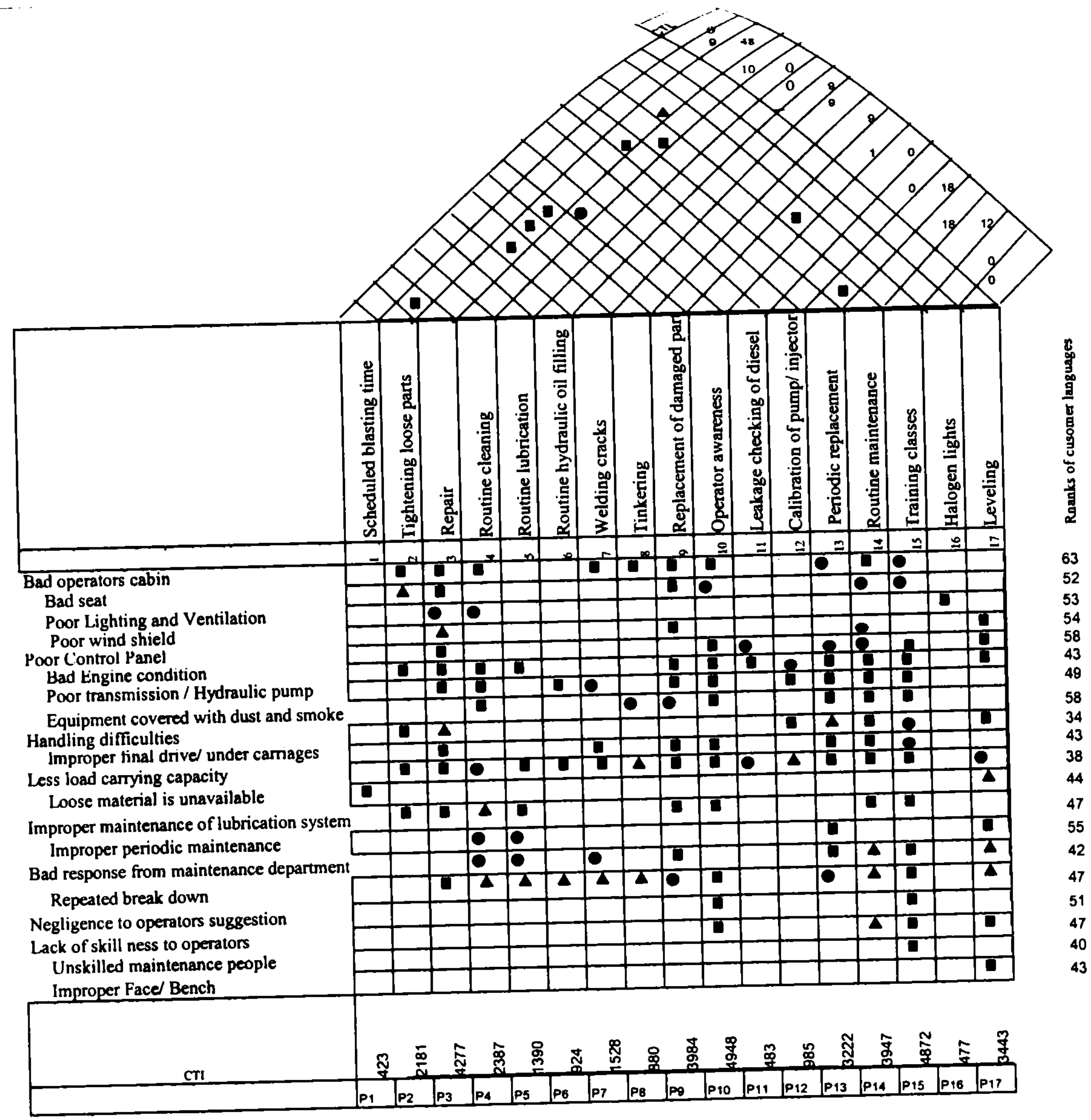
Bucket is the part that holds the materials that needs to be transferred. Bucket Problem includes bucket welding, bucket repair and bucket tooth trouble . Bucket problem is one of the frequently occurring problems. There are two buckets available as standby. These are to be kept 'ready to use' condition always.

#### 8.3.4.8. Probability of Seasonal Problems

An interesting fact observed through the analysis of failures is that all the machines show breakdowns in high numbers during the months June and July, during which monsoon occurs. So the machines' tendency for failure during various months should be studied and proper check-ups must be done.

## 8.4. Construction of HoQ

In order to construct HoQ, the customer reactions were obtained using a questionnaire. The operators of the dozers and dumpers were considered as the customers of this mine. By making use of the long experience of the Deputy Chief Engineer and Plant Engineer, the list containing the maintenance quality aspects was prepared. Based on that, a questionnaire shown in Annexure C was developed and distributed to the equipment operators. In order to enable better understanding, the question were translated in local language Malayalam. The equipment operators were asked to mark their reactions against those aspects. In total, the reactions from 24 equipment operators were collected pertaining to 20 maintenance quality aspects. The data collected through this questionnaire-based survey is tabulated in Table 8.5.




CTI=Customer technical interactive score

CTL=Correlated weightage of the technical language

Figure 8.21 HoQ Matrix

As an example, the details of the data presented against serial number 1 in Table 8.5 are illustrated here. This question aimed to gather the reaction of each oprator about the condition of operator's cabin of the vehicle. Out of the 24 operators, none of them have mentioned 'excellent', while 2, 9, 9, and 4 of them respectively have mentioned that it is 'good', 'average', 'bad' and 'extremely bad'. None of them have felt that the operator's cabin of the equipment that they drive is in excellent condition. The selection of maintenance quality aspect was prioritised on the basis of operators' reactions in the order ranging from 'Bad' to 'Excellent'. That is, the maintenance quality aspects in which 'Bad' reactions dominate are given the highest priority in choosing for subsequent study. It is gradually decreased from average to excellent reactions. The priorities were quantified by assigning weightages 0,1,2,3, and 4 for the reactions 'Excellent', 'Good', 'Average', 'Bad' and 'Extremely bad', respectively. The priority thus computed has been entered in the last column of Table 8.5. As a sample the computation of the expected value against the condition of the operator's seat is presented below.

Number of 'Excellent' reactions × 0+ Number of 'Good' reactions × 1+ Number of 'Average' reactions × 2+ Number of 'Bad' reactions × 3+ Number of 'Extremely Bad' reactions × 4= $(0 \times 0+ 2 \times 1 + 9 \times 2 + 9 \times 3 + 4 \times 4) = 63$.

**Table 8.5.** Data on Customers' voice

| Serial Number | Customers' voice | Number of operator' response | | | | | Priority Scores |
|---|---|---|---|---|---|---|---|
| | | Excellent Priority | Good Priority | Average Priority | Bad Priority | Extremely bad Priority | |
| 1 | Bad Operators' Cabin | 0 | 2 | 9 | 9 | 4 | 63 |
| 2 | Bad seat | 2 | 1 | 14 | 5 | 2 | 52 |
| 3 | Poor Lighting & Ventilation at Cabin | 0 | 5 | 10 | 8 | 1 | 53 |
| 4 | Poor Wind Shield | 0 | 3 | 12 | 9 | 0 | 54 |
| 5 | Poor Control Panel | 0 | 2 | 12 | 8 | 2 | 58 |
| 6 | Bad Engine Condition | 1 | 6 | 14 | 3 | 0 | 43 |

Table Contd...

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7 | Poor transmission/ Hydraulic pump | 1 | 4 | 12 | 7 | 0 | 49 |
| 8 | Equipment covered with dust and smoke | 2 | 0 | 8 | 14 | 0 | 58 |
| 9 | Improper final drive/ under carriage | 4 | 8 | 10 | 2 | 0 | 34 |
| 10 | Less load carrying capacity | 3 | 3 | 14 | 4 | 0 | 43 |
| 11 | Handling difficulties | 2 | 6 | 16 | 0 | 0 | 38 |
| 12 | Improper maintenance of Lubrication System | 1 | 4 | 17 | 2 | 0 | 44 |
| 13 | Improper Periodic Maintenance | 3 | 1 | 14 | 6 | 0 | 47 |
| 14 | Improper face/ Bench | 1 | 3 | 8 | 12 | 0 | 55 |
| 15 | Loose material is Unavailable | 4 | 2 | 14 | 4 | 0 | 42 |
| 16 | Bad Response from Maintenance department | 1 | 6 | 10 | 7 | 0 | 47 |
| 17 | Repeated breakdowns | 1 | 4 | 11 | 7 | 1 | 51 |
| 18 | Negligence to operator's suggestions | 1 | 4 | 14 | 5 | 0 | 47 |
| 19 | Lack of skill ness to operators | 2 | 6 | 15 | 0 | 1 | 40 |
| 20 | Unskilled Maintenance People | 2 | 6 | 11 | 5 | 0 | 43 |

As shown in the last column of Table 8.5, the 'bad operators cabin' and 'equipment covered with dust and smoke' shall be the highest priorities for choosing subsequent study since their scores are 63 and 58 respectively. These scores are highest among all. These details were the inputs of 'HoQ' (Besterfield et.al 2004).

**Table 8.6** Technical descriptors and their computed scores

| Serial Number. | Technical descriptors | Customer technical interactive score (CTI) (1) | Percentage normalized value of customers technical interactive score (2) | Correlated weightage of the technical language (CTWL) (3) | Percentage normalized value of correlated weightage (4) | Sum of (2)+(4) |
|---|---|---|---|---|---|---|
| 1 | Schedule blasting time | 423 | 1.05 | 0 | 0 | 1.05 |
| 2 | Tightening loose parts | 2181 | 5.41 | 9 | 6.29 | 11.7 |
| 3 | Repair | 4277 | 10.7 | 48 | 33.6 | 44.3 |
| 4 | Routine cleaning | 2387 | 5.92 | 10 | 6.99 | 12.9 |
| 5 | Routine lubrication | 1390 | 3.44 | 0 | 0 | 3.44 |
| 6 | Routine Hydraulic Oil Filling | 924 | 2.29 | 0 | 0 | 2.29 |
| 7 | Welding Cracks | 1528 | 3.79 | 9 | 6.29 | 10.1 |
| 8 | Tinkering | 880 | 2.18 | 9 | 6.29 | 8.47 |
| 9 | Replacement of damaged parts | 3984 | 9.87 | 9 | 6.29 | 16.2 |
| 10 | Operator awareness | 4948 | 12.3 | 1 | 0.7 | 13 |
| 11 | Leakage checking of diesel | 483 | 1.2 | 0 | 0 | 1.2 |
| 12 | Calibration of pump/ injector | 985 | 2.44 | 0 | 0 | 2.44 |
| 13 | Periodic replacement | 3222 | 7.98 | 18 | 12.6 | 20.6 |
| 14 | Routine maintenance | 3947 | 9.78 | 18 | 12.6 | 22.4 |
| 15 | Training Classes | 4872 | 12.1 | 12 | 8.39 | 20.5 |
| 16 | Halogen lamp | 447 | 1.18 | 0 | 0 | 1.18 |
| 17 | Leveling | 3443 | 8.53 | 0 | 0 | 8.53 |

After this, 17 technical languages were prepared by exploiting the long term experience of the Deputy Chief Engineer and Plant Engineer. The HoQ constructed during this implementation study is shown in Figure 8.21. The methodology explained in chapter 6 was adopted to construct this HoQ. The calculated CTI and CTWL and other related terms are given in Table 8.6.

Table 8.6 Technical descriptors and their computed scores

As shown in Table 8.6, the weighted correlated value against the technical parameter 'tightening loose parts' is 9.In order to visualize the relative weightages of technical correlation, the percentage normalized value of correlated weights were calculated using the following formula.

Percentage normalized value of correlated weightage =

$$\frac{\text{Correlated weightage of the technical language}}{\text{Sum of Correlated weightages}} \times 100$$

Example: Percentage normalized of correlated weightage against the technical parameter 'tightening loose parts'= 9/143× 100 =6.29

Both percentage normalized score of CTI score and percentage normalized value of correlated weightage have been added and entered in the side of correlation matrix of HoQ and are termed as total normalized values.The Deputy Chief Engineer and Plant Engineer were interviewed to spell out the technical descriptors. They also expressed the feasibility of implementing all the technical requirements.

According to the procedure of implementing MQFD model, the Deputy chief Engineer and Plant Engineer were asked to make strategic decisions to either direct the technical requirements towards the implementation through TPM eight pillars implementation or an immediate and direct implementation However these technical requirements could not be implemented in this mines because it is an Indian state government run public sector, which requires decision making by the top level committee by following long democratic procedures. Hence the Deputy chief Engineer and Plant Engineer were asked to anticipate the result of implementing the MQFD by considering the six maintenance quality parameters of MQFD model. In order to compare the present and future performance, the past data of eleven equipments were collected. They are depicted in Tables 8.7 to 8.17. The calculations of maintenance quality parameters (Chan et.al, 2005,Juran and Gryna,1997) are presented in the subsequent subsections.

## 8.5. Calculations of maintenance quality parameters

In order to calculate the maintenance quality parameters of equipments, the author reviewed the equipments' datasheets maintained by the company.

The practice of recoring the machine running time, break down and planned maintenance time in the logbook was being regularly undertaken. This led the author a notion to interpret the effectiveness of maintenance based on some parameters. This approach could lead to tangible interpretation.

Generally the effectiveness of maintenance is calculated based on 10 parameters. They are

1.OEE, 2. MTBF, 3. MTTR, 4. Performance quality, 5. MDT,6. Availability,7. Improved maintenance, 8. Increased profit, 9. Improved core competence and 10. Enhanced goodwill.

### 8.5.1. Computation of OEE

Performance efficiency was assigned a constant value as $^{350}/_{600}$ to PC 650 machines. Since the capacity of these machines is 600 Tph but achieved is just 350 Tonnes. It is assigned a value of $^{350}/_{400}$ for EX 400 since its capacity is 400 tones per hour (Tph) but achieved is 350 Tph. Dumpers' performance rate value was assigned a value of 0.85. The rate of quality was assigned the value of 0.95.

Using these values, OEE for equipment 1 (PC2) during the month of January 2004 was calculated as follows:

$$\text{OEE} = 94.60 \text{ X } 0.90 \text{ X } (350/600)$$
$$= 52.42\%$$

### 8.5.2. Computation of Availability

The equipment availability is calculated as follows.

$$\text{Availability} = \frac{\text{(Planned production hours -Downtime)}}{\text{(Planned production hours)}}$$

Generally for the purpose of calculations, the time is calculated on daily, or monthly or yearly basis depending on the operating condition of the equipment. Here Planned production hours (PPH) is the planned time available for production operations, and downtime is the total time during which the system is not operating because of equipment failures, setup/ adjustment requirements, and other fixtures, etc. Therefore during the implementation study being reported here, availability was expressed as the ratio of actual operating time to loading time. Availability is a measure of the total time the equipment is available for use. It is calculated using the following formula.

$$\text{Availability} = \frac{\{\text{PPH} - (\text{Breakdown time} + \text{Maintenance time})\}}{(\text{Planned production hours})}$$

For example, Availability of PC2 during the month January 2004 is,

$$\text{Availability} = \frac{236.5}{250} \times 100$$

$$= 94.60\%$$

### 8.5. 3. Computation of MDT

MDT is the average down time of the equipment. That is, the average time equipment would be out of service during a specified month once it breaks down or is brought for service. The method adopted to calculate MDT is presented below.

$$\text{MDT} = \frac{(\text{Breakdown time} + \text{Maintenance time} + \text{Idle time})}{(\text{Number of breakdowns} + \text{Number of maintenance} + \text{Number of idle})}$$

For example, the MDT of PC 2 during the month January 2004 is,

$$\text{MDT} = \frac{(8.5 + 5 + 142.5)\ \text{hours}}{(10+2+18)}$$

$$= 5.20\ \text{hours}$$

### 8.5. 4. Computation of MTBF

MTBF is the average time equipment would run trouble-free before experiencing any sort of failure. The methodology adopted to compute MTBF is presented below.

$$\text{MTBF} = \frac{\text{Total Running time}}{(\text{Number of breakdowns} + \text{Number of maintenance})}$$

For example, the MTBF of PC 2 during the month January 2004 is,

$$\text{MTBF} = \frac{94 \text{ hours}}{12}$$

$$= 7.23 \text{ hours}$$

### 8.5. 5. Computation of MTTR

MTTR is the average time taken to repair equipment once it is brought into service.

It is given by the following formula

MTTR = (Break down time +maintenance time) / (Number of break down + number of maintenance)

For example, for PC 2 during the month January 2004,

$$\text{MTTR} = \frac{13.5 \text{ hours}}{12}$$

$$= 1.13 \text{ hours}$$

## 8.6. Primary data

The primary data obtained from the mines department for the purpose of conducting implementation study of MQFD are shown in Tables 8.7 to 8.17. These tables contain the maintenance records of the eleven equipments, which were selected for the implementation of MQFD.

**Table 8.7.** Equipment maintenance data of EX 400 during the years 2004 and 2005

| Machine Name : EXCAVATOR EX 400 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time (hours) | Maintenance time (hours) | Number of breakdowns | Number of maintenance | Number of idle |
| January 2004 | 387.5 | 151.5 | 7 | 50 | 3 | 1 | 44 |
| February 2004 | 362.5 | 118.5 | 83.5 | 0 | 12 | 0 | 43 |
| March 2004 | 112.5 | 38.25 | 2 | 0.5 | 4 | 1 | 18 |
| April 2004 | Major Overhauling | | | | | | |
| May 2004 | | | | | | | |
| June 2004 | | | | | | | |
| July 2004 | | | | | | | |
| August 2004 | 37.5 | 9 | 0 | 0 | 1 | 0 | 7 |
| September 2004 | 375 | 162.5 | 49 | 3 | 1 | 0 | 21 |
| October 2004 | 387 | 116.25 | 10.5 | 50 | 11 | 2 | 49 |
| November 2004 | 394.5 | 99.25 | 4.5 | 0 | 4 | 1 | 27 |
| December 2004 | 387 | 90 | 6 | 150 | 2 | 1 | 25 |
| January 2005 | 387.5 | 149 | 20 | 0.5 | 6 | 1 | 47 |
| February 2005 | 350 | 175 | 14 | 0.5 | 5 | 1 | 51 |
| March 2005 | 387.5 | 195.5 | 32.5 | 0 | 14 | 0 | 47 |
| April 2005 | 375 | 129.25 | 3 | 0 | 5 | 0 | 46 |
| May 2005 | 387.5 | 146 | 10.45 | 0 | 5 | 0 | 49 |
| June 2005 | 375 | 148.5 | 8 | 6.5 | 3 | 2 | 51 |
| July 2005 | 387.5 | 85.5 | 120.5 | 0.5 | 4 | 1 | 35 |
| August 2005 | 387 | 158 | 81.25 | 3.25 | 5 | 4 | 43 |
| September 2005 | Maintenance | | | | | | |
| October 2005 | 387.5 | 204.75 | 50 | 8.45 | 8 | 7 | 52 |

**Table 8.8. Equipment maintenance data of PC2 during the years 2004 and 2005**

| Machine Name : PC 2 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Break down time (hours) | Maintenance time (hours) | Number of breakdowns | Number of maintenance | Number of idle |
| January 2004 | 250 | 94 | 8.5 | 5 | 10 | 2 | 18 |
| February 2004 | 362.5 | 158 | 15.25 | 4.75 | 5 | 4 | 21 |
| March 2004 | 387.5 | 192.5 | 15.25 | 25.5 | 11 | 12 | 32 |
| April 2004 | 375 | 195.25 | 8 | 7.25 | 4 | 2 | 23 |
| May 2004 | 387.5 | 185.5 | 20.75 | 1 | 11 | 1 | 27 |
| June 2004 | 375 | 76.5 | 1.75 | 201 | 2 | 2 | 12 |
| July 2004 | 387 | 196 | 19.5 | 14 | 5 | 2 | 33 |
| August 2004 | 387.5 | 127.25 | 16 | 12.5 | 5 | 1 | 26 |
| September 2004 | 375 | 69.25 | 43 | 169 | 3 | 1 | 18 |
| October 2004 | 387.5 | 144.25 | 42 | 0 | 13 | 0 | 22 |
| November 2004 | 375 | 94 | 4 | 144.5 | 2 | 3 | 12 |
| December 2004 | 387.5 | 165.75 | 5.75 | 125 | 6 | 2 | 27 |
| January 2005 | 387.5 | 143.5 | 30.75 | 0 | 9 | 0 | 31 |
| February 2005 | 350 | 127 | 109.25 | 4 | 2 | 1 | 30 |
| March 2005 | 387.5 | 139 | 31.75 | 52.25 | 14 | 2 | 37 |
| April 2005 | 375 | 194.5 | 24 | 31.25 | 10 | 3 | 43 |
| May 2005 | 387.5 | 176.25 | 22 | 6 | 12 | 3 | 46 |
| June 2005 | 375 | 131 | 32.5 | 0 | 26 | 0 | 42 |
| July 2005 | 387.5 | 141 | 39.5 | 30.25 | 16 | 5 | 35 |
| August 2005 | 387.5 | 116.5 | 134.25 | 2 | 5 | 1 | 28 |
| September 2005 | 370 | 109.5 | 44.5 | 136.5 | 6 | 5 | 32 |
| October 2005 | 350 | 137.75 | 76.25 | 84.5 | 7 | 1 | 29 |
| November 2005 | 388 | 220.5 | 40.75 | 2 | 8 | 1 | 53 |
| December 2005 | 387.5 | 138.25 | 152.75 | 2 | 3 | 2 | 29 |

**Table 8.9. Equipment maintenance data of PC3 during the years 2004 and 2005**

| Machine Name : EXCAVATOR PC3 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time(hours) | Maintenance time(hours) | Number of breakdown | Number of maintenance | Number of idle |
| January 2004 | 387.5 | 145.5 | 30.25 | 0.5 | 10 | 1 | 24 |
| February 2004 | 362.5 | 46 | 15.5 | 277.5 | 6 | 1 | 11 |
| March 2004 | 387.5 | 206 | 14.5 | 21 | 10 | 4 | 44 |
| April 2004 | 375 | 173 | 10.5 | 4.25 | 9 | 4 | 43 |
| May2004 | 387.5 | 132 | 8.25 | 2 | 7 | 1 | 39 |
| June2004 | 375 | 154.5 | 35.75 | 18.75 | 4 | 1 | 36 |
| July 2004 | 387.5 | 105.25 | 20.25 | 137.5 | 8 | 1 | 27 |
| August 2004 | 387.5 | 121.25 | 14.5 | 25 | 5 | 1 | 37 |
| September 2004 | 375 | 139.25 | 9.75 | 87.5 | 3 | 1 | 35 |
| October 2004 | 387.5 | 15.25 | 7.75 | 325 | 1 | 1 | 5 |
| November 2004 | 375 | 141 | 18.25 | 18.75 | 10 | 1 | 43 |
| December 2004 | 387 | 178 | 37 | 0 | 10 | 0 | 44 |
| January 2005 | 387.5 | 110.75 | 28 | 112.5 | 9 | 1 | 19 |
| February 2005 | 350 | 131.75 | 37.5 | 87.5 | 1 | 2 | 19 |
| March 2005 | 387 | 168 | 35 | 57.75 | 14 | 2 | 31 |
| April 2005 | 375 | 179.25 | 22.5 | 1 | 14 | 1 | 33 |
| May 2005 | 387.5 | 130 | 38.75 | 56.25 | 13 | 3 | 27 |
| June 2005 | 375 | 94.75 | 153.75 | 0.5 | 14 | 1 | 24 |
| July 2005 | 387.5 | 114 | 26.75 | 62.5 | 12 | 9 | 33 |
| August 2005 | 387.5 | 142.75 | 9.5 | 26.5 | 6 | 3 | 38 |
| September 2005 | 375 | 110.5 | 5.5 | 10.25 | 14 | 6 | 28 |
| October 2005 | 325 | 142.25 | 24.75 | 6 | 11 | 3 | 30 |
| November 2005 | 375 | 126.25 | 113.25 | 63.5 | 4 | 2 | 26 |
| December 2005 | 387.5 | 188.75 | 113.25 | 1 | 11 | 1 | 35 |

**Table 8.10. Equipment maintenance data of H1 during the years 2004 and 2005**

| Machine Name : HAUL PACK H1 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time(hours) | Maintanence time(hours) | Number of breakdown | Number of maintanence | Number of idle |
| January 2004 | 387.5 | 183.75 | 12.75 | 33.25 | 5 | 2 | 49 |
| February 2004 | 362.5 | 131 | 23.5 | 12.75 | 3 | 4 | 49 |
| March 2004 | 387.5 | 194 | 7.25 | 24.25 | 4 | 2 | 45 |
| April 2005 | 375 | 200.5 | 2.5 | 12.5 | 1 | 2 | 53 |
| May 2004 | 387.5 | 77 | 7.75 | 218.5 | 3 | 4 | 22 |
| June 2004 | 375 | 193 | 14.75 | 50 | 4 | 2 | 43 |
| July 2004 | 387.5 | 246.75 | 2.25 | 0 | 1 | 0 | 49 |
| August 2004 | 387.5 | 173.75 | 30.5 | 56.25 | 8 | 2 | 37 |
| September 2004 | 375 | 89.5 | 20.5 | 218.75 | 7 | 1 | 20 |
| October 2004 | 387.5 | 176.75 | 51.5 | 95.75 | 5 | 2 | 23 |
| November 2004 | 375 | 83.35 | 14.25 | 237.5 | 3 | 1 | 18 |
| December 2004 | | | | | | | |
| January 2005 | | | | | | | |
| February 2005 | **Major Overhauling** | | | | | | |
| March 2005 | | | | | | | |
| April 2005 | | | | | | | |
| May 2005 | | | | | | | |
| June 2005 | | | | | | | |
| July 2005 | | | | | | | |
| August 2005 | | | | | | | |
| September 2005 | | | | | | | |
| October 2005 | | | | | | | |
| November 2005 | | | | | | | |
| December 2005 | | | | | | | |

**Table 8.11. Equipment maintenance data of H2 during the years 2004 and 2005**

| Machine Name : HAUL PACK H2 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time(hours) | Maintenance time(hours) | Number of breakdown | Number of maintenance | Number of idle |
| January 2004 | 387.5 | 203.25 | 37 | 8 | 6 | 2 | 55 |
| February 2004 | 362.5 | 184.75 | 9.25 | 3 | 1 | 1 | 54 |
| March 2004 | 387.5 | 240.5 | 11 | 3 | 4 | 1 | 51 |
| April 2004 | 375 | 182 | 0 | 25 | 0 | 1 | 53 |
| May 2004 | 387.5 | 193 | 8.25 | 2 | 4 | 1 | 59 |
| June 2004 | 375 | 166.75 | 24.75 | 0 | 7 | 0 | 48 |
| July 2004 | 387.5 | 174.5 | 40.75 | 23.25 | 11 | 2 | 47 |
| August 2004 | 387.5 | 211.5 | 38.75 | 0 | 10 | 0 | 51 |
| September 2004 | 375 | 220.25 | 35.5 | 50 | 8 | 2 | 38 |
| October 2004 | 387.5 | 246.5 | 29.25 | 0 | 8 | 0 | 47 |
| November (04) | 375 | 246.75 | 31 | 0 | 8 | 0 | 39 |
| December 2004 | 387.5 | 220 | 27.25 | 0 | 4 | 0 | 44 |
| January 2005 | 387.5 | 221.25 | 17.5 | 0 | 4 | 0 | 51 |
| February 2005 | 350 | 181 | 18.75 | 0 | 3 | 0 | 48 |
| March 2005 | 394 | 155 | 4.5 | 68.75 | 2 | 2 | 44 |
| April 2005 | 375 | 217 | 22 | 6.25 | 8 | 1 | 48 |
| May 2005 | 387.5 | 223.5 | 54.75 | 0 | 5 | 0 | 49 |
| June 2005 | 375 | 157 | 43.25 | 0 | 6 | 0 | 48 |
| July 2005 | 387.5 | 151.25 | 48.5 | 53.75 | 10 | 3 | 40 |
| August 2005 | 387.5 | 155.5 | 97.25 | 27.5 | 8 | 5 | 37 |
| September 2005 | 375 | 209.75 | 4.75 | 3.5 | 3 | 6 | 50 |
| October 2005 | 325 | 157 | 37.25 | 60 | 6 | 5 | 24 |
| November 2005 | 381.5 | 236.5 | 11.5 | 1.5 | 3 | 3 | 43 |
| December 2005 | 394 | 172.25 | 136 | 1 | 5 | 1 | 28 |

**Table 8.12. Equipment maintenance data of H3 during the years 2004 and 2005**

| Machine Name : HAUL PACK H3 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time(hours) | Maintenance time(hours) | Number of breakdown | Number of maintenance | Number of idle |
| January 2004 | 387.5 | 211.25 | 2.5 | 0 | 1 | 0 | 46 |
| February 2004 | 362.5 | 159 | 0 | 6.5 | 0 | 2 | 51 |
| March 2004 | 387.5 | 214 | 22.5 | 37.25 | 6 | 4 | 42 |
| April 2004 | 375 | 145 | 20.75 | 21.75 | 6 | 4 | 41 |
| May 2004 | 387.5 | 134.25 | 16.75 | 89.5 | 4 | 4 | 43 |
| June 2004 | 375 | 183.5 | 11.25 | 0 | 5 | 0 | 53 |
| July 2004 | 387.5 | 105.25 | 20.5 | 212.5 | 3 | 3 | 23 |
| August 2004 | 387.5 | 4.25 | 2 | 318.75 | 1 | 2 | 11 |
| September 2004 | 375 | 77 | 37.75 | 200 | 7 | 4 | 19 |
| October 2004 | 387.5 | 285.75 | 18.75 | 0 | 7 | 0 | 37 |
| November 2004 | 375 | 256.75 | 40.75 | 0 | 9 | 0 | 40 |
| December 2004 | 387.5 | 191 | 23 | 37 | 3 | 1 | 34 |
| January 2005 | 387.5 | 231 | 19.25 | 19.25 | 5 | 4 | 42 |
| February 2005 | 350 | 234 | 0 | 0.5 | 0 | 1 | 43 |
| March 2005 | 394 | 223.25 | 16 | 1 | 6 | 2 | 48 |
| April 2005 | 375 | 177.5 | 49.5 | 0 | 6 | 0 | 48 |
| May 2005 | 350 | 225 | 15.75 | 0 | 5 | 0 | 53 |
| June 2005 | 375 | 164.5 | 12.25 | 5.75 | 3 | 3 | 48 |
| July 2005 | 387.5 | 200.75 | 36.5 | 1 | 12 | 2 | 42 |
| August 2005 | 387.5 | 250.75 | 31.5 | 3 | 6 | 4 | 40 |
| September 2005 | 375 | 206 | 26 | 1 | 5 | 2 | 47 |
| October 2005 | 387.5 | 251.75 | 19.5 | 5.25 | 5 | 5 | 29 |
| November 2005 | 394.5 | 239 | 56.5 | 11 | 2 | 6 | 31 |
| December 2005 | 394 | 274 | 13.5 | 25 | 2 | 4 | 35 |

**Table 8.13. Equipment maintenance data of H4 during the years 2004 and 2005**

| Machine Name : HAUL PACK H4 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time(hours) | Maintenance time(hours) | Number of breakdown | Number of maintenance | Number of idle |
| January 2004 | 387.5 | 237 | 19.75 | 0 | 4 | 0 | 34 |
| February 2004 | 362.5 | 218.25 | 9.5 | 23.75 | 4 | 4 | 35 |
| March 2004 | 387.5 | 260.5 | 9.5 | 0 | 4 | 0 | 42 |
| April 2004 | 375 | 225.75 | 12 | 9.75 | 4 | 1 | 47 |
| May 2004 | 387.5 | 207.5 | 33.25 | 0 | 8 | 0 | 46 |
| June 2004 | 375 | 212.75 | 9.75 | 17.25 | 6 | 1 | 38 |
| July 2004 | 387.5 | 202.5 | 19.25 | 87.5 | 6 | 2 | 30 |
| August 2004 | 387.5 | 165.5 | 12.25 | 150 | 5 | 2 | 27 |
| September 2004 | 375 | 229 | 8.5 | 62.5 | 4 | 1 | 32 |
| October 2004 | 375 | 0 | 0 | 375 | 0 | 1 | 0 |
| November 2004 | 375 | 0 | 0 | 375 | 0 | 1 | 0 |
| December 2004 | 262 | 177 | 5.75 | 0 | 2 | 0 | 22 |
| January 2005 | 387.5 | 91.75 | 35.75 | 137.5 | 8 | 2 | 20 |
| February 2005 | 350 | 226 | 18 | 1.5 | 4 | 3 | 38 |
| March 2005 | 393 | 259 | 0.75 | 9.5 | 3 | 4 | 51 |
| April 2005 | 375 | 263 | 15.25 | 11.25 | 5 | 5 | 35 |
| May 2005 | 394 | 249.25 | 15.75 | 2 | 6 | 5 | 44 |
| June 2005 | 375 | 202 | 16.75 | 1.5 | 6 | 6 | 44 |
| July 2005 | 393 | 242.75 | 17.75 | 18 | 6 | 4 | 41 |
| August 2005 | 387.5 | 232.25 | 42 | 1.5 | 5 | 3 | 47 |
| September 2005 | 375 | 223 | 9.5 | 3.5 | 3 | 4 | 37 |
| October 2005 | 387.5 | 268.25 | 8 | 2 | 4 | 5 | 28 |
| November 2005 | 375 | 282 | 8.75 | 21.5 | 5 | 4 | 43 |
| December 2005 | 387.5 | 29 | 342.5 | 3.5 | 1 | 1 | 4 |

**Table 8.14. Equipment maintenance data of H5 during the years 2004 and 2005**

| Machine Name : HAUL PACK H-5 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time(hours) | Maintenance time(hours) | Number of breakdown | Number of maintenance | Number of idle |
| January 2004 | 387.5 | 170.5 | 15 | 0 | 6 | 0 | 45 |
| February 2004 | 362.5 | 150.75 | 15.75 | 18 | 5 | 2 | 49 |
| March 2004 | 387.5 | 241 | 24 | 9.5 | 6 | 3 | 53 |
| April 2004 | 375 | 144 | 8 | 66 | 2 | 5 | 51 |
| May 2004 | 387.5 | 187.5 | 38.75 | 31.25 | 5 | 4 | 47 |
| June 2004 | 375 | 145.5 | 18.25 | 112.75 | 6 | 3 | 41 |
| July 2004 | 387.5 | 210.25 | 28.75 | 25 | 11 | 1 | 38 |
| August 2004 | 387.5 | 234.75 | 23.25 | 12.5 | 9 | 1 | 44 |
| September 2004 | 375 | 256 | 11.5 | 12.5 | 6 | 1 | 48 |
| October 2004 | 387.5 | 156 | 40 | 137.5 | 14 | 1 | 30 |
| November 2004 | 375 | 130.5 | 34 | 62 | 8 | 1 | 25 |
| December 2004 | 387.5 | 266 | 19.25 | 0 | 5 | 0 | 41 |
| January 2005 | 387.5 | 234.25 | 11.25 | 1.5 | 3 | 2 | 50 |
| February 2005 | 350 | 216.25 | 13.5 | 4 | 5 | 4 | 39 |
| March 2005 | 394 | 252 | 2.25 | 46.75 | 2 | 5 | 51 |
| April 2005 | 375 | 278 | 0 | 7 | 5 | 5 | 55 |
| May 2005 | 387.5 | 210 | 17.25 | 0 | 5 | 0 | 54 |
| June 2005 | 375 | 101 | 145 | 0 | 6 | 0 | 37 |
| July 2005 | 362.5 | 227 | 9.5 | 5.5 | 5 | 5 | 51 |
| August 2005 | 362.5 | 229.75 | 19.75 | 2 | 6 | 4 | 50 |
| September 2005 | 175 | 136 | 0 | 1 | 0 | 2 | 26 |
| October 2005 | 387.5 | 231.5 | 17.25 | 7 | 8 | 5 | 47 |
| November 2005 | 394 | 276 | 30.75 | 13 | 12 | 8 | 42 |

**Table 8.15.** Equipment maintenance data of H6 during the years 2004 and 2005

| Machine Name : HAUL PACK H-6 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time(hours) | Maintenance time(hours) | Number of breakdown | Number of maintenance | Number of idle |
| January 2004 | 387.5 | 120.25 | 9 | 62.5 | 4 | 2 | 51 |
| February 2004 | 362.5 | 159 | 1.25 | 14.5 | 7 | 2 | 44 |
| March 2004 | 387.5 | 78 | 42 | 153.5 | 7 | 4 | 45 |
| April 2004 | 375 | 168.5 | 12.5 | 50.75 | 7 | 3 | 38 |
| May 2004 | 387.5 | 170 | 24.75 | 8.25 | 13 | 2 | 39 |
| June 2004 | 375 | 114 | 7.75 | 175 | 8 | 1 | 42 |
| July 2004 | 387.5 | 217.75 | 10 | 7.25 | 7 | 3 | 49 |
| August 2004 | 387.5 | 207.75 | 31.25 | 32.75 | 3 | 2 | 29 |
| September 2004 | 375 | 198.5 | 47.75 | 37.5 | 9 | 1 | 44 |
| October 2004 | 387.5 | 226.25 | 21.25 | 62.5 | 3 | 2 | 44 |
| November 2004 | 375.5 | 223 | 24.5 | 0 | 8 | 0 | 38 |
| December 2004 | 387.5 | 296 | 31 | 0 | 1 | 0 | 37 |
| January 2005 | 387.5 | 220.5 | 11 | 0 | 4 | 0 | 47 |
| February 2005 | 350 | 185 | 14.5 | 0 | 5 | 0 | 36 |
| March 2005 | 387 | 253.75 | 11.25 | 8.25 | 4 | 2 | 46 |
| April 2005 | 375 | 205.75 | 24 | 5.5 | 9 | 2 | 48 |
| May 2005 | 387.5 | 234.25 | 24.25 | 32.25 | 5 | 3 | 50 |
| June 2005 | 375 | 254 | 26.5 | 1 | 8 | 3 | 42 |
| July 2005 | 387.5 | 250.5 | 9.5 | 2 | 4 | 4 | 50 |
| August 2005 | 394 | 230 | 31.5 | 2.5 | 11 | 4 | 46 |
| September 2005 | 100 | 69.5 | 6.75 | 0.5 | 3 | 1 | 8 |
| October 2005 | 275 | 161 | 8.5 | 6 | 5 | 5 | 34 |
| November 2005 | 394.5 | 126 | 87 | 105 | 4 | 2 | 24 |
| December 2005 | 394 | 187.25 | 41.5 | 2 | 10 | 2 | 48 |

**Table 8.16. Equipment maintenance data of H7 during the years 2004 and 2005**

| Machine Name : HAUL PACK H-7 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time(hours) | Maintenance time(hours) | Number of breakdown | Number of Number of maintenance | Number of idle |
| January 2004 | 387.5 | 70.5 | 3.5 | 237.5 | 1 | 1 | 22 |
| February 2004 | 362.5 | 122.75 | 22 | 23 | 5 | 6 | 30 |
| March 2004 | 387.5 | 155.25 | 6.75 | 73.25 | 3 | 4 | 31 |
| April 2004 | 375 | 195.5 | 12.25 | 6.25 | 4 | 1 | 38 |
| May 2004 | 387.5 | 108.75 | 8.25 | 137.5 | 3 | 1 | 27 |
| June 2004 | 375 | 7.75 | 3.5 | 362.5 | 1 | 2 | 2 |
| July 2004 | 387.5 | 0 | 0 | 387.5 | 0 | 1 | 0 |
| August 2004 | 387.5 | 4.5 | 15.25 | 356.25 | 4 | 2 | 4 |
| September 2004 | 375 | 204.25 | 19 | 62.5 | 3 | 1 | 36 |
| October 2004 | 387.5 | 180.85 | 152 | 0 | 5 | 0 | 28 |
| November 2004 | 375 | 236 | 14 | 0 | 4 | 0 | 40 |
| December 2004 | 387.5 | 232 | 23.25 | 23.45 | 10 | 4 | 42 |
| January 2005 | 387.5 | 207 | 17.75 | 0 | 4 | 0 | 43 |
| February 2005 | 350 | 144.25 | 11.25 | 72.5 | 4 | 2 | 32 |
| March 2005 | 394 | 250.5 | 15.25 | 10.5 | 6 | 2 | 39 |
| April 2005 | 375 | 225.75 | 39.75 | 0.5 | 8 | 1 | 35 |
| May 2005 | 387.5 | 214 | 17.75 | 50 | 3 | 2 | 44 |
| June 2005 | 275 | 221.25 | 2 | 1 | 2 | 2 | 44 |
| July 2005 | 225 | 108.25 | 17 | 46.75 | 9 | 10 | 18 |
| August 2005 | 75 | 39 | 14.5 | 0.5 | 5 | 1 | 9 |
| September 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| October 2005 | 387.5 | 250.45 | 23.5 | 2 | 8 | 4 | 32 |
| November 2005 | 375 | 236 | 14 | 0 | 4 | 0 | 40 |
| December 2005 | 387.5 | 232 | 23.25 | 23.45 | 10 | 4 | 42 |

**Table 8.17. Equipment maintenance data of H 8 during the years 2004 and 2005**

| Machine Name : HAUL PACK H-8 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | PPH (hours) | Run time (hours) | Breakdown time(hours) | Maintenance time(hours) | Number of breakdown | Number of maintenance | Number of idle |
| January 2004 | 387.5 | 185 | 31.25 | 7.75 | 7 | 2 | 50 |
| February 2004 | 362.5 | 207.75 | 6 | 2 | 2 | 1 | 49 |
| March 2004 | 387.5 | 167.5 | 13 | 8 | 5 | 2 | 46 |
| April 2004 | 375 | 180.75 | 7.5 | 0 | 3 | 0 | 51 |
| May 2004 | 387.5 | 182.75 | 0 | 2.5 | 0 | 1 | 56 |
| June 2004 | 375 | 213 | 21.75 | 0 | 10 | 0 | 146 |
| July 2004 | 387.5 | 226.5 | 17 | 0 | 8 | 0 | 52 |
| August 2004 | 387.5 | 40 | 11 | 262.5 | 2 | 1 | 15 |
| September 2004 | | | | | | | |
| October 2004 | | | | | | | |
| November 2004 | | | | | | | |
| December 2004 | | | | | | | |
| January 2005 | | | | | | | |
| February 2005 | | | | Major Overhauling | | | |
| March 2005 | 287.5 | 29 | 200 | 6 | 1 | 1 | 15 |
| April 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| May 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 2005 | 262.5 | 116.75 | 21.25 | 5.5 | 6 | 4 | 35 |
| July 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| August 2005 | 162.5 | 84.5 | 55.5 | 4.5 | 7 | 1 | 26 |
| September 2005 | 175 | 34 | 5.25 | 1.5 | 2 | 1 | 17 |
| October 2005 | 312.5 | 183.25 | 23 | 75.5 | 8 | 3 | 39 |
| November 2005 | 381.5 | 253 | 63.5 | 3.5 | 12 | 2 | 33 |
| December 2005 | 407 | 286.5 | 23.25 | 1.5 | 6 | 3 | 41 |

## 8.7. Calculation of maintenance parameters and analysis of failures

During this stage of implementation study, the maintenance parameters were calculated separately for all the eleven equipments. The values of these parameters are tabulated in Tables 8.18-8.28 and plotted in graphs shown in Figures 8.22-8.44. These graphs were selected to identify desirable and undesirable trends. Desirable trends were ignored and the undesirable variations from the mean were carefully analysed. After analysis the reasons for these variations were studied and suggestions were given.

### 8.7.1. Maintenance Quality Analysis of EX 400

The values of maintenance quality parameters pertaining to the equipment EX 400 are shown Table 8.18. The values are graphically depicted in Figure 8.22. - 8.26.

#### Findings

A study of these Table and Figures indicated that there has been sudden variations in availability during the months December 2004 and July 2005 of the otherwise stable equipment, EX 400. Records show that this is the most stable equipment used in the mines. During these months, records show that the maintenance time was also high. So the appropriate personnel were consulted and reasons for these variations were identified. It was the replacements of the boom, stick, level cylinders and the maintenance of swivel joint, which caused the reduction in the availability.

#### Suggestions

Considering the fact that no maintenance is possible for the cylinders, the following suggestions were given:

- A stock of cylinders must be maintained at the store so as to make the maintenance faster
- Seals must be readily available in the stores.

- Monitor the seals and cylinders that are working properly now and those which are outdated or which have exceeded their lifetime must be replaced since the failure of cylinders can lead to the failure of other components also.

Also the hydraulic problems and their causes must be analysed thoroughly since most of the breakdowns are due to hydraulic problems and elimination of which can improve the availability of machine considerably.

**Table 8.18. Maintenance parameters of EX 400 during the years 2004 and 2005**

| Month | Availability(%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE(%) |
|---|---|---|---|---|---|
| January 2004 | 85.29 | 37.88 | 4.92 | 14.25 | 47.27 |
| February 2004 | 76.97 | 9.88 | 4.44 | 6.96 | 42.65 |
| March 2004 | 97.78 | 7.65 | 3.23 | 0.50 | 54.19 |
| April 2004 | MAJOR OVERHAULING | | | | |
| May 2004 | | | | | |
| June 2004 | | | | | |
| July 2004 | | | | | |
| August 2004 | 100.00 | 9.00 | 4.07 | 0.00 | 55.42 |
| September 2004 | 86.13 | 162.50 | 10.12 | 0.00 | 47.73 |
| October 2004 | 81.30 | 8.94 | 4.37 | 4.65 | 45.05 |
| November 2004 | 99.00 | 19.85 | 9.23 | 0.90 | 54.86 |
| December 2004 | 59.65 | 30.00 | 10.61 | 52.00 | 33.06 |
| January 2005 | 94.80 | 21.29 | 4.42 | 2.86 | 52.54 |
| February 2005 | 96.00 | 29.17 | 3.07 | 2.33 | 53.20 |
| March2005 | 91.60 | 13.96 | 3.15 | 2.32 | 50.76 |
| April 2005 | 99.20 | 25.85 | 4.82 | 0.60 | 54.97 |
| May 2005 | 97.20 | 29.20 | 4.47 | 2.09 | 53.87 |
| June 2005 | 96.13 | 29.70 | 4.04 | 2.90 | 53.27 |
| July 2005 | 69.00 | 17.10 | 7.55 | 24.20 | 38.24 |
| August 2005 | 78.20 | 17.56 | 4.40 | 9.39 | 43.34 |
| September 2005 | Maintenance | | | | |
| October 2005 | 84.90 | 13.65 | 2.73 | 3.90 | 47.05 |
| November 2005 | | | | | |
| December 2005 | | | | | |

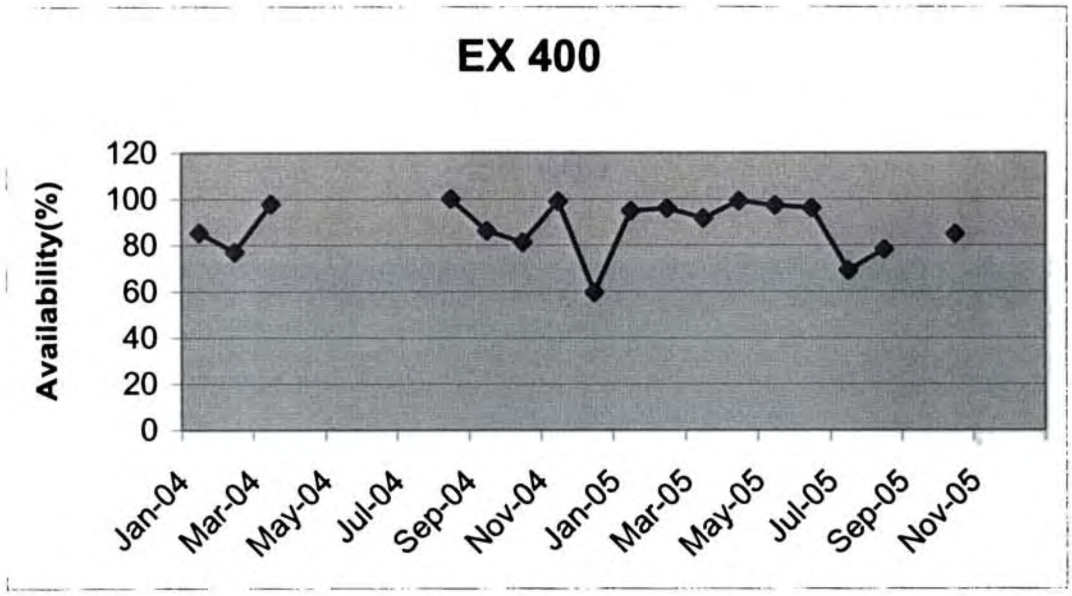



**Figure 8.22**. Variation of availability of EX 400 during 2004 and 2005

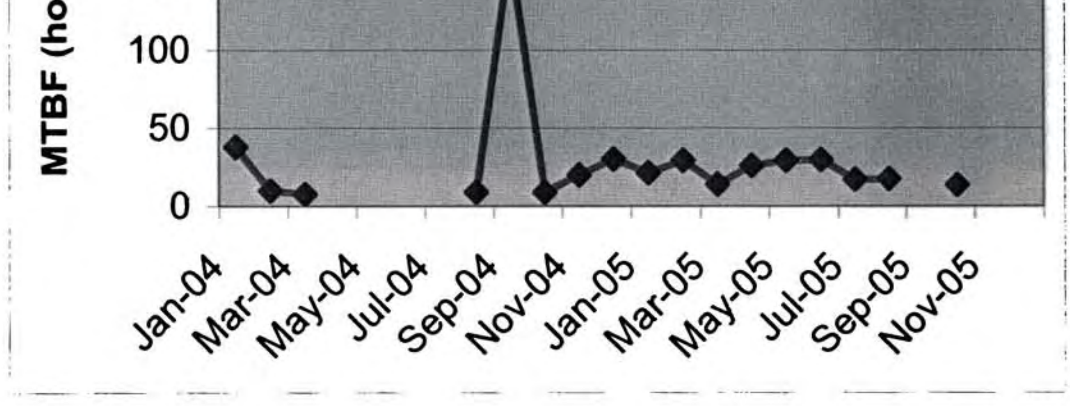



**Figure 8.23** .Variation of MTBF of EX 400 during 2004 and 2005

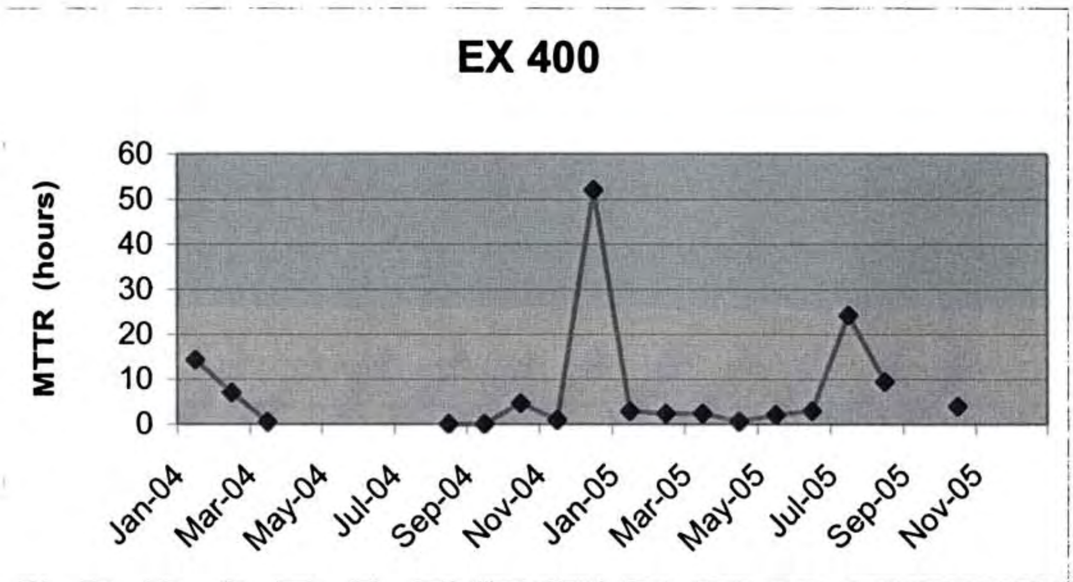



**Figure 8.24** .Variation of MTTR of EX 400 during 2004 and 2005

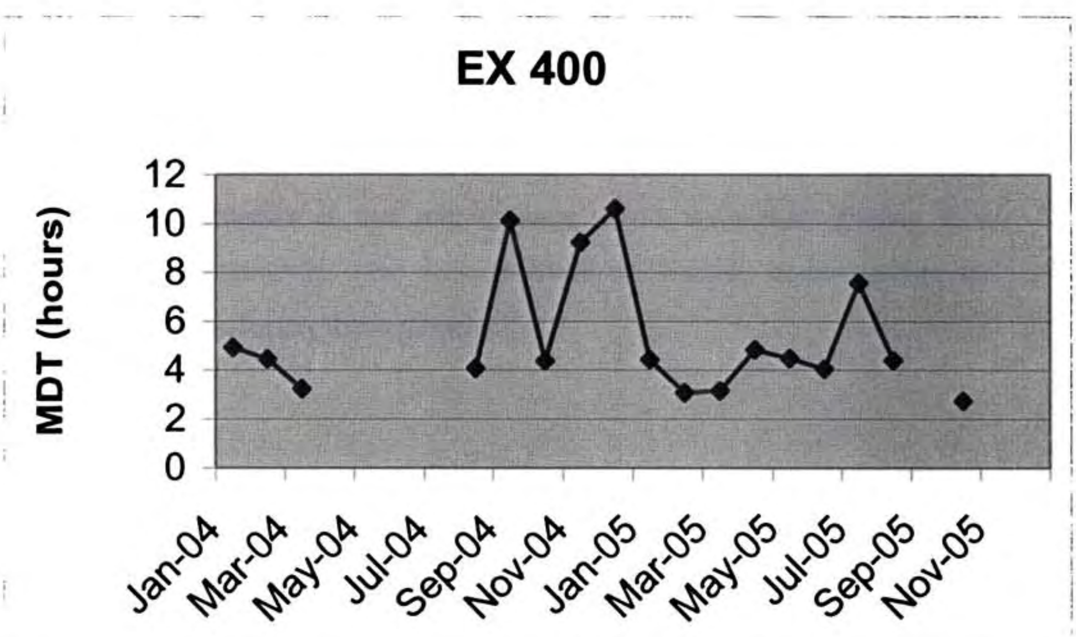



**Figure 8. 25** .Variation of MDT of EX 400 during 2004 and 2005

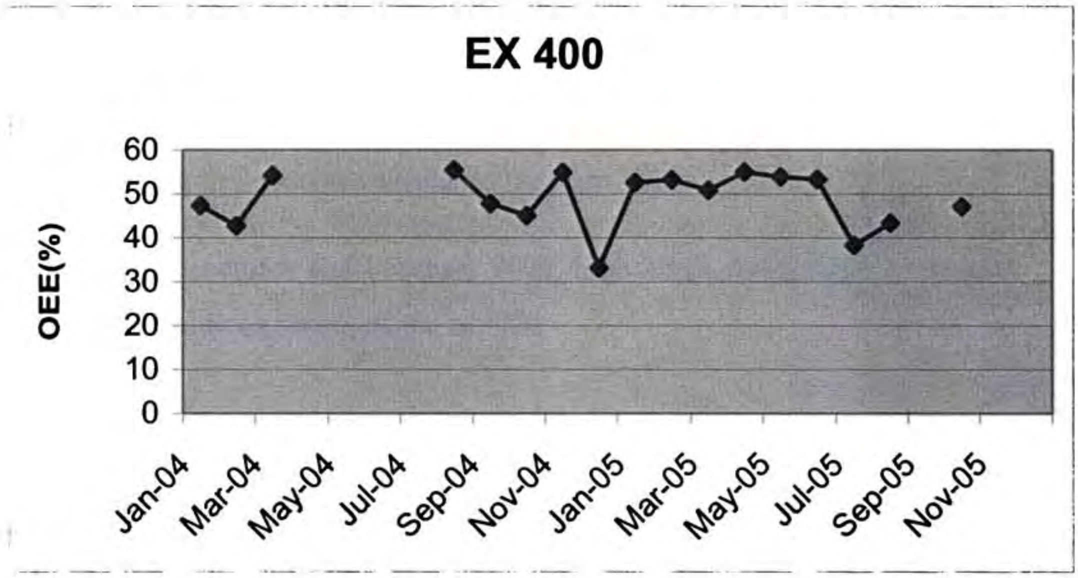



**Figure 8. 26.** Variation of OEE of EX 400 during 2004 and 2005

## 8.7.2. Maintenance Quality Analysis of PC 2

The values of maintenance quality parameters pertaining to the equipment PC 2are shown Table 8.19. The values are graphically depicted from Figure 8.27. to 8.26. A study of these table and figures indicated that there has been a sudden decrease in the availability during June and September 2004. The reasons to this situation is that maintenance works were done during these periods. The maintenances were done to eliminate bucket, undercarriage and structural problems during these months.

### Findings

January, March and October 2004 record a very low value in MTBF and the major reason other than those specified above is the high number of breakdowns during these months. Number of unscheduled maintenance would also high especially during March 2004. The MTTR had increased during the months June, September and November 2004 due to undercarriage welding.

During September and October 2005 availability was low as a lot of maintenance works were carried out during these months. The reason for decrease in availability during 2005 are exactly the same that caused a decrease in its availability during 2004. During March, June and July 2005, MTBF was low, This is attributed due to the reason that a high number of brake downs occurred during these months similar to the year 2004.

During December and February 2005, high break down hours combined with bucket problems increased the MTTR.

**Table 8.19. Maintenance parameters of PC2 during the year 2004 and 2005**

| Month | Availability (%) | MTBF (hrs) | MDT (hrs) | MTTR (hrs) | OEE(%) |
|---|---|---|---|---|---|
| January 2004 | 94.60 | 7.83 | 5.20 | 1.13 | 52.42 |
| February 2004 | 94.48 | 17.56 | 6.82 | 2.22 | 52.36 |
| March 2004 | 89.48 | 8.37 | 3.55 | 1.77 | 49.59 |
| April 2004 | 95.93 | 32.54 | 6.20 | 2.54 | 53.16 |
| May 2004 | 94.39 | 15.46 | 5.18 | 1.81 | 52.31 |
| June 2004 | 45.93 | 19.13 | 18.66 | 50.69 | 25.45 |
| July 2004 | 91.34 | 28.00 | 4.78 | 4.79 | 50.62 |
| August 2004 | 92.65 | 21.21 | 8.13 | 4.75 | 51.34 |
| September 2004 | 43.47 | 17.31 | 13.90 | 53.00 | 24.09 |
| October 2004 | 89.16 | 11.10 | 6.95 | 3.23 | 49.41 |
| November 2004 | 60.40 | 18.80 | 16.53 | 29.70 | 33.47 |
| December 2004 | 66.26 | 20.72 | 6.34 | 16.34 | 36.72 |
| January 2005 | 92.06 | 15.94 | 6.10 | 3.42 | 51.02 |
| February 2005 | 67.64 | 42.33 | 6.76 | 37.75 | 37.49 |
| March 2005 | 78.32 | 8.69 | 4.69 | 5.25 | 43.40 |
| April 2005 | 85.27 | 14.96 | 3.22 | 4.25 | 47.25 |
| May 2005 | 92.77 | 11.75 | 3.46 | 1.87 | 51.41 |
| June 2005 | 91.33 | 5.04 | 3.59 | 1.25 | 50.61 |
| July 2005 | 82.00 | 6.71 | 4.40 | 3.32 | 45.44 |
| August 2005 | 64.84 | 19.42 | 7.97 | 22.71 | 35.93 |
| September 2005 | 51.08 | 9.95 | 6.06 | 16.45 | 28.31 |
| October 2005 | 54.07 | 17.22 | 5.74 | 20.09 | 29.96 |
| November 2005 | 88.98 | 24.50 | 2.70 | 4.75 | 49.31 |
| December 2005 | 60.06 | 27.65 | 7.33 | 30.95 | 33.29 |

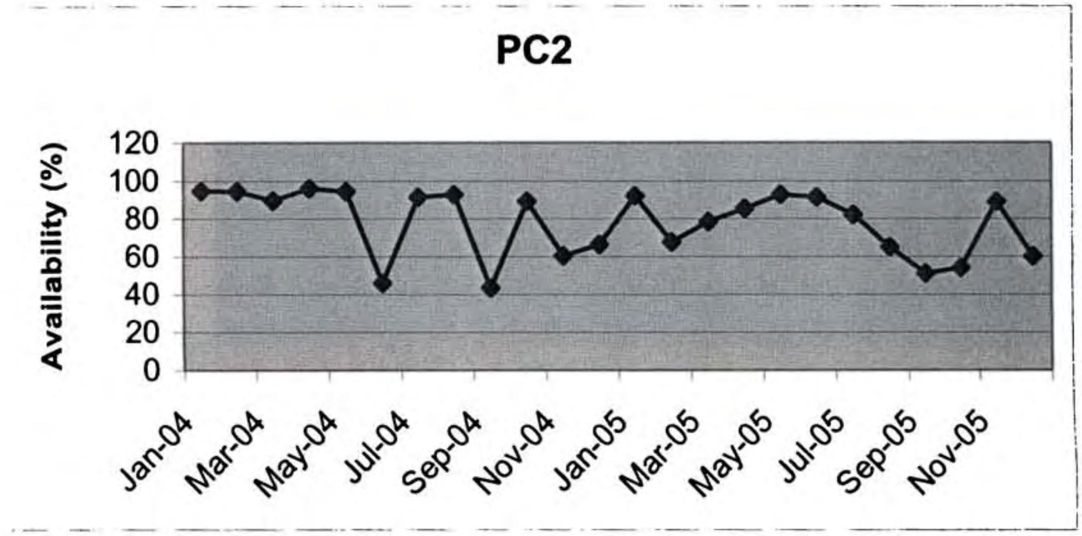



**Figure 8. 27** .Variation of availability of PC 2 during 2004 and 2005

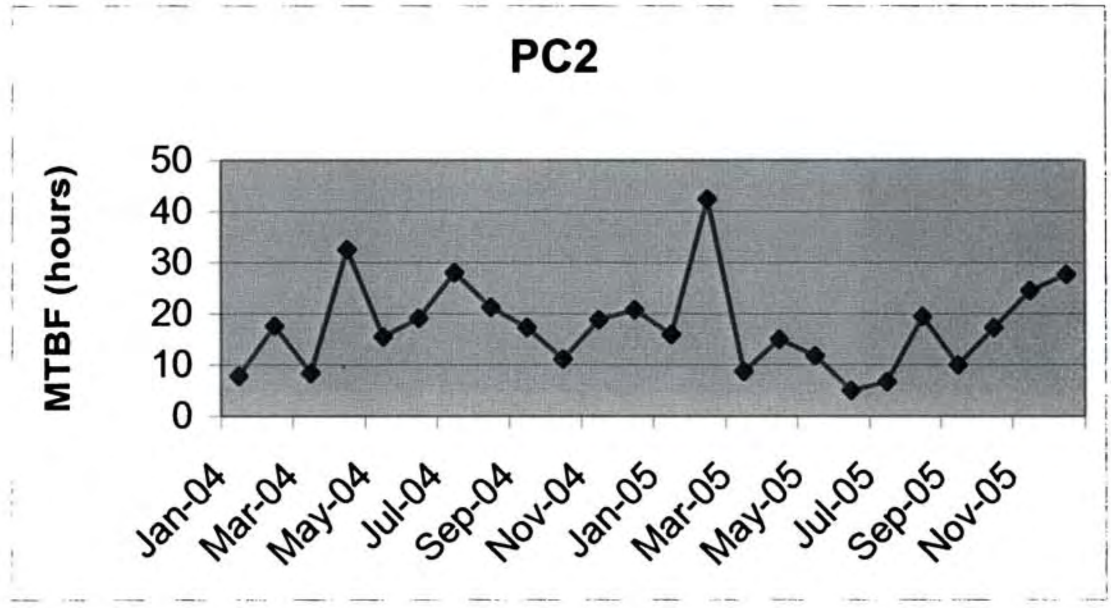



**Figure 8. 28** .Variation of MTBF of PC 2 during 2004 and 2005

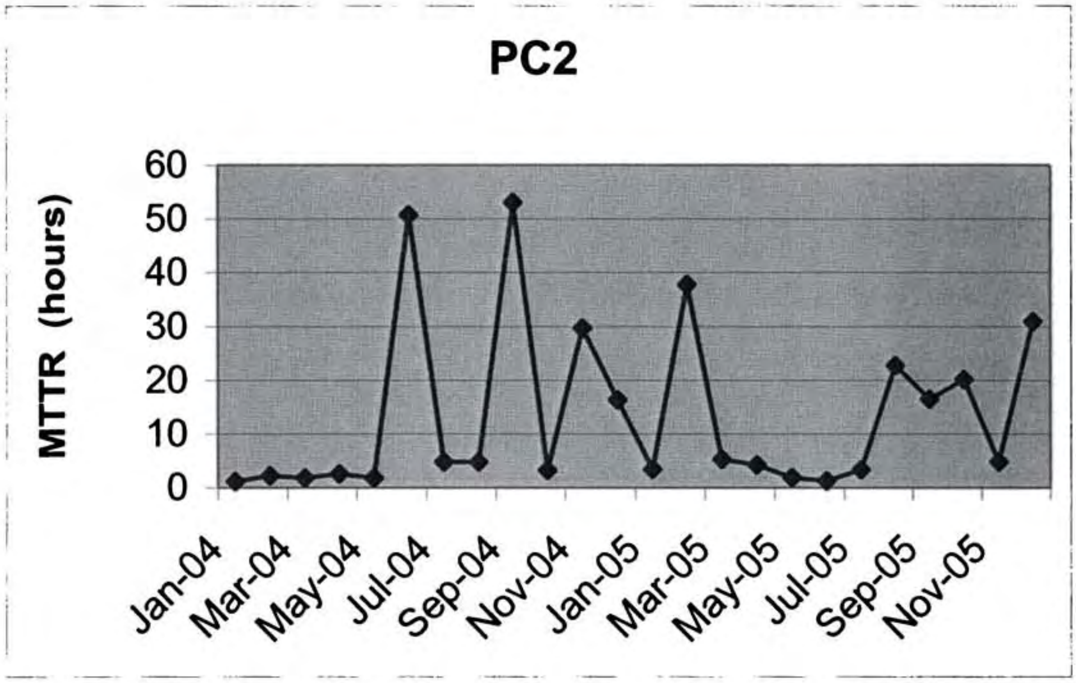



**Figure 8. 29.** Variation of MTTR of PC 2 during 2004 and 2005

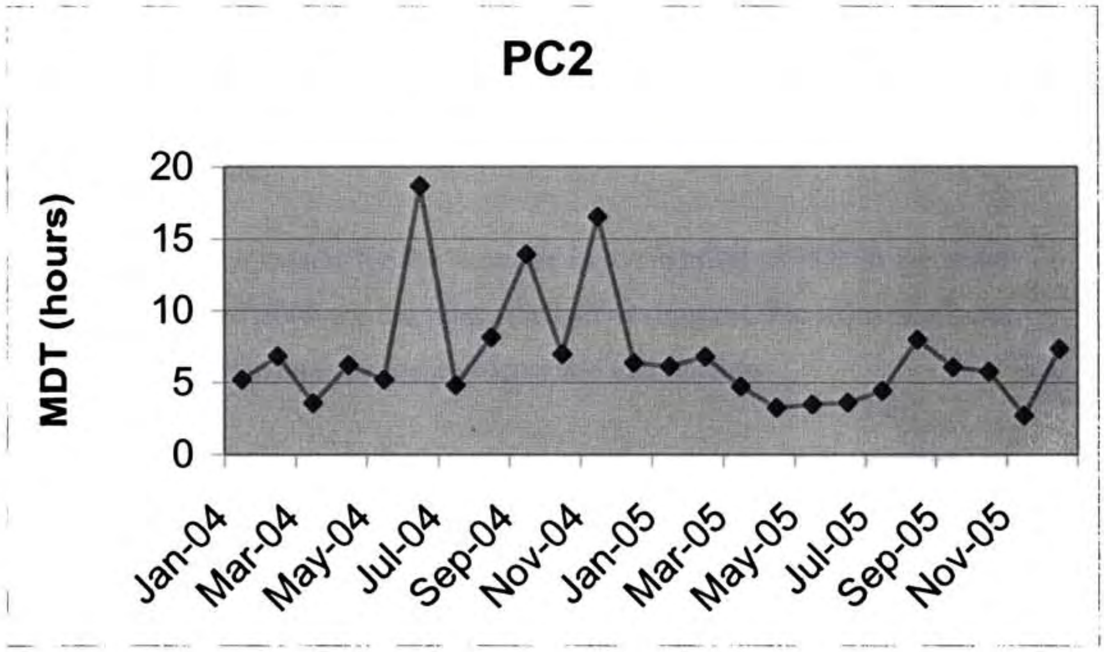



**Figure 8. 30.** Variation of MDT of PC 2 during 2004 and 2005

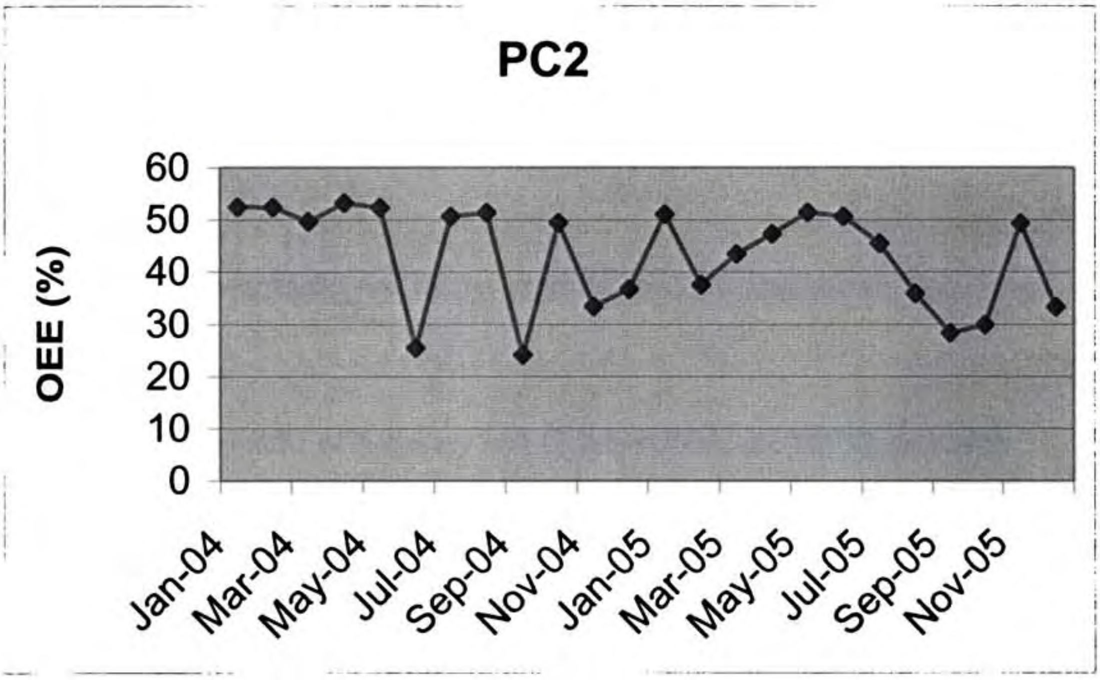



**Figure 8. 31.** Variation of OEE of PC 2 during 2004 and 2005

**Suggestions**

After recording and analyzing the above observations, the following suggestions are made:

- Since the reason for the decrease in availability of PC2 in the years 2004 and 2005 are the same, the author suggests that strict care must be taken to analyze the problems and their causes.
- The machine during certain months shows high number of breakdowns. This matters since even a small breakdown can cause considerable wastage of time.
- Even though the MTBF shows an increasing trend from September 2005 –December 2005, under carriage and bucket problems are also occurring every month constantly. This must be eliminated to increase the availability.

### 8.7.3. Maintenance Quality Analysis of PC 3

The values of maintenance quality parameters pertaining to the equipment PC 3 are shown Table 8.20. The values are graphically depicted in Figure 8.32-8.36.

A study of these tables and figures revealed the following observations.

**Year 2004**

During the months of February and October 2004, the MTTR was high due to the failure of front and rear bucket and engine failure. Hence the availability was low during these months.

**Table 8. 20. Maintenance parameters of PC3 during the years 2004 and 2005**

| Month | Availability(%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE(%) |
|---|---|---|---|---|---|
| January2004 | 92.06 | 13.23 | 6.91 | 2.80 | 51.02 |
| February2004 | 19.17 | 6.57 | 17.58 | 41.86 | 10.62 |
| March 2004 | 90.84 | 14.71 | 3.13 | 2.54 | 50.34 |
| April 2004 | 96.07 | 13.31 | 3.61 | 1.13 | 53.24 |
| May 2004 | 97.35 | 16.50 | 5.44 | 1.28 | 53.95 |
| June 2004 | 85.47 | 30.90 | 5.38 | 10.90 | 47.36 |
| July 2004 | 59.29 | 11.69 | 7.84 | 17.53 | 32.86 |
| August 2004 | 89.81 | 20.21 | 6.19 | 6.58 | 49.77 |
| September 2004 | 74.07 | 34.81 | 6.04 | 24.31 | 41.05 |
| October 2004 | 14.13 | 7.63 | 53.18 | 166.38 | 7.83 |
| November 2004 | 90.13 | 12.82 | 4.33 | 3.36 | 49.95 |
| December 2004 | 90.44 | 17.80 | 3.87 | 3.70 | 50.12 |
| January 2005 | 63.74 | 11.08 | 9.54 | 14.05 | 35.32 |
| February 2005 | 64.29 | 43.92 | 9.92 | 41.67 | 35.63 |
| March 2005 | 76.03 | 10.50 | 4.66 | 5.80 | 42.14 |
| April 2005 | 93.73 | 11.95 | 4.08 | 1.57 | 51.94 |
| May 2005 | 75.48 | 8.13 | 5.99 | 5.94 | 41.83 |
| June2005 | 58.87 | 6.32 | 7.19 | 10.28 | 32.62 |
| July 2005 | 76.97 | 5.43 | 5.06 | 4.25 | 42.65 |
| August 2005 | 90.71 | 15.86 | 5.21 | 4.00 | 50.27 |
| September 2005 | 95.80 | 5.53 | 5.51 | 0.79 | 53.09 |
| October 2005 | 90.54 | 10.16 | 4.15 | 2.20 | 50.17 |
| November 2005 | 52.87 | 21.04 | 7.77 | 29.46 | 29.30 |
| December 2005 | 70.52 | 15.73 | 4.23 | 9.52 | 39.08 |

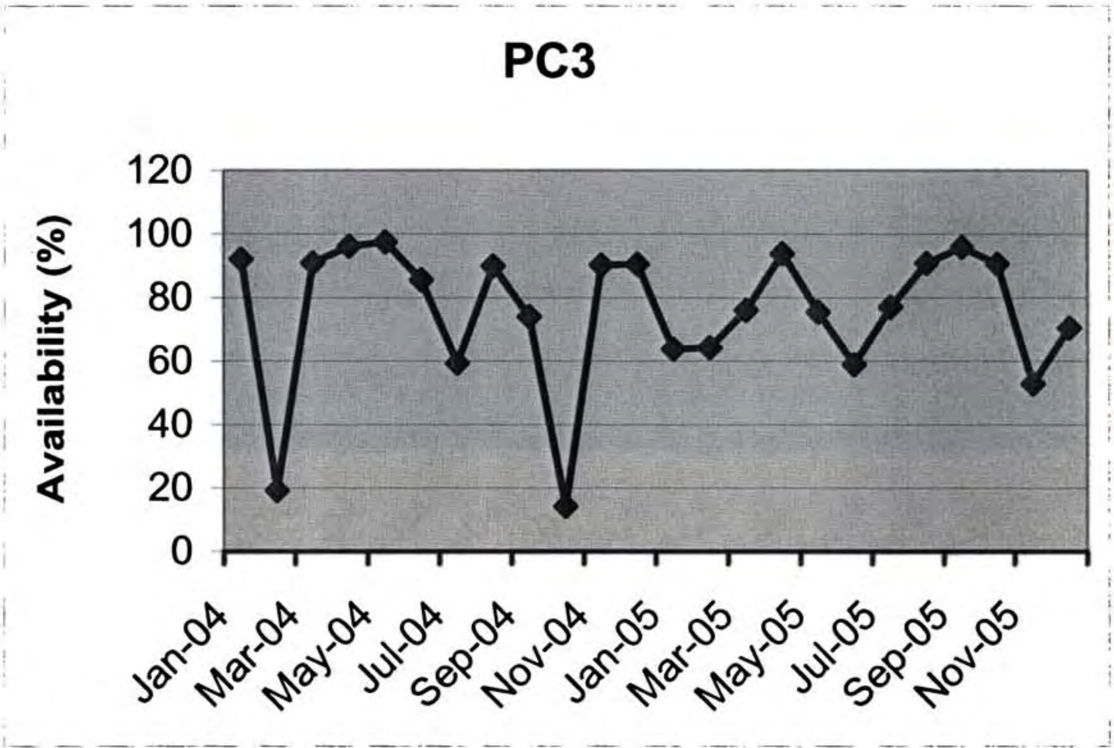



**Figure 8. 32.** Variation of availability of PC 3 during 2004 and 2005

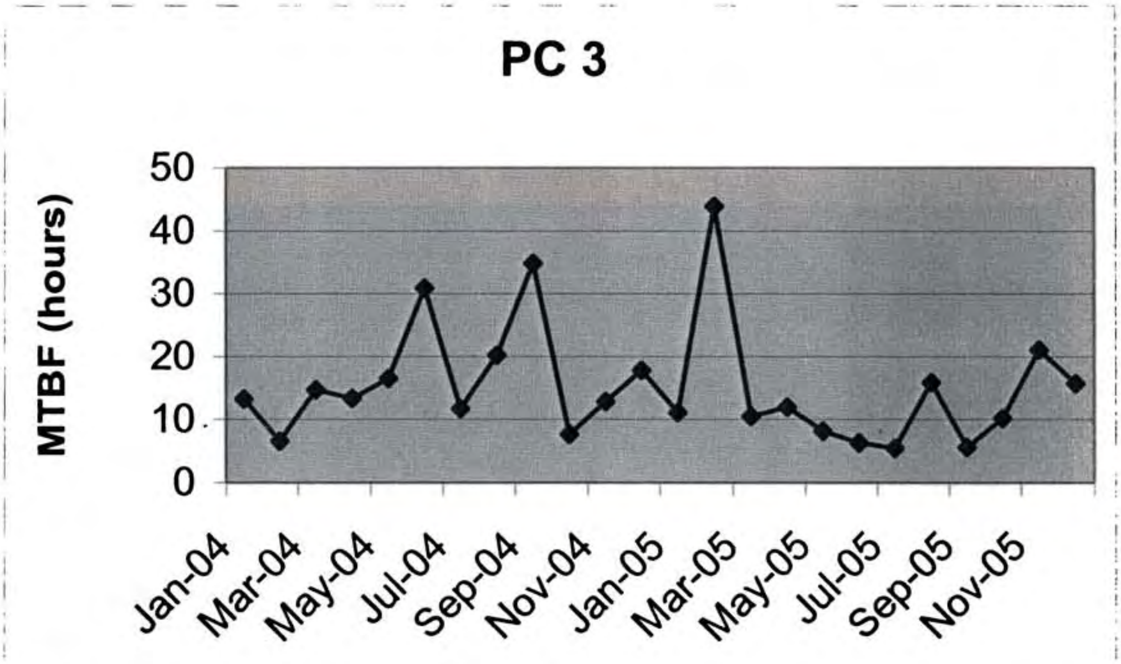



**Figure 8. 33.** Variation of MTBF of PC 3 during 2004 and 2005

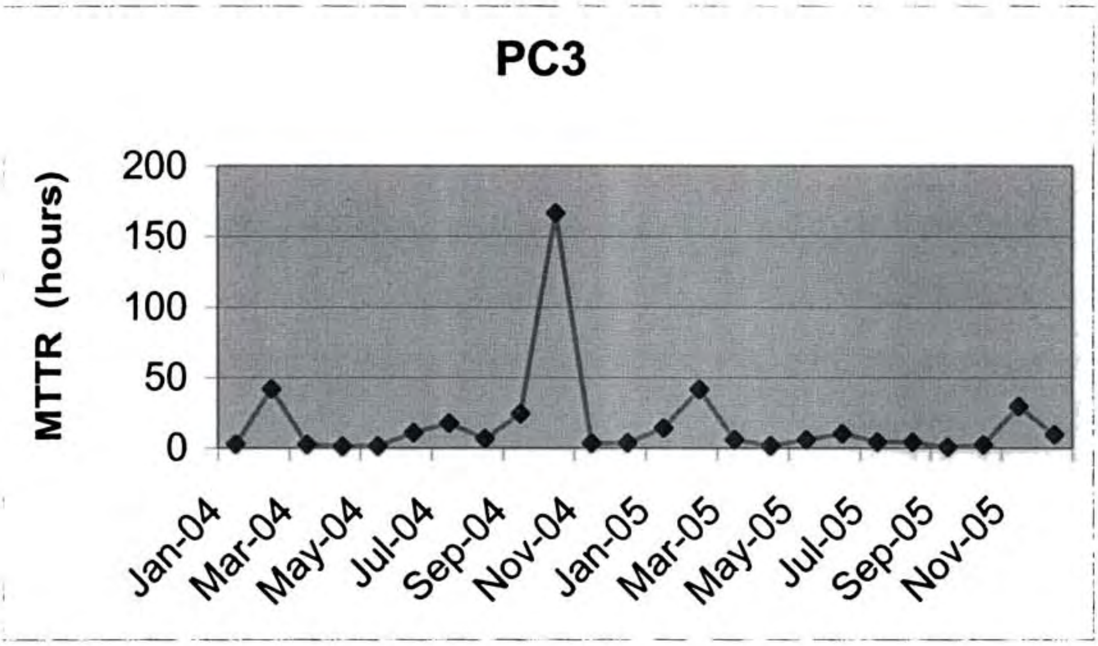



**Figure 8. 34.** Variation of MTTR of PC 3 during 2004 and 2005

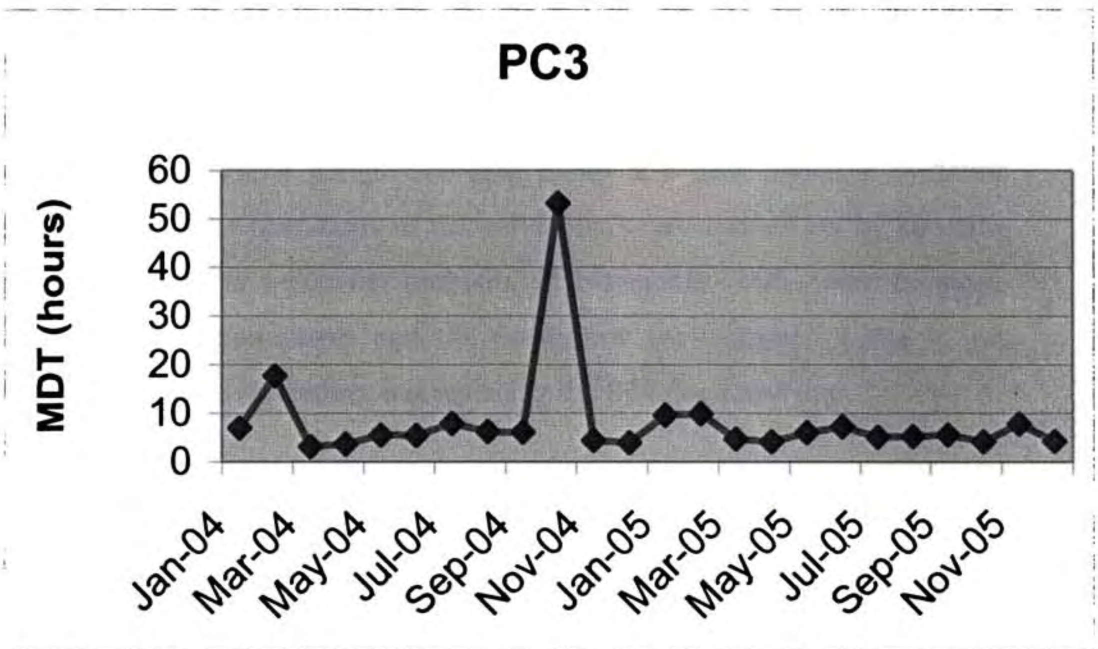



**Figure 8. 35.** Variation of MDT of PC 3 during 2004 and 2005

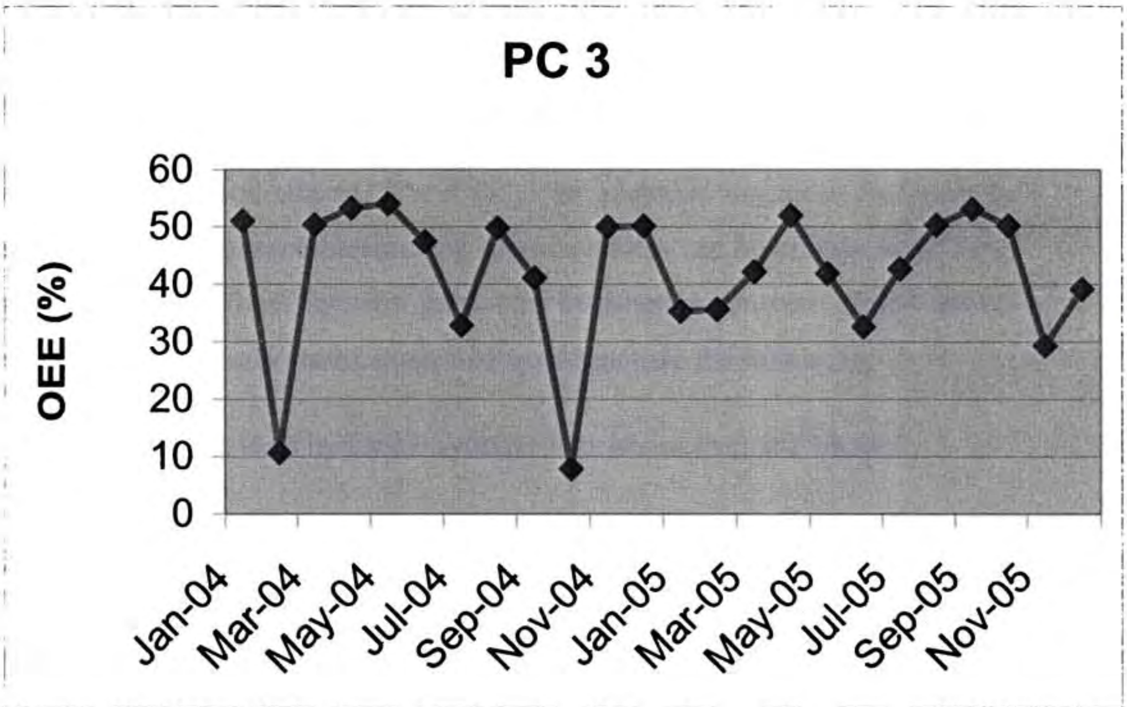



**Figure 8. 36.** Variation of OEE of PC 3 during 2004 and 2005

**Year 2005**

MTBF and MTTR were high due to the bucket, PTO and structural problem. The equipment has commissioned after changing the welded bucket and rectifying the PTO problem. In June 2005, the availability was low due to the failure of charging pump. Charging pump is a gear operated hydraulic pump. All the pilot operations of the valve blanks are carried out by charging pump. Its failure is a peculiar problem. In November 2005, some problems occurred in the equipments and the equipment got stopped . Later it was rectified by structural welding and replacing the PTO by a new one.

**Suggestions**

Even though the equipment got more than 75% availability consistently, few moths (6 out of 24 months) the availability was low. It can be rectified by

i) Keeping a stand by of overhauled / new engine.

ii) Keeping a stand by of ready front and rear bucket

iii) Keeping a stand by of ready arm.

### 8.7.4. Common suggestions for PC 2 and PC 3

Hydraulic excavator PC 2 and PC 3 are identical machines. In order to improve the maintenance parameters, sub-assemblies can be procured and kept as standby units. Such standby units can be fitted in anyone of the above excavators. The standby units suggested would include the following:

1. At least one each hydraulic cylinder with boom arm, and bucket.
2. Bucket assembly
3. Hydraulic pump assemblies
4. Engine assemblies
5. One set of final drive
6. Arm assemblies

When comparing PC2 and PC3, hydraulic oil leak contributed to the major portion of breakdown distribution. This contributes more than 50percent in case of PC 2. In order to curb this, replacement of entire hydraulic hoses and O-rings are suggested.

### 8.7. 5. Maintenance Quality Analysis of Dumpers

In this section, the maintenance quality analyses of dumpers are presented.

#### 8.7.5.1. Maintenance Quality Analysis of H 1

The values of maintenance quality parameters pertaining to the equipment Hl are shown in Table 8.21. The values are graphically depicted from Figures 8.37 to 8.41. The study of these table and figures indicated that there has been the problems arising in this machine are those which cause stoppage of the machine. The decrease in the availability, MTBF and MTTR occurred due to transmission problems and engine failure. The machine is now in the workshop and is undergoing major overhauling. A better performance is expected after its major overhauling. It must be noted that the machine is in the workshop for the past 18 months and the work must be speeded up.

**Table 8.21. Maintenance parameters of H1 during the years 2004 and 2005**

| Month | Availability (%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE (%) |
|---|---|---|---|---|---|
| January 2004 | 88.13 | 26.25 | 3.64 | 6.57 | 71.16 |
| February 2004 | 90.00 | 18.71 | 4.13 | 5.18 | 72.68 |
| March 2004 | 91.87 | 32.33 | 3.79 | 5.25 | 74.19 |
| April 2004 | 96.00 | 66.83 | 3.12 | 5.00 | 77.52 |
| May 2004 | 41.61 | 11.00 | 10.71 | 32.32 | 33.60 |
| June 2004 | 82.73 | 32.17 | 3.71 | 10.79 | 66.81 |
| July 2004 | 99.42 | 246.75 | 2.82 | 2.25 | 80.28 |
| August 2004 | 77.61 | 17.38 | 4.55 | 8.68 | 62.67 |
| September 2004 | 36.20 | 11.19 | 10.20 | 29.91 | 29.23 |
| October 2004 | 62.00 | 25.25 | 7.03 | 21.04 | 50.07 |
| November 2004 | 32.87 | 20.84 | 13.26 | 62.94 | 26.54 |
| December 2004 | MAJOR OVERHAULING | | | | |
| January 2005 | | | | | |
| February 2005 | | | | | |
| March 2005 | | | | | |
| April 2005 | | | | | |
| May 2005 | | | | | |
| June 2005 | | | | | |
| July 2005 | | | | | |
| August 2005 | | | | | |
| September 2005 | | | | | |
| October 2005 | | | | | |
| November 2005 | | | | | |
| December 2005 | | | | | |

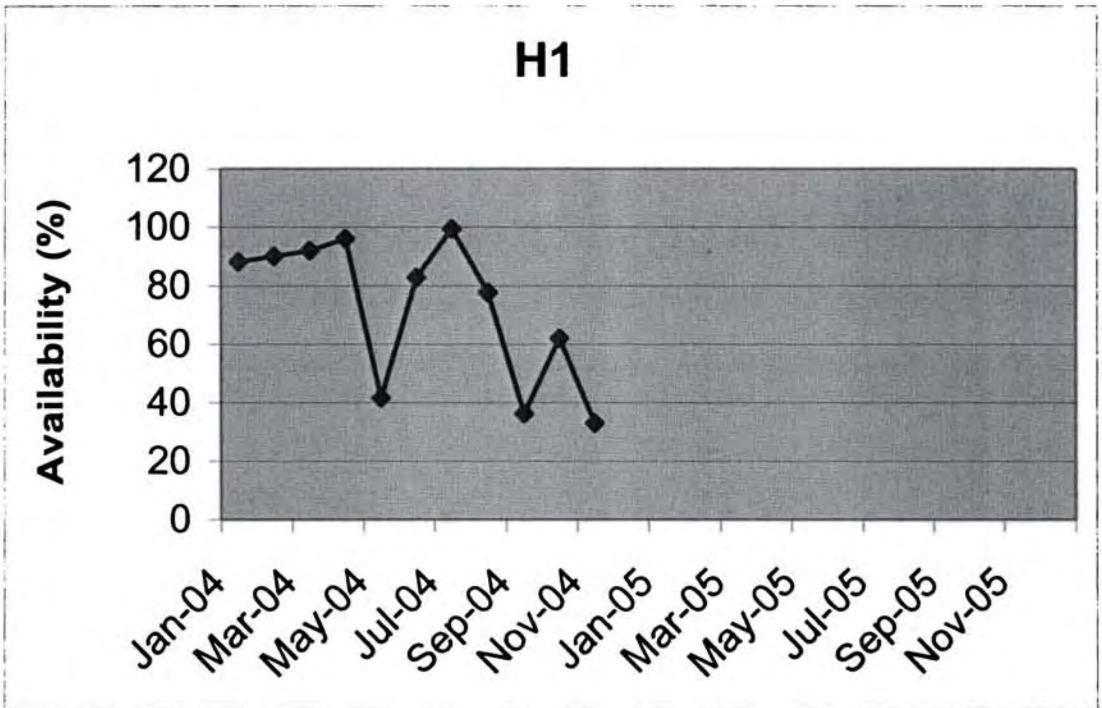



**Figure 8.37.** Variation of availability of H1 during 2004 and 2005

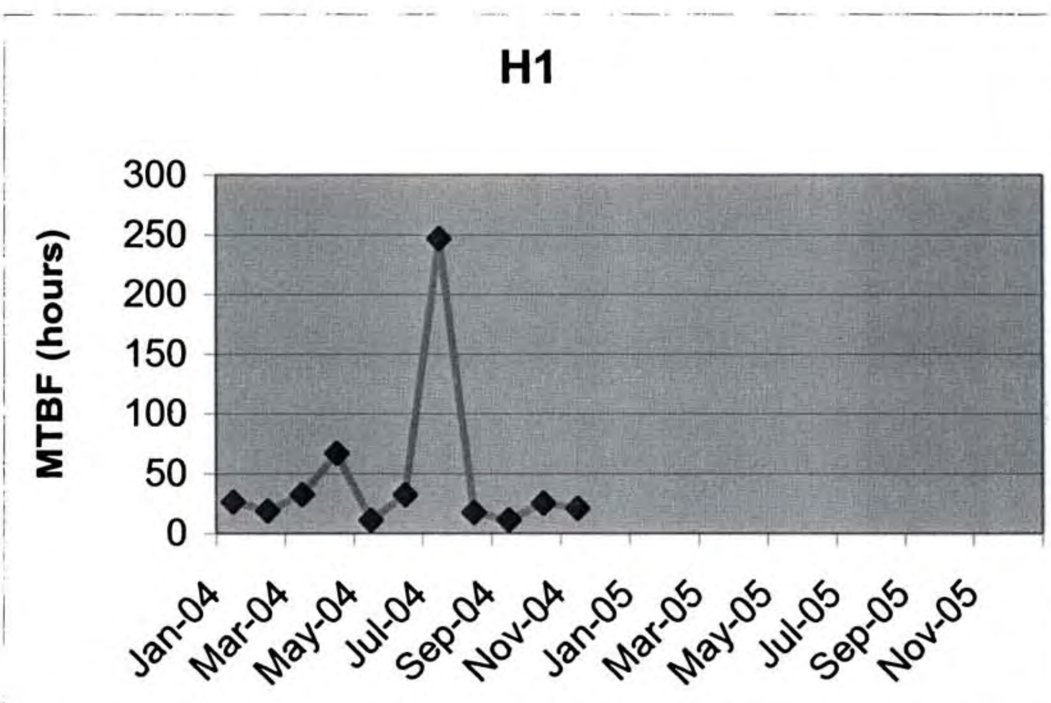



**Figure 8.38.** Variation of MTBF of H1 during 2004 and 2005

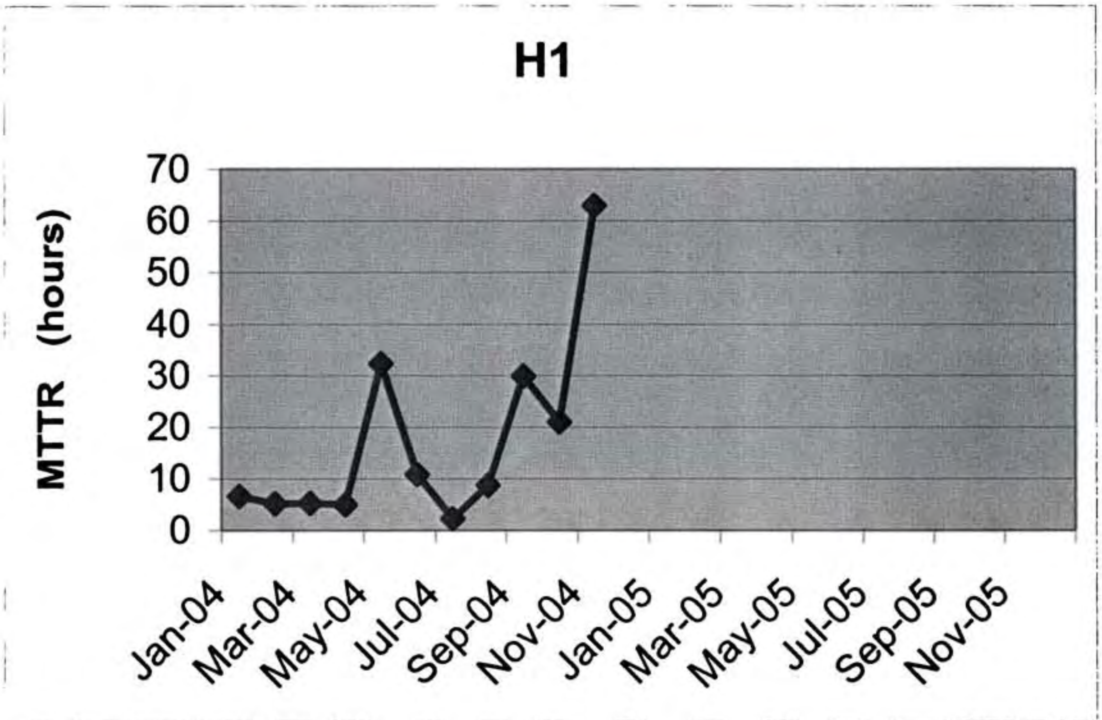



**Figure 8.39.** Variation of MTTR of H1 during 2004 and 2005

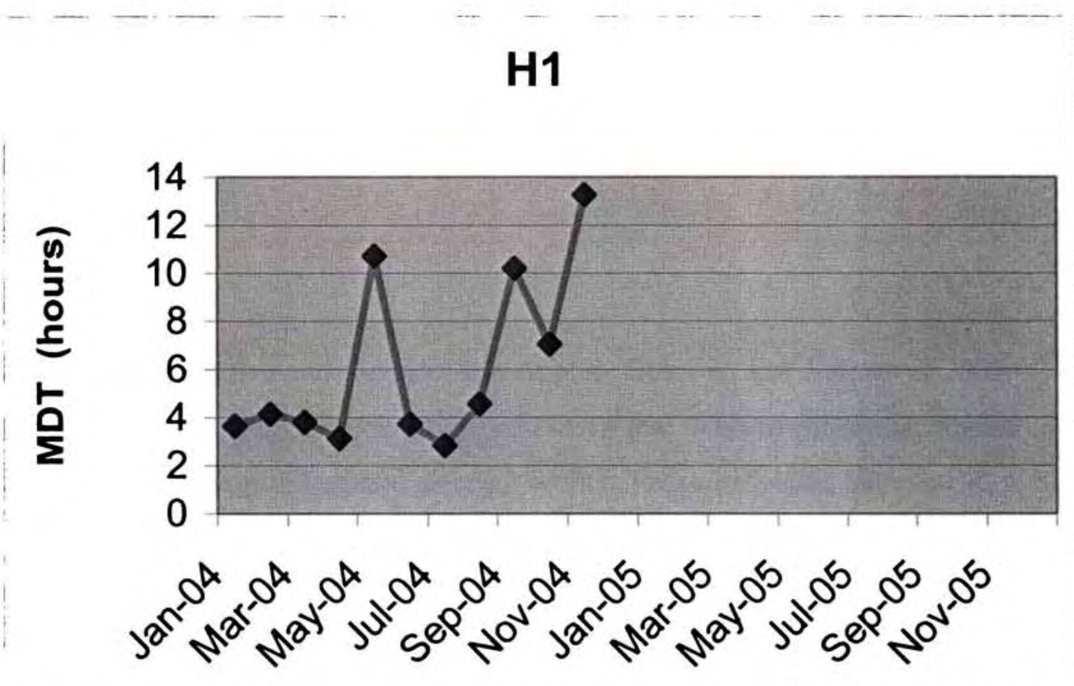



**Figure 8.40.**Variation of MDT of H1 during 2004 and 2005

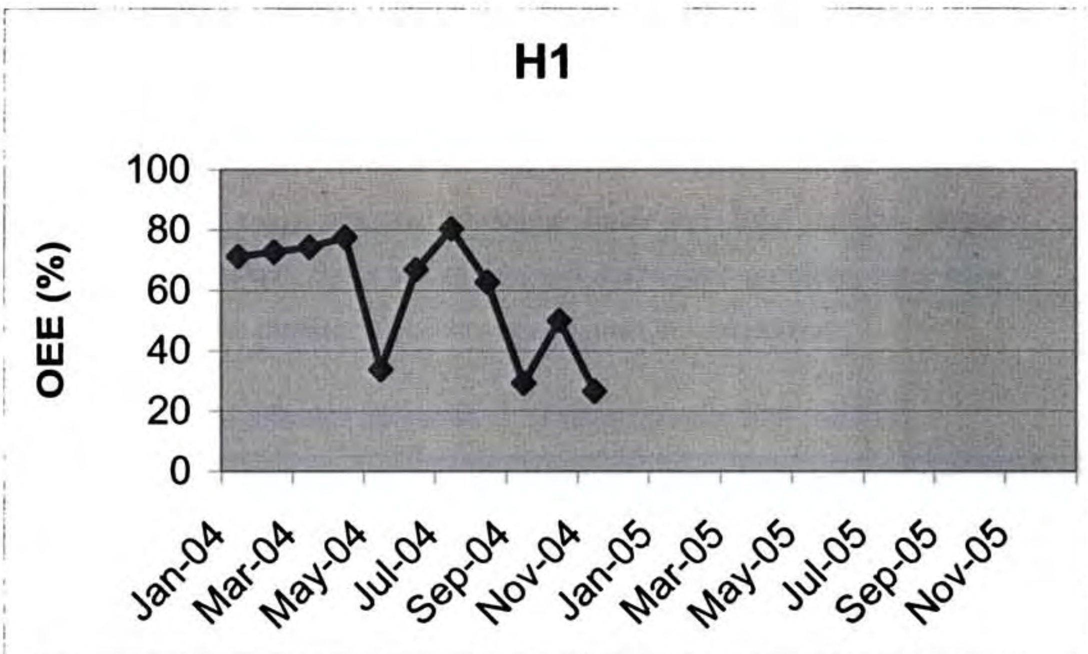



**Figure 8.41.** Variation of OEE of H1 during 2004 and 2005

### 8.7.5.2. Maintenance Quality Analysis of H2

The values of maintenance quality parameters pertaining to the equipment EX 400 are shown Table 8.22. The values are graphically depicted in Figures from 8.42. to 8.46.

**Findings**

Months that demand alertness are August, October, and December 2005. The reasons being a high number of breakdowns due to brake problems, engine seizure suspension problem and steering works. These problems have led to a decrease in the availability of the machine which otherwise shows a high availability.

During July 2004, July 2005 and August 2005, a low value of MTBF was recarded due to high number of breakdowns. Form July 2005, MTBF has been showing a decreasing trend. During March and December 2005, a high value of MTTR was recorded. Bucket welding, engine seizure and suspension problems have contributed to this high value of MTTR.

## Suggestions

During July 2004 and July 2005, a high number of breakdowns occurred. The effect of the various climatic seasons on the machine must be analysed. Especially during rainy seasons spanning June and July months proper measures must be taken. Since the engine and suspension problems have been on the rise, condition monitoring of these parts must be carried out.

**Table 8.22. Maintenance parameters of H2 during the years 2004 and 2005**

| Month | Availability (%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE (%) |
|---|---|---|---|---|---|
| January 2004 | 88.39 | 25.41 | 2.92 | 5.63 | 71.37 |
| February 2004 | 96.62 | 92.38 | 3.17 | 6.13 | 78.02 |
| March 2004 | 96.39 | 48.10 | 2.63 | 2.80 | 77.83 |
| April 2004 | 93.33 | 182.00 | 3.57 | 25.00 | 75.37 |
| May 2004 | 97.35 | 38.60 | 3.04 | 2.05 | 78.61 |
| June 2004 | 93.40 | 23.82 | 3.79 | 3.54 | 75.42 |
| July 2004 | 83.48 | 13.42 | 3.55 | 4.92 | 67.41 |
| August 2004 | 90.00 | 21.15 | 2.89 | 3.88 | 72.68 |
| September 2004 | 77.20 | 22.03 | 3.22 | 8.55 | 62.34 |
| October 2004 | 92.45 | 30.81 | 2.56 | 3.66 | 74.65 |
| November 2004 | 91.73 | 30.84 | 2.73 | 3.88 | 74.07 |
| December 2004 | 92.97 | 55.00 | 3.49 | 6.81 | 75.07 |
| January 2005 | 95.48 | 55.31 | 3.02 | 4.38 | 77.10 |
| February 2005 | 94.64 | 60.33 | 3.31 | 6.25 | 76.42 |
| March 2005 | 81.41 | 38.75 | 4.98 | 18.31 | 65.74 |
| April 2005 | 92.47 | 24.11 | 2.77 | 3.14 | 74.67 |
| May 2005 | 85.87 | 44.70 | 3.04 | 10.95 | 69.34 |
| June 2005 | 88.47 | 26.17 | 4.04 | 7.21 | 71.44 |
| July 2005 | 73.61 | 11.63 | 4.46 | 7.87 | 59.44 |
| August 2005 | 67.81 | 11.96 | 4.64 | 9.60 | 54.75 |
| September 2005 | 97.80 | 23.31 | 2.80 | 0.92 | 78.97 |
| October 2005 | 70.08 | 14.27 | 4.80 | 8.84 | 56.59 |
| November 2005 | 96.59 | 39.42 | 2.96 | 2.17 | 78.00 |
| December 2005 | 65.23 | 28.71 | 6.52 | 22.83 | 52.67 |

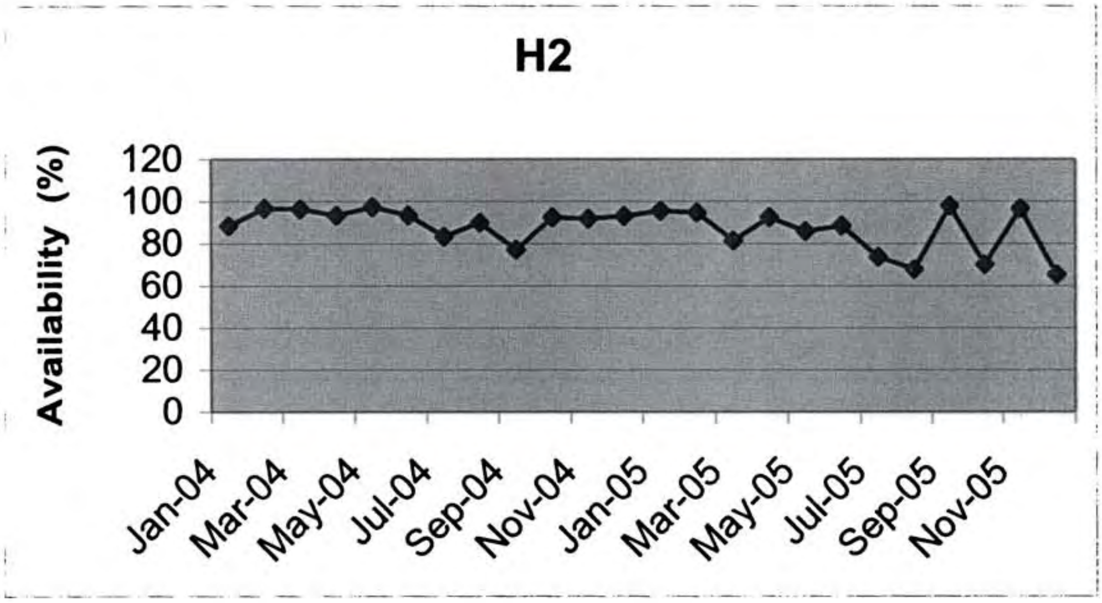



**Figure 8.42.** Variation of availability of H2 during 2004 and 2005

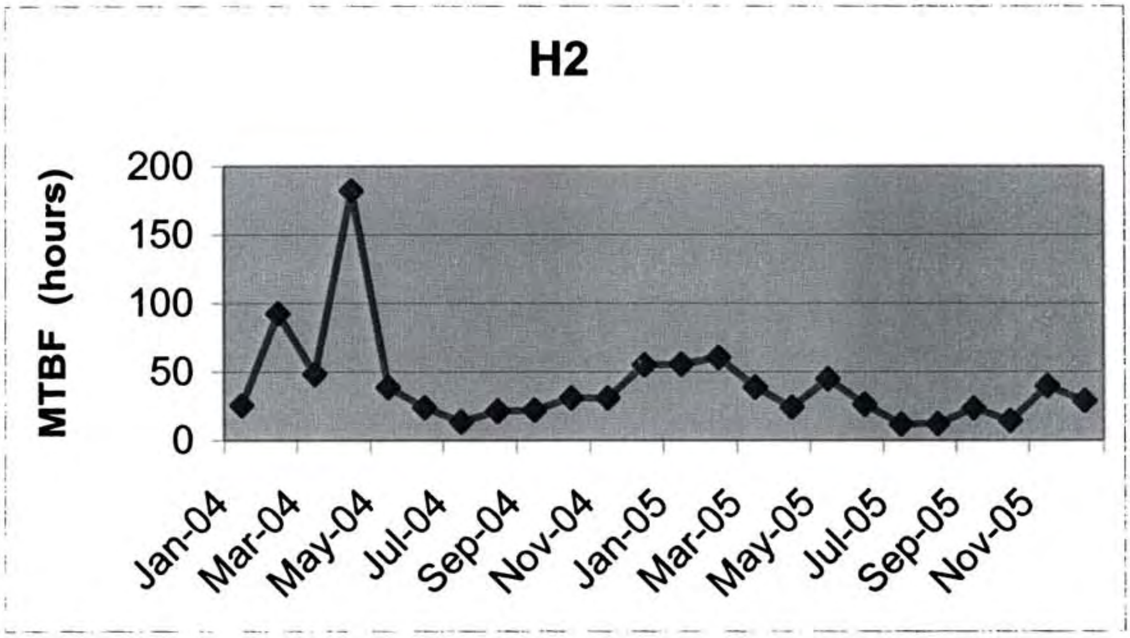



**Figure 8.43.** Variation of MTBF of H2 during 2004 and 2005

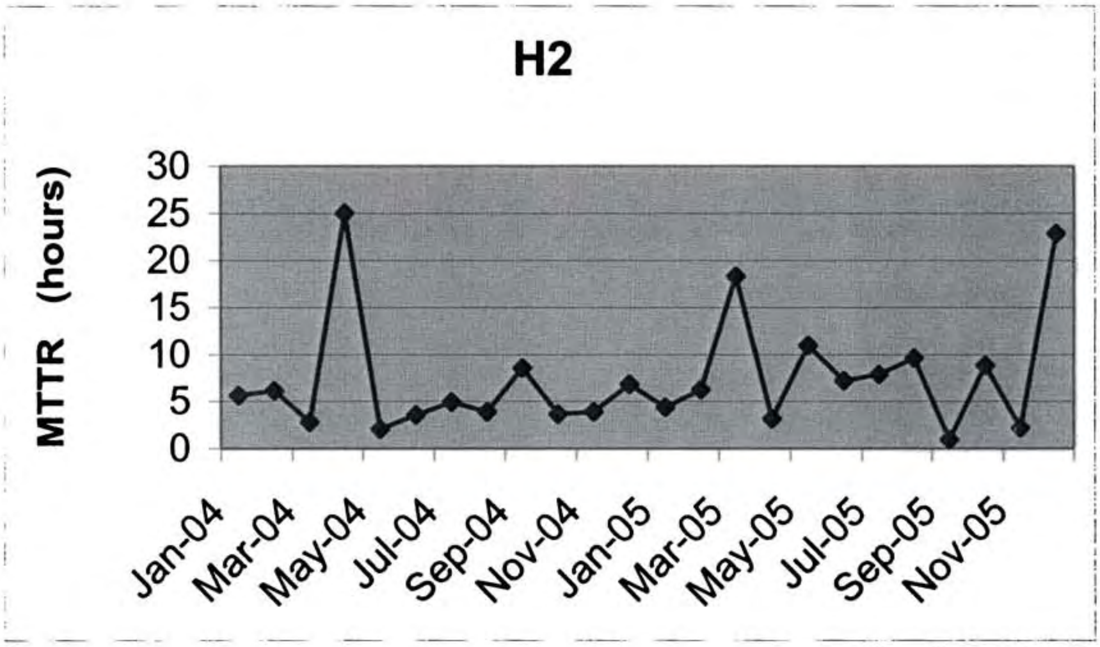



**Figure 8.44.** Variation of MTTR of H2 during 2004 and 2005

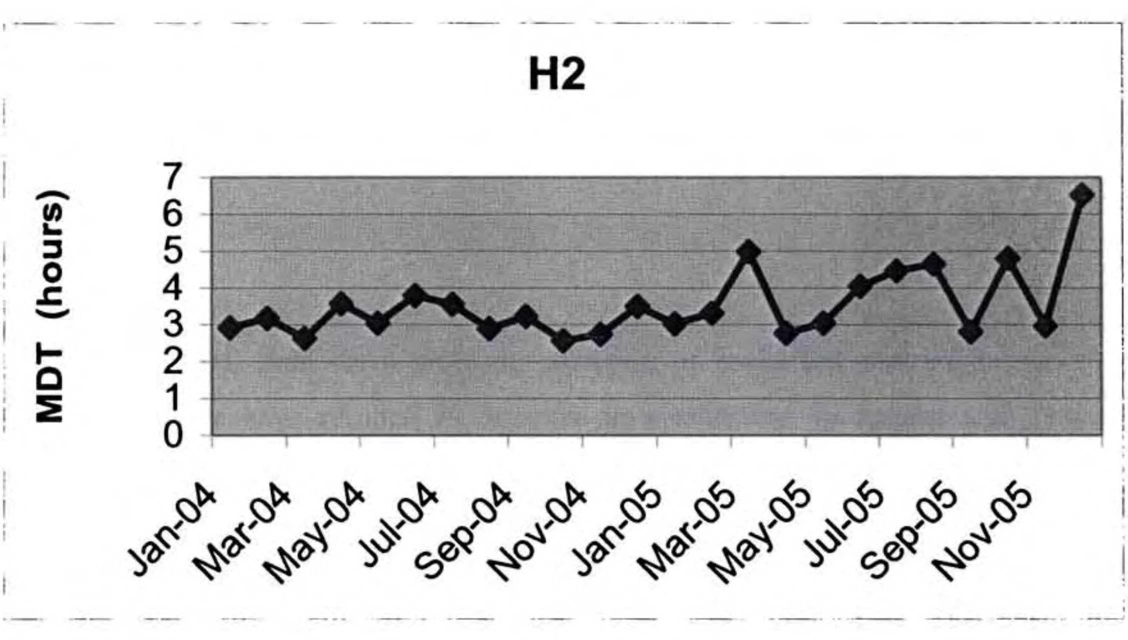



**Figure 8.45.** Variation of MDT of H2 during 2004 and 2005

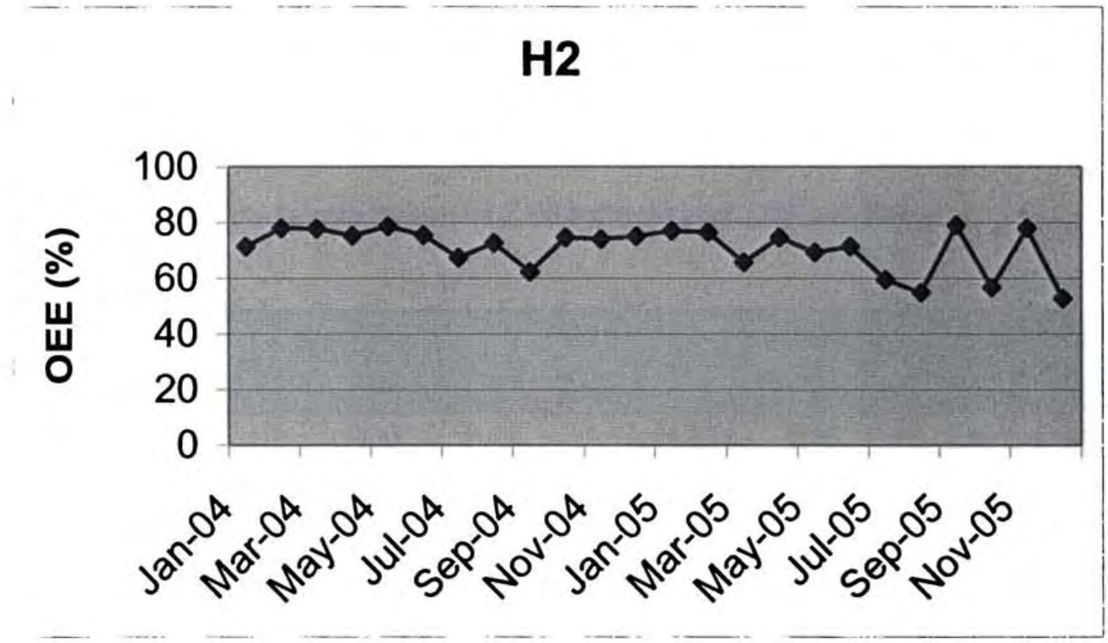



**Figure 8.46.** Variation of OEE of H2 during 2004 and 2005

### 8.7.5.3. Maintenance Quality Analysis of H 3

The values of maintenance quality parameters pertaining to the equipment H3 are shown Table 8.23. The values are graphically depicted in Figures 8.47 to 8.51. A study of these table and figures reveal the following observations.

**Findings**

In July 2004, final drive problem, changing of brake line and engine component failure have resulted in decrease in availability. In August and September 2004, a lot of engine work lead to new engine being mounted and this has contributed to decrease in availability. In July 2005, a high number of brake problems have resulted in low MTBF.

**Suggestions**

Final drive problems can be reduced to some extent by decreasing the load carried by the machine. Recurrence of component failure and subsequent engine work occurred as new engine was mounted. The machine is also showing tyre problems continuously from December 2004 to December 2005. Frequent occurrence of this problem must be carefully analyzed and proper actions have to be taken.

**Table 8.23. Maintenance parameters of H3 during the years 2004 and 2005**

| Month | Availability (%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE (%) |
|---|---|---|---|---|---|
| January 2004 | 99.35 | 211.25 | 3.75 | 2.50 | 80.23 |
| February 2004 | 98.21 | 79.50 | 3.84 | 3.25 | 79.30 |
| March 2004 | 84.58 | 21.40 | 3.34 | 5.98 | 68.30 |
| April 2004 | 88.67 | 14.50 | 4.51 | 4.25 | 71.60 |
| May 2004 | 72.58 | 16.78 | 4.97 | 13.28 | 58.61 |
| June 2004 | 97.00 | 36.70 | 3.30 | 2.25 | 78.33 |
| July 2004 | 39.87 | 17.54 | 9.73 | 38.83 | 32.20 |
| August 2004 | 17.23 | 1.42 | 27.38 | 106.92 | 13.91 |
| September 2004 | 36.60 | 7.00 | 9.93 | 21.61 | 29.55 |
| October 2004 | 95.16 | 40.82 | 2.31 | 2.68 | 76.84 |
| November 2004 | 89.13 | 28.53 | 2.41 | 4.53 | 71.98 |
| December 2004 | 84.52 | 47.75 | 5.17 | 15.00 | 68.25 |
| January 2005 | 90.06 | 25.67 | 3.07 | 4.28 | 72.73 |
| February 2005 | 99.86 | 234.00 | 2.64 | 0.50 | 80.63 |
| March 2005 | 95.69 | 27.91 | 3.05 | 2.13 | 77.27 |
| April 2005 | 86.80 | 29.58 | 3.66 | 8.25 | 70.09 |
| May 2005 | 95.50 | 45.00 | 2.16 | 3.15 | 77.12 |
| June 2005 | 95.20 | 27.42 | 3.90 | 3.00 | 76.87 |
| July 2005 | 90.32 | 14.34 | 3.33 | 2.68 | 72.94 |
| August 2005 | 91.10 | 25.08 | 2.74 | 3.45 | 73.56 |
| September 2005 | 92.80 | 29.43 | 3.13 | 3.86 | 74.94 |
| October 2005 | 93.61 | 25.18 | 3.48 | 2.48 | 75.59 |
| November 2005 | 82.89 | 29.88 | 3.99 | 8.44 | 66.93 |
| December 2005 | 90.23 | 45.67 | 2.93 | 6.42 | 72.86 |

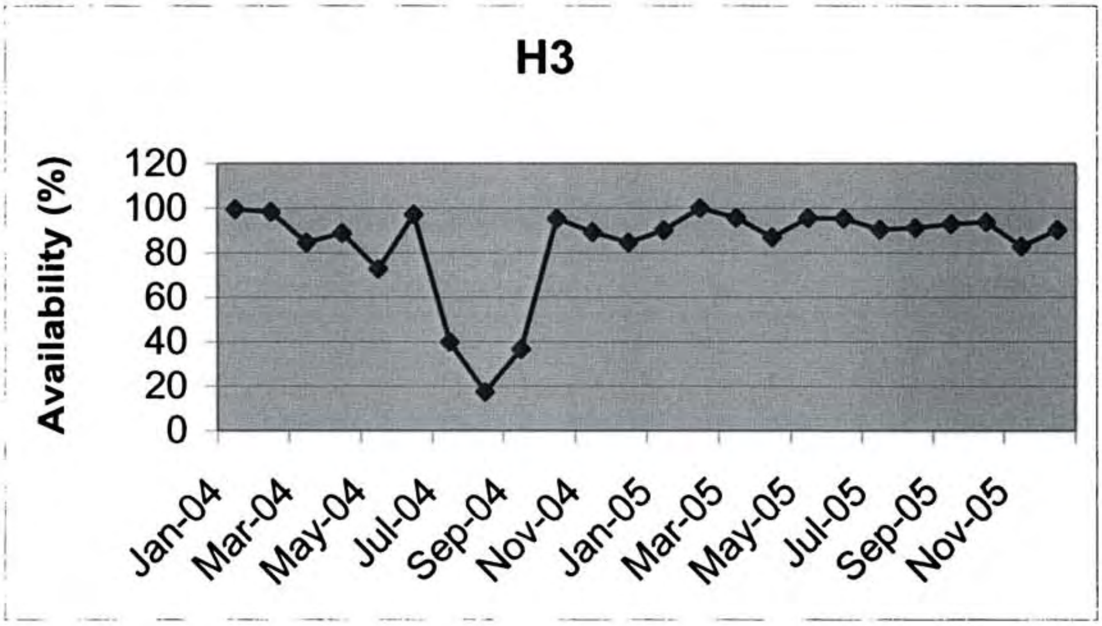



**Figure 8.47.** Variation of availability of H3 during 2004 and 2005

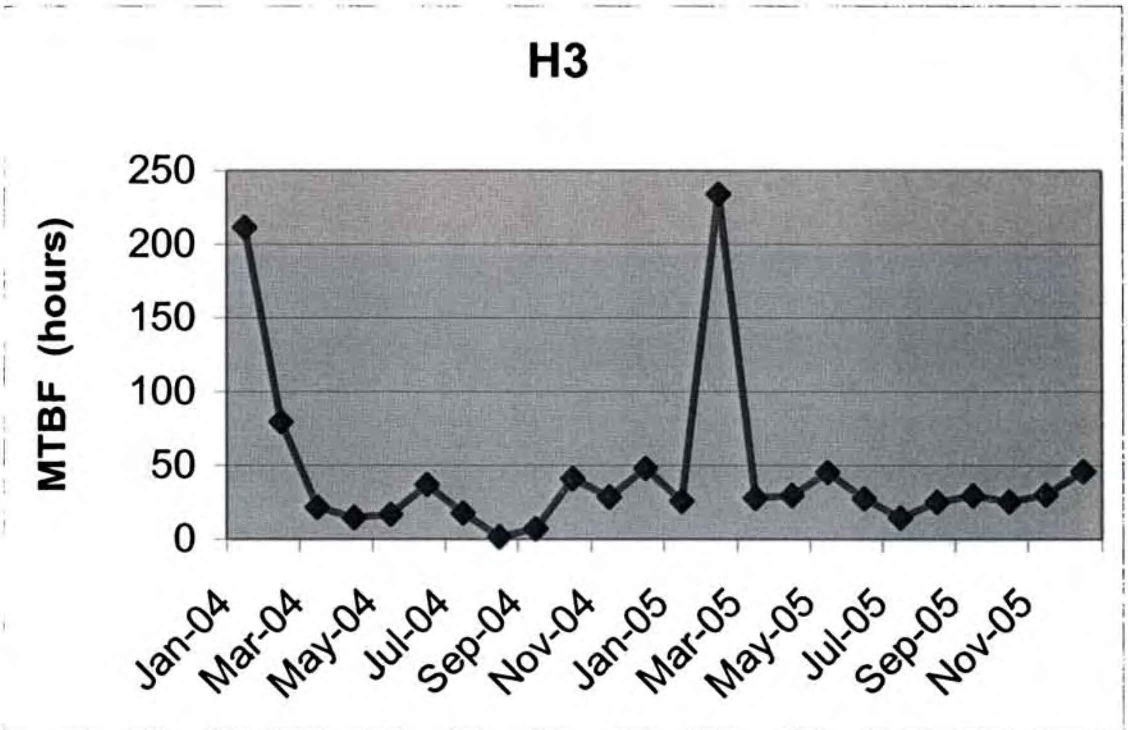



**Figure 8.48.** Variation of MTBF of H3 during 2004 and 2005

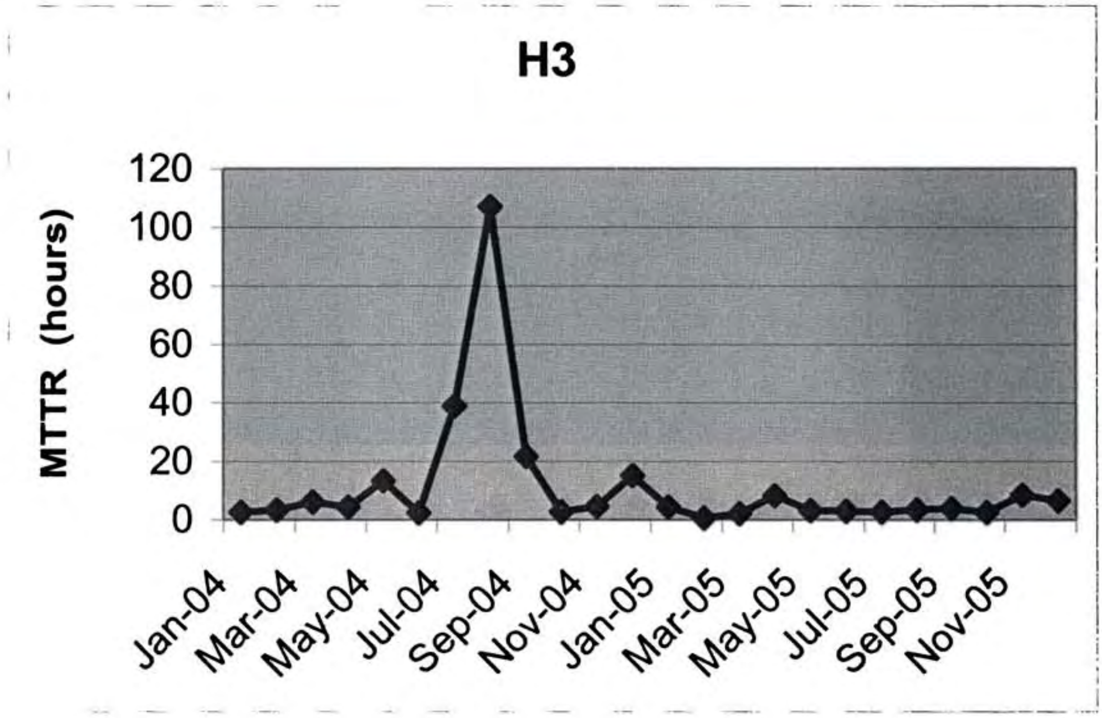



**Figure 8.49.** Variation of MTTR of H3 during 2004 and 2005

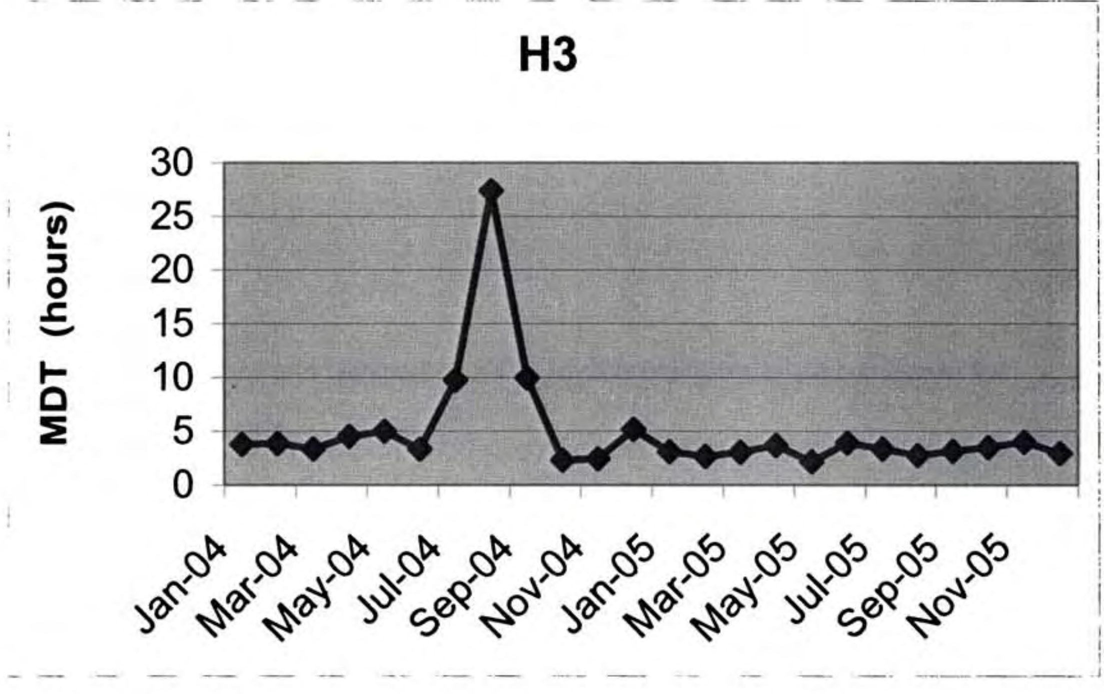



**Figure 8.50.** Variation of MDT of H3 during 2004 and 2005

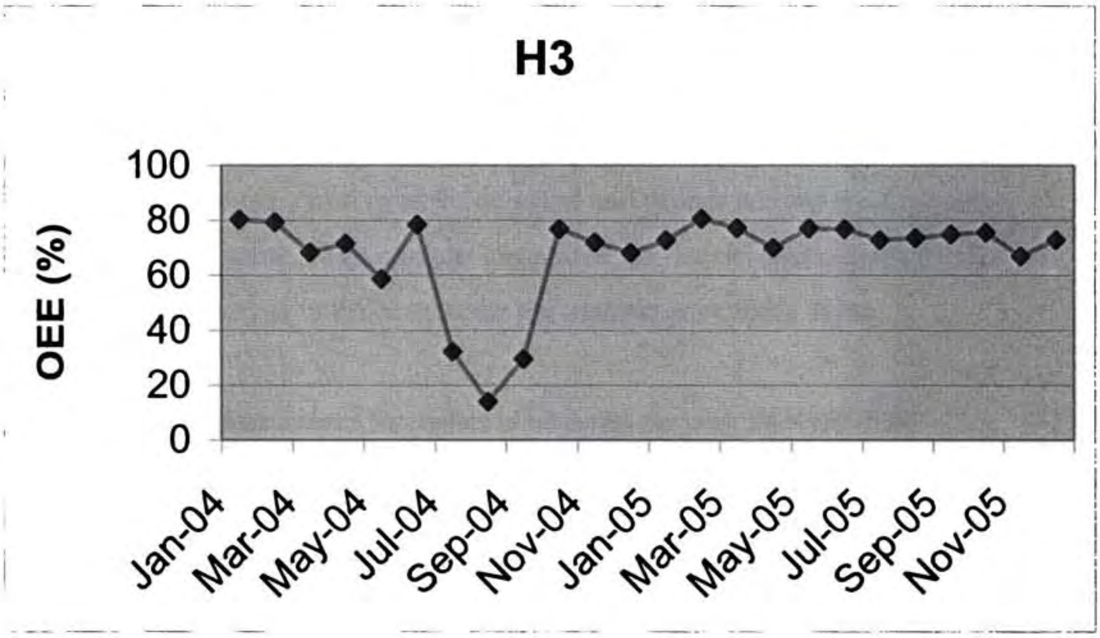



**Figure 8.51.** Variation of OEE of H3 during 2004 and 2005

### 8. 7.5.4. Maintenance Quality Analysis of H 4

The values of maintenance quality parameters pertaining to the equipment H4 are shown Table 8.24. The values are graphically depicted in Figure 8.52 to 8.56.

**Findings**

**Year 2004**

During October and November 2004, high breakdown occurred due to the breaking of engine axle.

**Year 2005**

During the months January and December 2005, breakdown due to transmission problem, engine failure, master cylinder booster problem and cabin problems has contributed to the reduction in the availability.

During June 2005, a high number of breakdown and maintenance stoppages have led to the increase in MTBF.

## Suggestions

The author observed a number of transmission problems occurring in this machine from July 2004 to November 2005 and at least two transmission problems are occurring every month in this period. Since transmission trouble being a critical one, its cause must be detected and proper actions must be taken to eliminate the same. The author suggested to stock spare gearbox and differential components in order to make the maintenance work faster.

**Table 8.24. Maintenance parameters of H4 during the years 2004 and 2005**

| Month | Availability (%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE (%) |
|---|---|---|---|---|---|
| January 2004 | 94.90 | 59.25 | 3.96 | 4.94 | 76.63 |
| February 2004 | 90.83 | 27.28 | 3.35 | 4.16 | 73.34 |
| March 2004 | 97.55 | 65.13 | 2.76 | 2.38 | 78.77 |
| April 2004 | 94.20 | 45.15 | 2.87 | 4.35 | 76.07 |
| May 2004 | 91.42 | 25.94 | 3.33 | 4.16 | 73.82 |
| June 2004 | 92.80 | 30.39 | 3.61 | 3.86 | 74.94 |
| July 2004 | 72.45 | 25.31 | 4.87 | 13.34 | 58.50 |
| August 2004 | 58.13 | 23.64 | 6.53 | 23.18 | 46.94 |
| September 2004 | 81.07 | 45.80 | 3.95 | 14.20 | 65.46 |
| October 2004 | 0.00 | 0.00 | 375.00 | 375.00 | 0.00 |
| November 2004 | 0.00 | 0.00 | 375.00 | 375.00 | 0.00 |
| December 2004 | 97.81 | 88.50 | 3.54 | 2.88 | 78.98 |
| January 2005 | 55.29 | 9.18 | 9.86 | 17.33 | 44.65 |
| February 2005 | 94.43 | 32.29 | 2.76 | 2.79 | 76.25 |
| March 2005 | 97.39 | 37.00 | 2.31 | 1.46 | 78.64 |
| April 2005 | 92.93 | 26.30 | 2.49 | 2.65 | 75.04 |
| May 2005 | 95.49 | 22.66 | 2.63 | 1.61 | 77.11 |
| June 2005 | 95.13 | 16.83 | 3.09 | 1.52 | 76.82 |
| July 2005 | 90.90 | 24.28 | 2.95 | 3.58 | 73.40 |
| August 2005 | 88.77 | 29.03 | 2.82 | 5.44 | 71.69 |
| September 2005 | 96.53 | 31.86 | 3.45 | 1.86 | 77.95 |
| October 2005 | 97.42 | 29.81 | 3.22 | 1.11 | 78.67 |
| November 2005 | 91.93 | 31.33 | 1.79 | 3.36 | 74.24 |
| December 2005 | 10.71 | 14.50 | 59.75 | 173.00 | 8.65 |

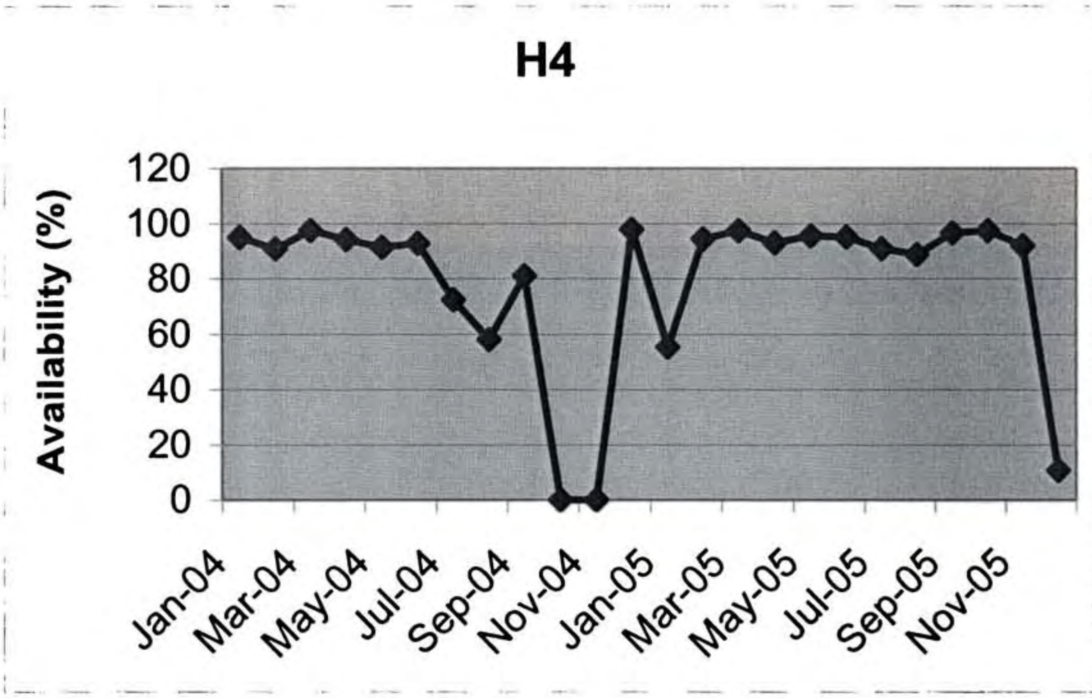



**Figure 8.52.** Variation of availability of H4 during 2004 and 2005

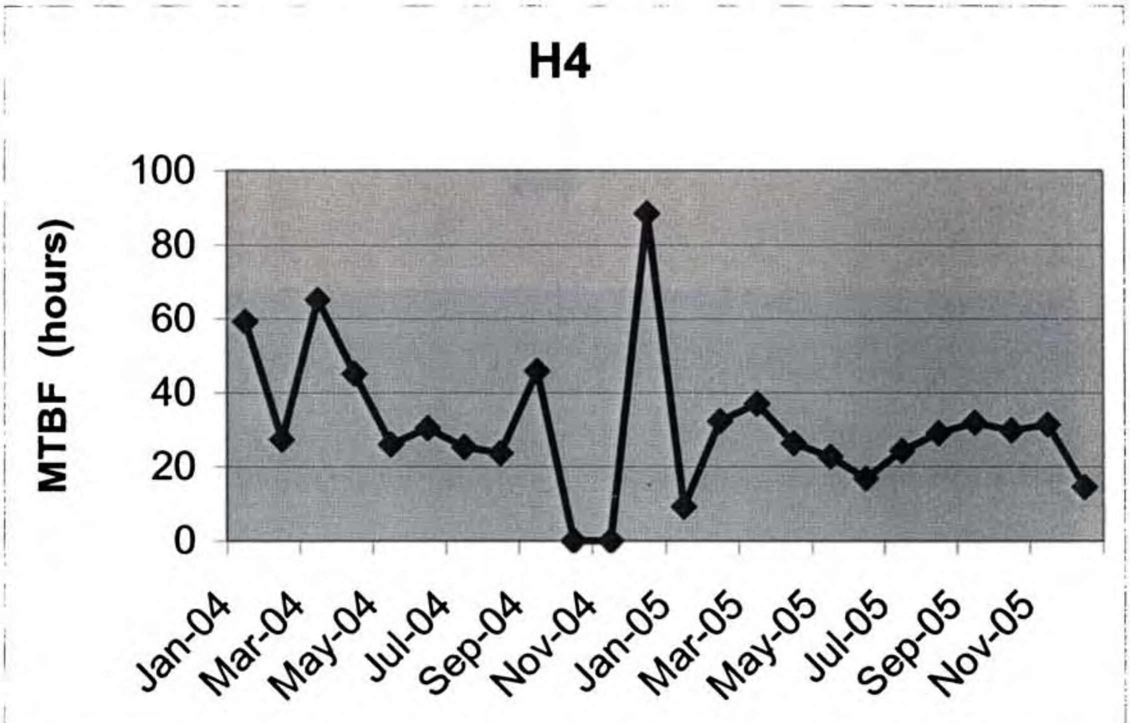



**Figure 8.53.** Variation of MTBF of H4 during 2004 and 2005

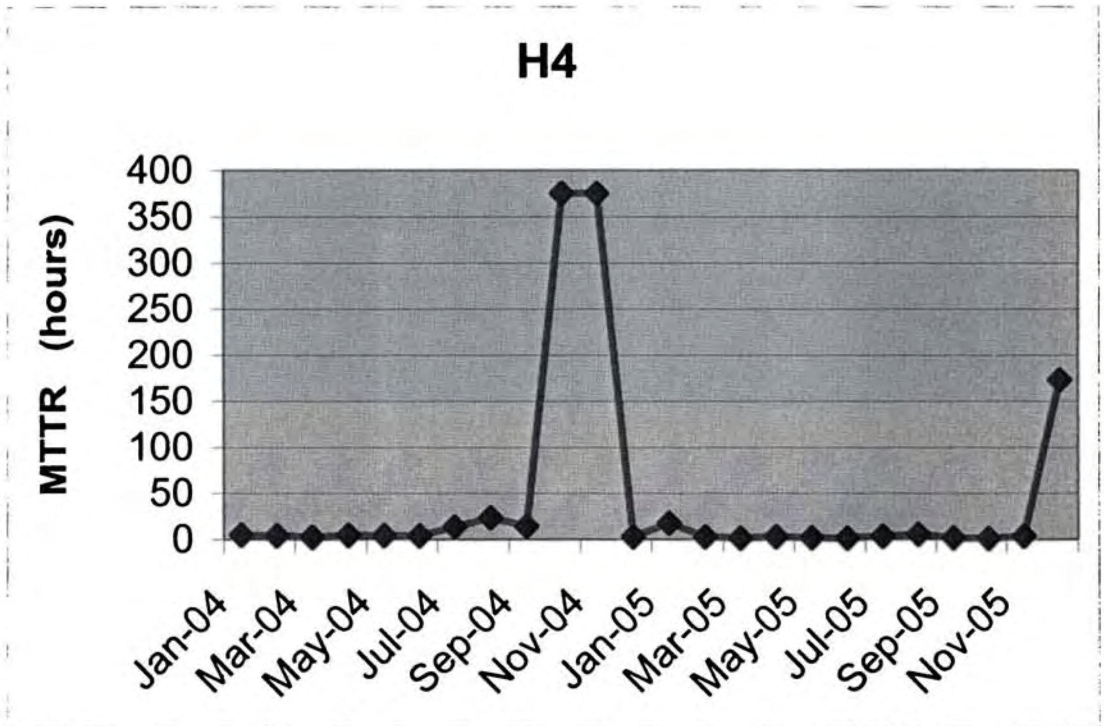



**Figure 8.54.** Variation of MTTR of H4 during 2004 and 2005

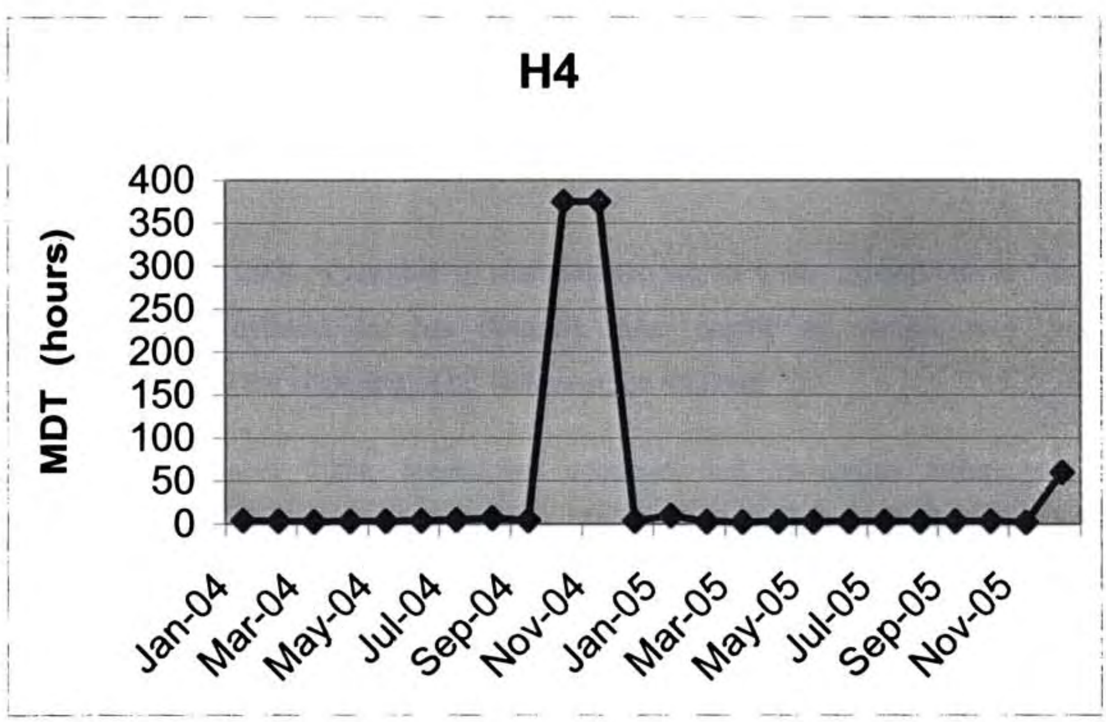



**Figure 8.55.** Variation of MDT of H4 during 2004 and 2005

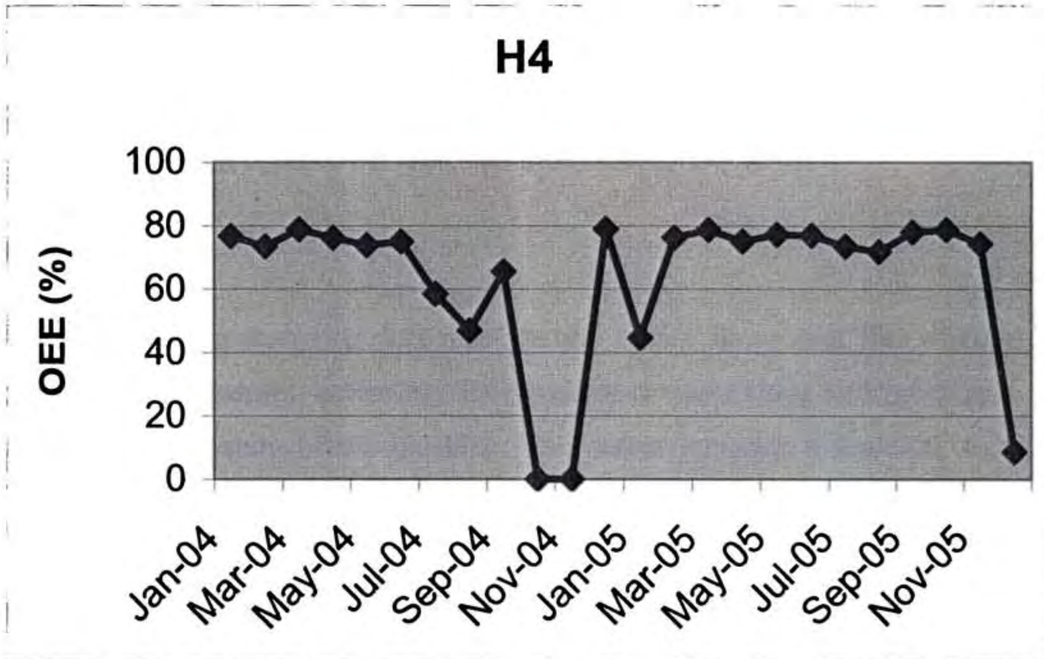



**Figure 8.56.** Variation of OEE of H4 during 2004 and 2005

### 8.7.5.5. Maintenance Quality Analysis of H5

The values of maintenance quality parameters pertaining to the equipment EX 400 are shown Table 8.25. The values are graphically depicted in Figures 8.57 to 8.61.

**Findings**

**Year 2004**

During June 2004, a number of maintenance works were carried out as the front wheel cylinder kit has changed. Also engine oil service was undertaken besides the changing of air leak component hose.

During October 2004, breakdown occurred due to engine failure, differential failure and final drive problem. These breakdows resulted in low availability.

During November 2004, vehicle accident has lead to cabin damage, which resulted in low MTBF.

### Year 2005

During June and November 2005, equipment was not taking load, which has resulted in high breakdown time, and thus causing low MTBF.

### Suggestions

By carefully analyzing this machine the author discovered that engine problems are frequently occurring. This resulted in less pulling and hence less load carrying capacity of the machine. The author suggests a thorough fuel injection pump calibration and weekly inspection of air filter. Also the author observed a number of transmission problems which must be looked into and proper actions should be initiated.

**Table 8.25. Maintenance parameters of H5 during the years 2004 and 2005**

| Month | Availability (%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE (%) |
|---|---|---|---|---|---|
| January 2004 | 96.13 | 28.42 | 4.25 | 2.50 | 77.62 |
| February 2004 | 90.69 | 21.54 | 3.78 | 4.82 | 73.23 |
| March 2004 | 91.35 | 26.78 | 2.36 | 3.72 | 73.77 |
| April 2004 | 80.27 | 20.57 | 3.98 | 10.57 | 64.82 |
| May 2004 | 81.94 | 20.83 | 3.57 | 7.78 | 66.16 |
| June 2004 | 65.07 | 16.17 | 4.59 | 14.56 | 52.54 |
| July 2004 | 86.13 | 17.52 | 3.55 | 4.48 | 69.55 |
| August 2004 | 90.77 | 23.48 | 2.83 | 3.58 | 73.30 |
| September 2004 | 93.60 | 36.57 | 2.16 | 3.43 | 75.58 |
| October 2004 | 54.19 | 10.40 | 5.14 | 11.83 | 43.76 |
| November 2004 | 74.40 | 14.50 | 7.19 | 10.67 | 60.08 |
| December 2004 | 95.03 | 53.20 | 2.64 | 3.85 | 76.74 |
| January 2005 | 96.71 | 46.85 | 2.79 | 2.55 | 78.09 |
| February 2005 | 95.00 | 24.03 | 2.79 | 1.94 | 76.71 |
| March 2005 | 87.56 | 36.00 | 2.45 | 7.00 | 70.71 |
| April 2005 | 98.13 | 27.80 | 1.49 | 0.70 | 79.24 |
| May 2005 | 95.55 | 42.00 | 3.01 | 3.45 | 77.16 |
| June 2005 | 61.33 | 16.83 | 6.37 | 24.17 | 49.53 |
| July 2005 | 95.86 | 22.70 | 2.22 | 1.50 | 77.41 |
| August 2005 | 94.00 | 22.98 | 2.21 | 2.18 | 75.91 |
| September 2005 | 99.43 | 68.00 | 1.39 | 0.50 | 80.29 |
| October 2005 | 93.74 | 17.81 | 2.60 | 1.87 | 75.70 |
| November 2005 | 88.90 | 13.80 | 1.90 | 2.19 | 71.78 |
| December 2005 | 87.73 | 20.64 | 2.18 | 3.63 | 70.84 |

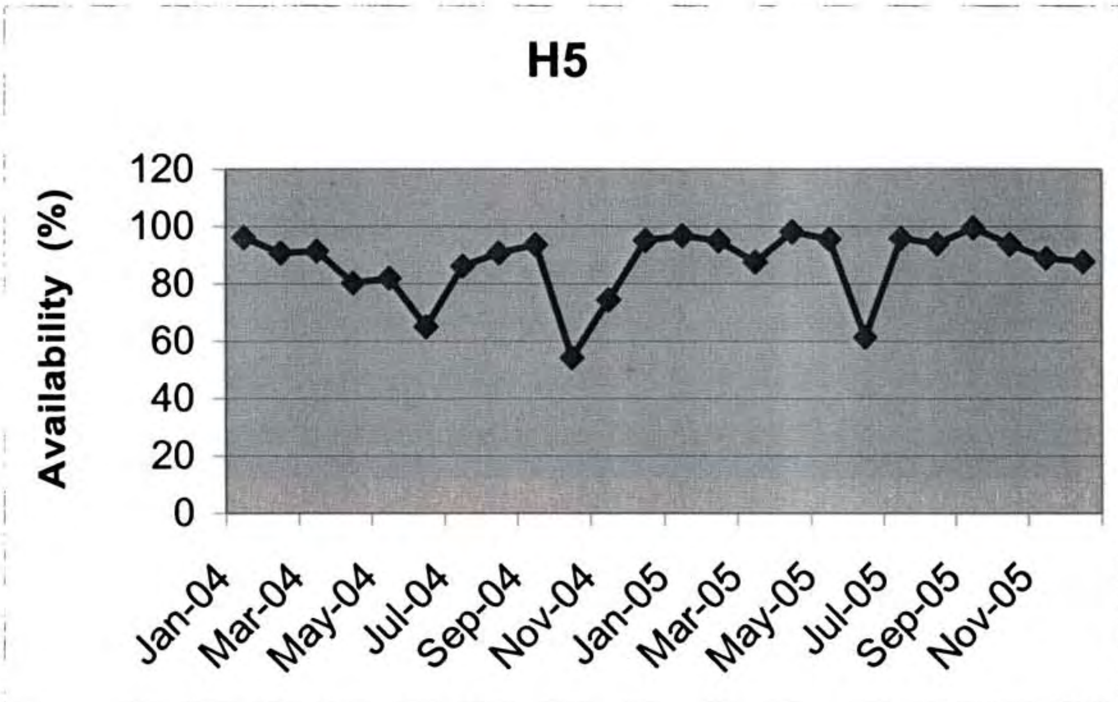



**Figure 8.57.** Variation of availability of H5 during 2004 and 2005

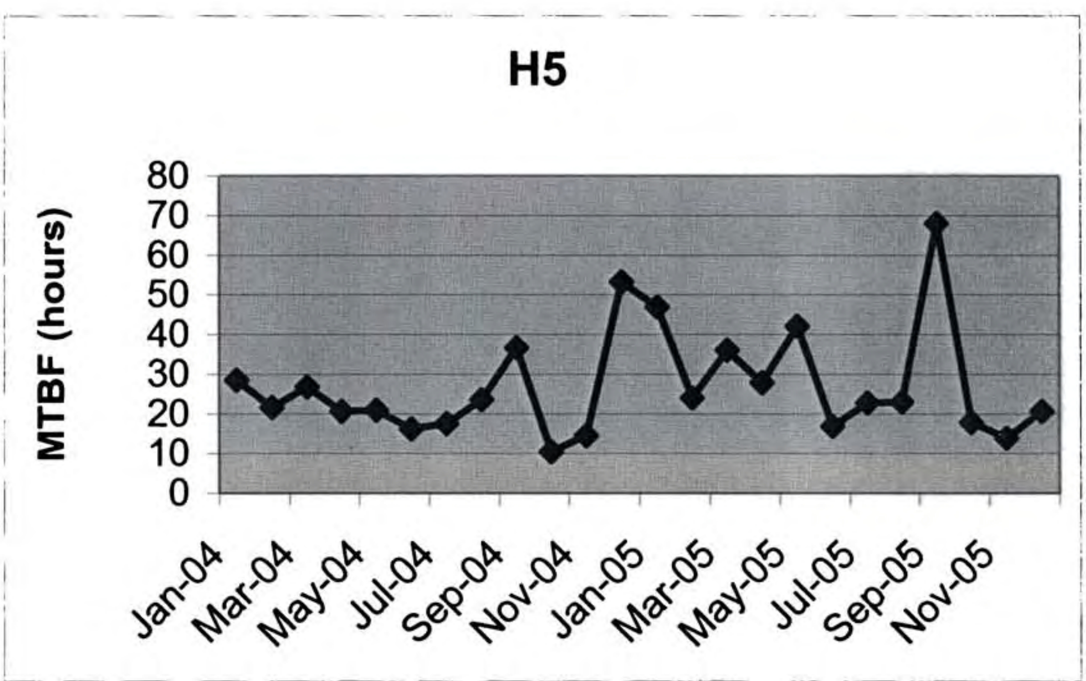



**Figure 8.58.** Variation of MTBF of H5 during 2004 and 2005

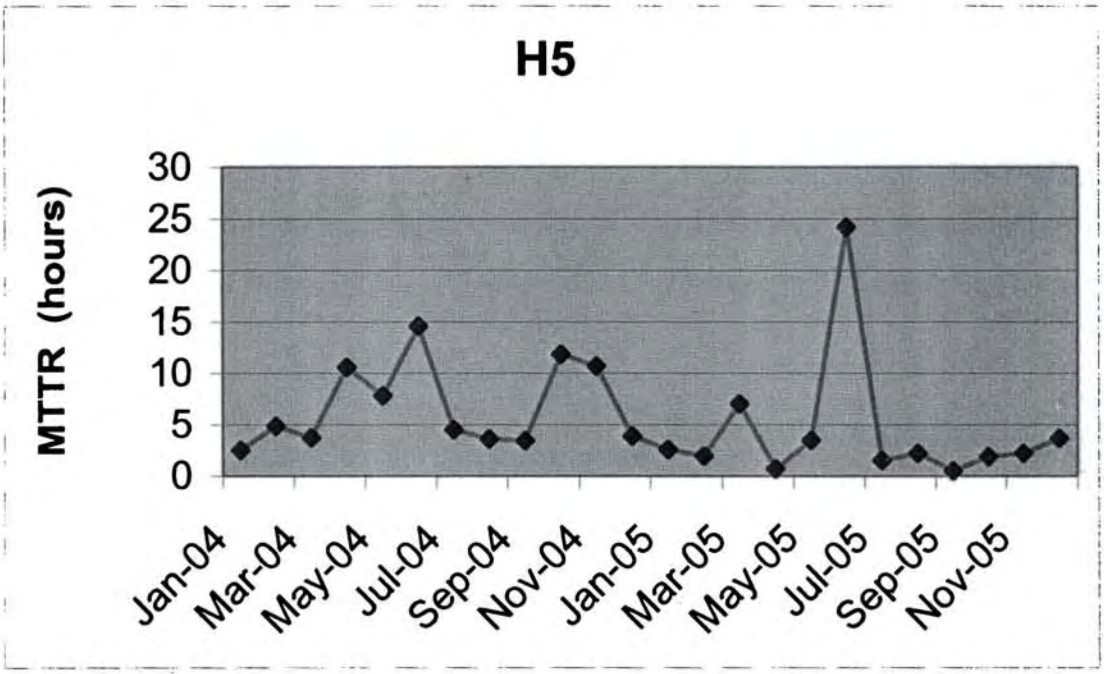



**Figure 8.59.** Variation of MTTR of H5 during 2004 and 2005

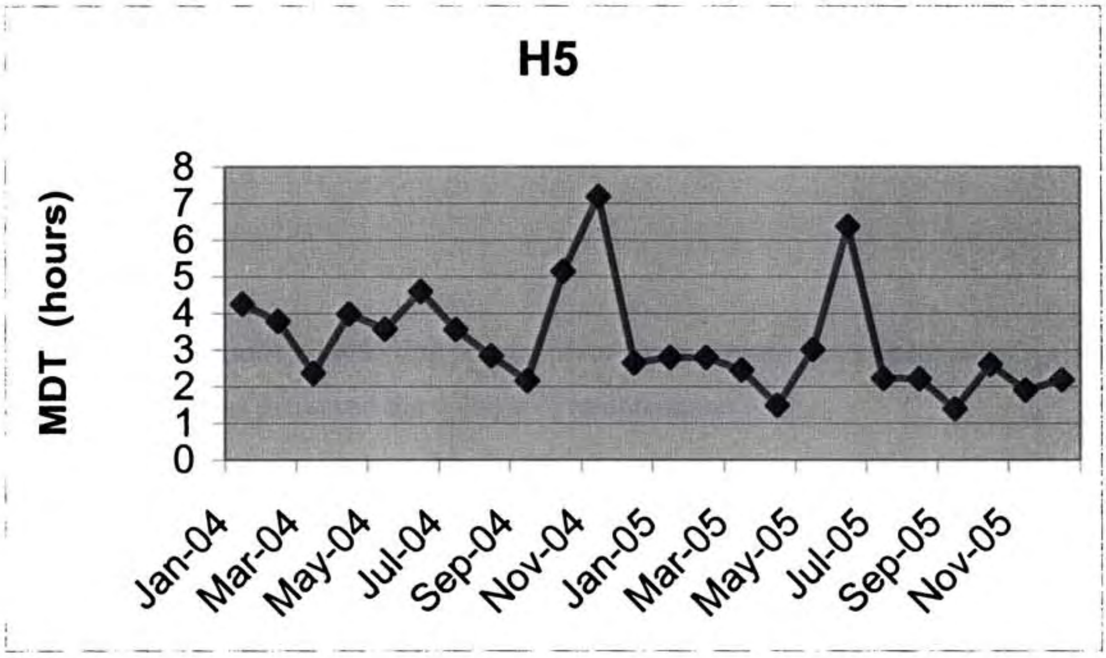



**Figure 8.60.** Variation of MDT of H5 during 2004 and 2005

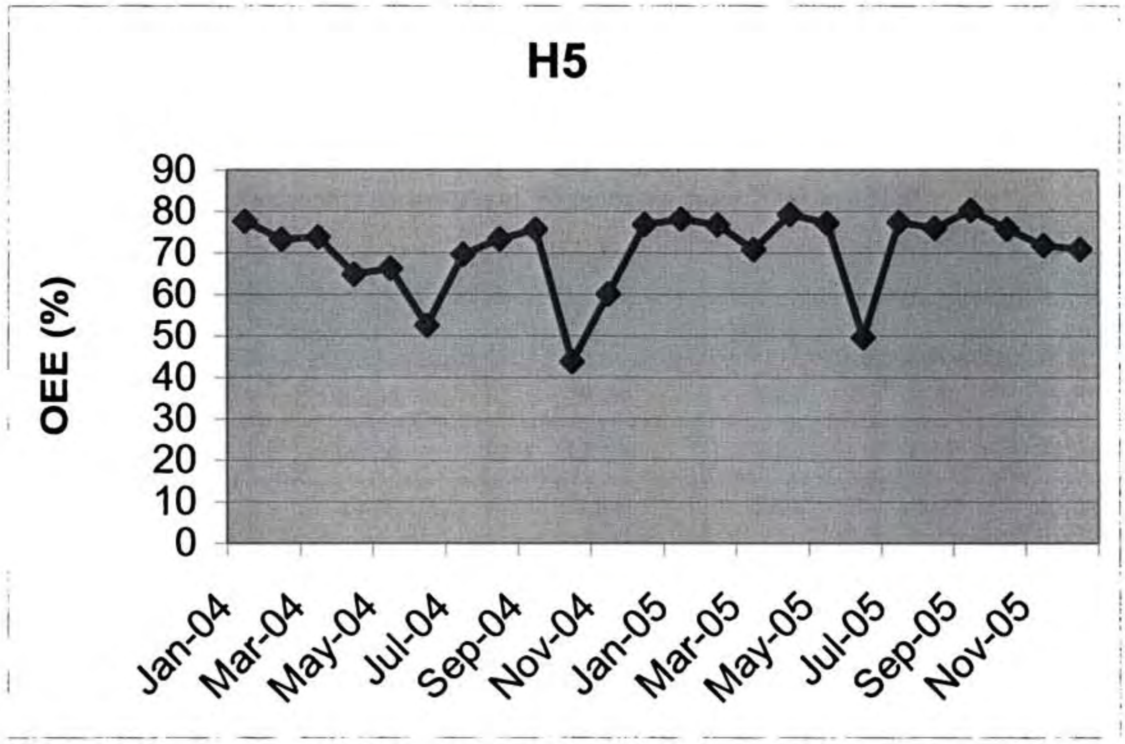



**Figure 8.61.** Variation of OEE of H5 during 2004 and 2005

### 8.7.5.6. Maintenance Quality Analysis of H6

The values of maintenance quality parameters pertaining to the equipment H6 are shown Table 8.26. The values are graphically depicted in Figures 8.62 to 8.66.

#### Findings

During November 2005, due to pin pivot work, transmission problems and engine problems increased the volume of maintenance works.

#### Suggestions

Even after carrying out a considerable amount of work on the engine, a number of problems like cooling, turbo, belt, oil leak and over smoke are frequently occurring. This shows that improper maintenance and check up have been carried out. Lubrication and cooling problems must be looked into which can reduce the turbo problems to some extent. Oil leak can be avoided by using good quality oil seals and their proper installation.

**Table 8.26. Maintenance parameters of H6 during the years 2004 and 2005**

| Month | Availability (%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE (%) |
|---|---|---|---|---|---|
| January 2004 | 81.55 | 20.04 | 4.69 | 11.92 | 65.85 |
| February 2004 | 95.66 | 17.67 | 3.84 | 1.75 | 77.24 |
| March 2004 | 49.55 | 7.09 | 5.53 | 17.77 | 40.01 |
| April 2004 | 83.13 | 16.85 | 4.30 | 6.33 | 67.13 |
| May 2004 | 91.48 | 11.33 | 4.03 | 2.20 | 73.87 |
| June 2004 | 51.27 | 12.67 | 5.12 | 20.31 | 41.40 |
| July 2004 | 95.55 | 21.78 | 2.88 | 1.73 | 77.16 |
| August 2004 | 83.48 | 41.55 | 5.29 | 12.80 | 67.41 |
| September 2004 | 77.27 | 19.85 | 3.27 | 8.53 | 62.39 |
| October 2004 | 78.39 | 45.25 | 3.29 | 16.75 | 63.30 |
| November 2004 | 93.48 | 27.88 | 3.32 | 3.06 | 75.48 |
| December 2004 | 92.00 | 296.00 | 2.41 | 31.00 | 74.29 |
| January 2005 | 97.16 | 55.13 | 3.27 | 2.75 | 78.46 |
| February 2005 | 95.86 | 37.00 | 4.02 | 2.90 | 77.40 |
| March 2005 | 94.96 | 42.29 | 2.56 | 3.25 | 76.68 |
| April 2005 | 92.13 | 18.70 | 2.87 | 2.68 | 74.40 |
| May 2005 | 85.42 | 29.28 | 2.64 | 7.06 | 68.98 |
| June 2005 | 92.67 | 23.09 | 2.28 | 2.50 | 74.83 |
| July 2005 | 97.03 | 31.31 | 2.36 | 1.44 | 78.35 |
| August 2005 | 91.37 | 15.33 | 2.69 | 2.27 | 73.78 |
| September 2005 | 92.75 | 17.38 | 2.54 | 1.81 | 74.90 |
| October 2005 | 94.73 | 16.10 | 2.59 | 1.45 | 76.49 |
| November 2005 | 51.33 | 21.00 | 8.95 | 32.00 | 41.45 |
| December 2005 | 88.96 | 15.60 | 3.45 | 3.63 | 71.83 |

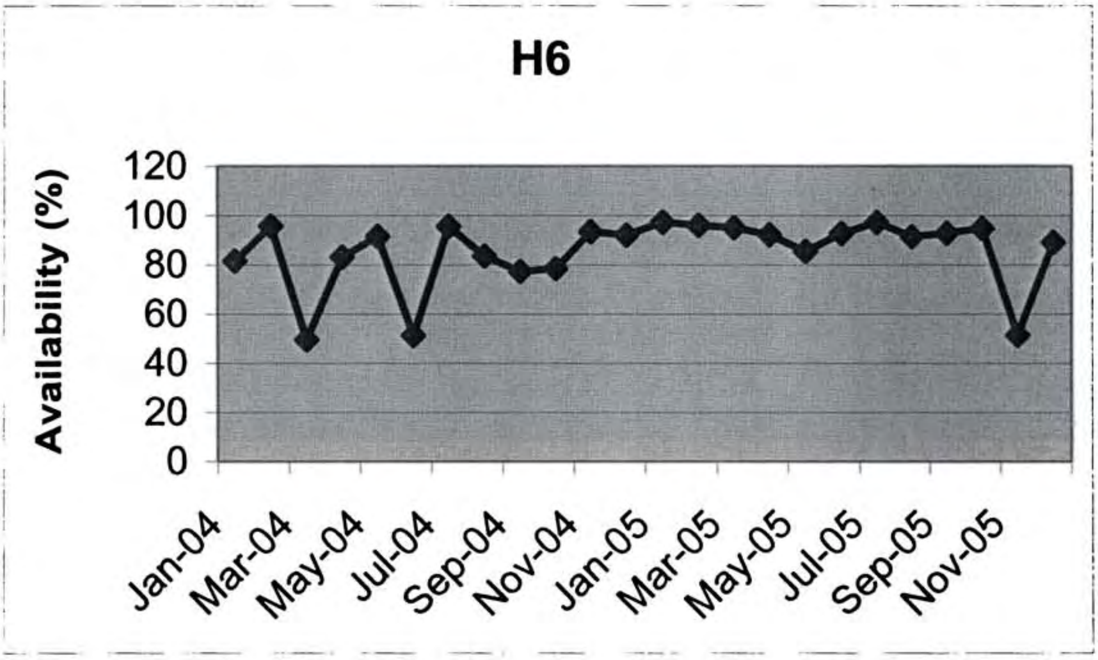



**Figure 8.62.** Variation of availability of H6 during 2004 and 2005

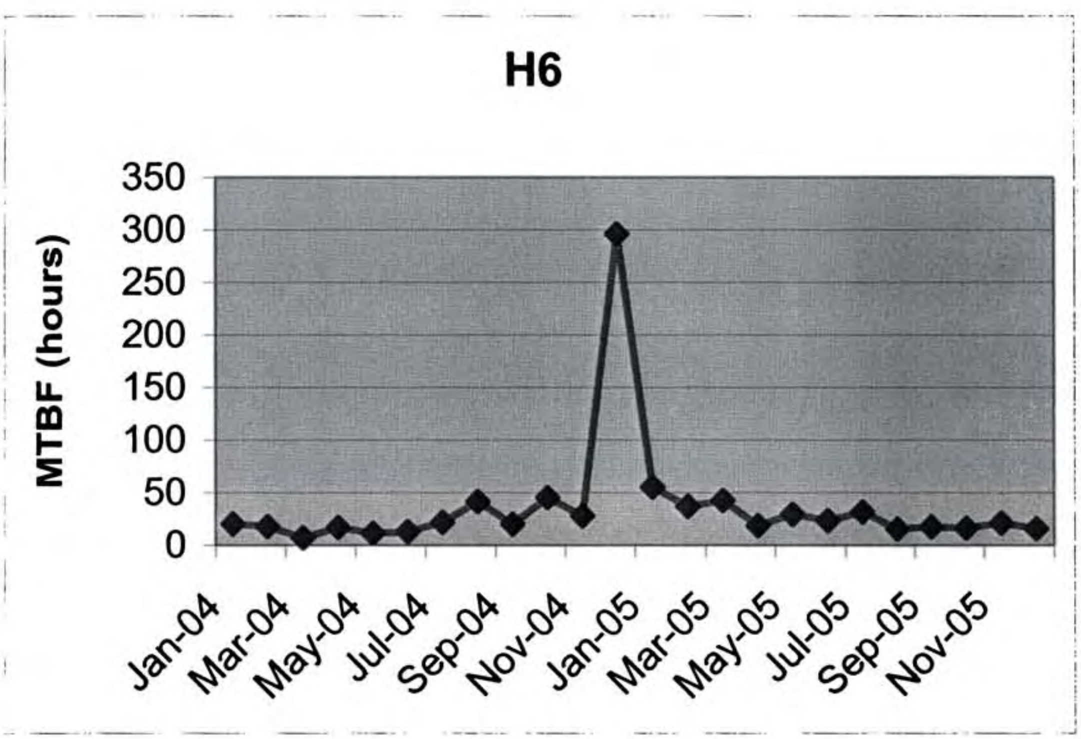



**Figure 8.63.** Variation of MTBF of H6 during 2004 and 2005

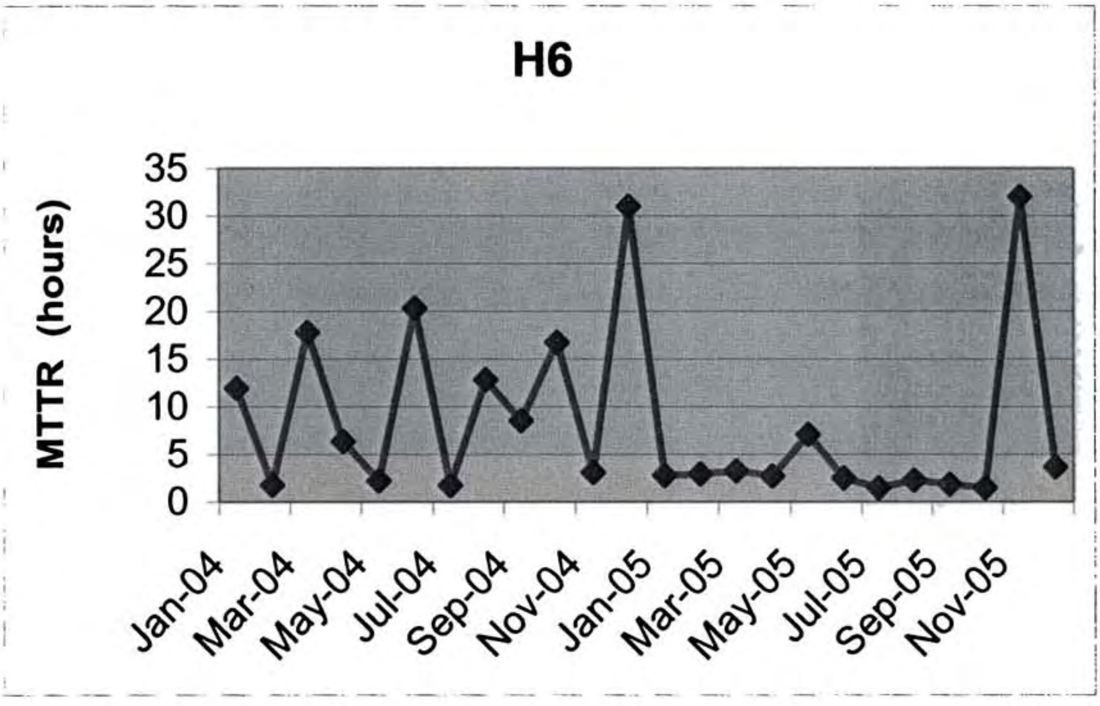



**Figure 8.64.** Variation of MTTR of H6 during 2004 and 2005

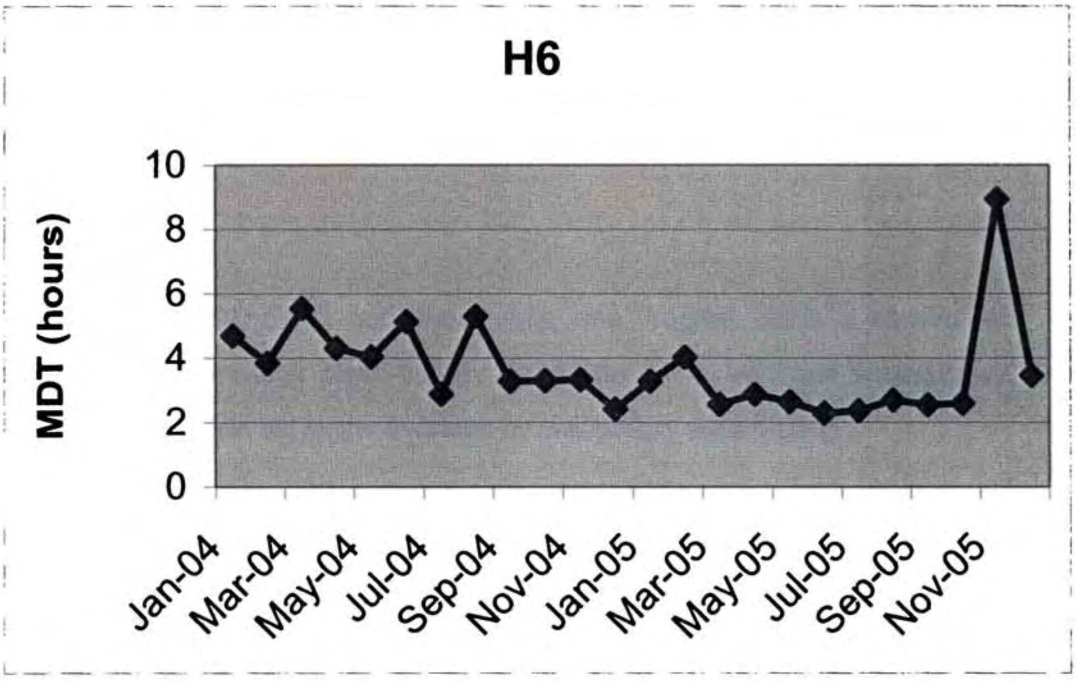



**Figure 8.65.** Variation of MDT of H6 during 2004 and 2005

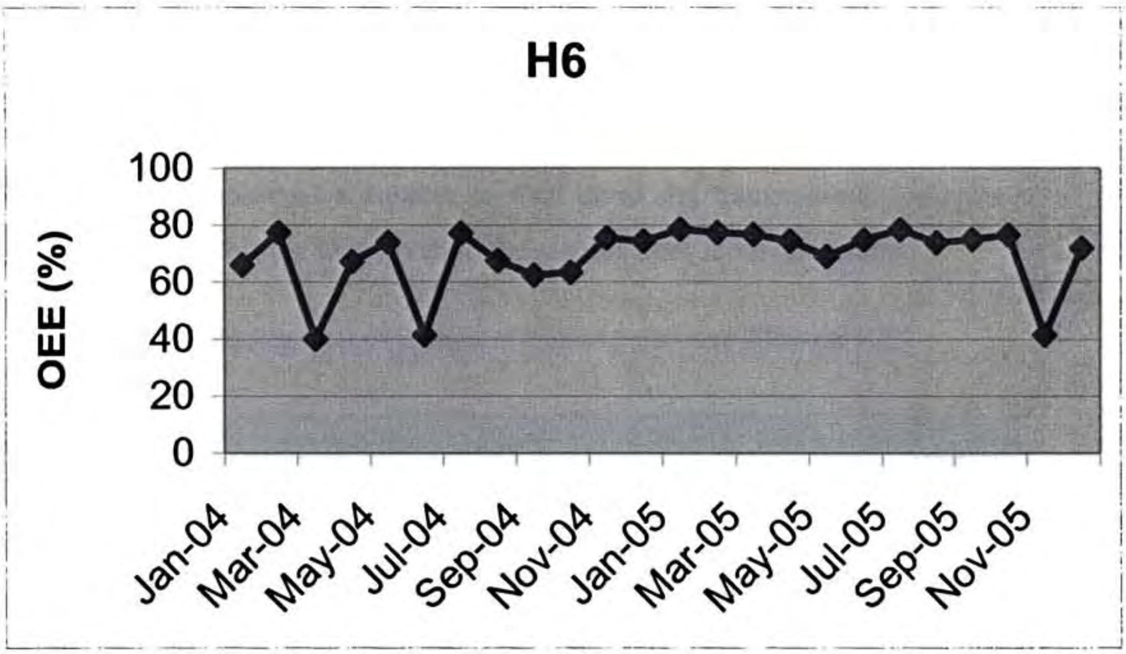



**Figure 8.66.** Variation of OEE of H6 during 2004 and 2005

### 8.7.5.7. Maintenance Quality Analysis of H7

The values of maintenance quality parameters pertaining to the equipment H7 are shown Table 8.27. The values are graphically depicted in Figures 8.67 - 8.71.

**Findings**

During January2005 and June, July, and August 2004, a number of maintenance works took place mainly due to the final drive and transmission complaints .This has led to the decrease in availability significantly.

The negative trend shown by graph from March 2005 is not due to the failures but due to the decrease in working hours. Also during April 2005, transmission, final drive and propeller shaft problems were reported. During December,2005, the number of breakdowns has increased and in July and August,2005, engine changing and release valve kit have been changed respectively. All these have contributed to the increase in MTBF.

**Suggestions**

The author observed a number of final drive and transmission problems and he suggested that the load given to the machine has to be decreased.

**Table 8. 27. Maintenance parameters of H7 during the years 2004 and 2005**

| Month | Availability (%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE(%) |
|---|---|---|---|---|---|
| January 2004 | 37.81 | 35.25 | 13.21 | 120.50 | 30.53 |
| February 2004 | 87.59 | 11.16 | 5.85 | 4.09 | 70.73 |
| March 2004 | 79.35 | 22.18 | 6.11 | 11.43 | 64.08 |
| April 2004 | 95.07 | 39.10 | 4.17 | 3.70 | 76.77 |
| May 2004 | 62.39 | 27.19 | 8.99 | 36.44 | 50.38 |
| June 2004 | 2.40 | 2.58 | 73.45 | 122.00 | 1.94 |
| July 2004 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| August 2004 | 4.13 | 0.75 | 38.30 | 61.92 | 3.33 |
| September 2004 | 78.27 | 51.06 | 4.27 | 20.38 | 63.20 |
| October 2004 | 60.77 | 36.17 | 6.26 | 30.40 | 49.08 |
| November 2004 | 96.27 | 59.00 | 3.16 | 3.50 | 77.74 |
| December 2004 | 87.95 | 16.57 | 2.78 | 3.34 | 71.02 |
| January 2005 | 95.42 | 51.75 | 3.84 | 4.44 | 77.05 |
| February 2005 | 76.07 | 24.04 | 5.41 | 13.96 | 61.43 |
| March 2005 | 93.46 | 31.31 | 3.05 | 3.22 | 75.47 |
| April 2005 | 89.27 | 25.08 | 3.39 | 4.47 | 72.08 |
| May 2005 | 82.52 | 42.80 | 3.54 | 13.55 | 66.63 |
| June 2005 | 98.91 | 55.31 | 1.12 | 0.75 | 79.87 |
| July 2005 | 71.67 | 5.70 | 3.16 | 3.36 | 57.87 |
| August 2005 | 80.00 | 6.50 | 2.40 | 2.50 | 64.60 |
| September 2005 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| October 2005 | 93.42 | 20.87 | 3.11 | 2.13 | 75.44 |
| November 2005 | 96.27 | 59.00 | 3.16 | 3.50 | 77.74 |
| December 2005 | 87.95 | 16.57 | 2.78 | 3.34 | 71.02 |

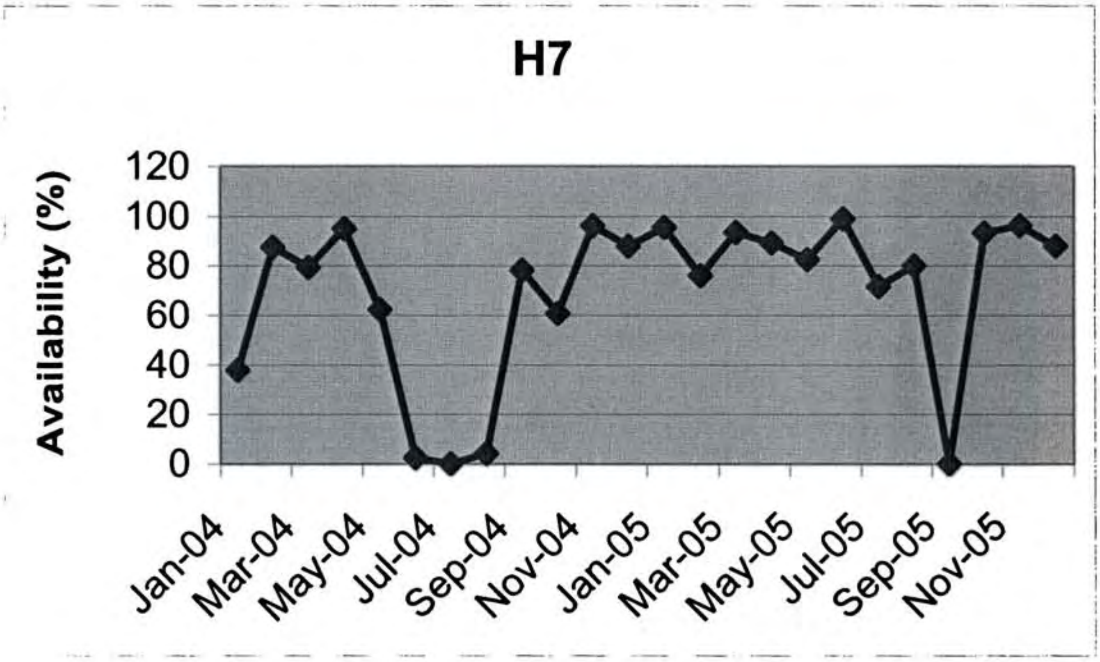



**Figure 8.67.** Variation of availability of H7 during 2004 and 2005

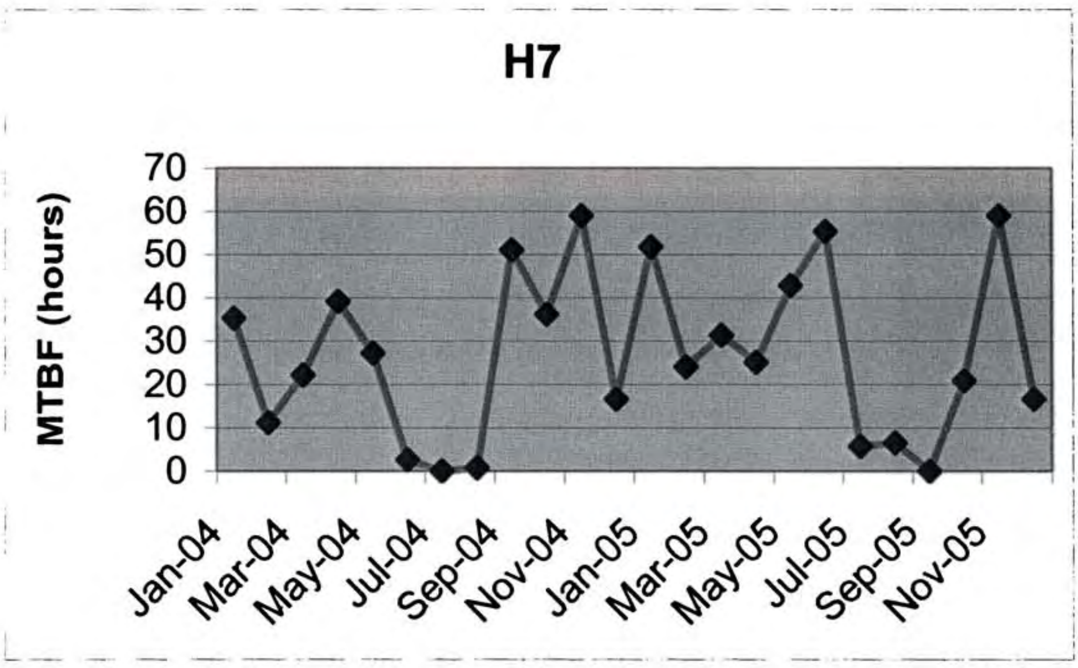



**Figure 8.68.** Variation of MTBF of H7 during 2004 and 2005

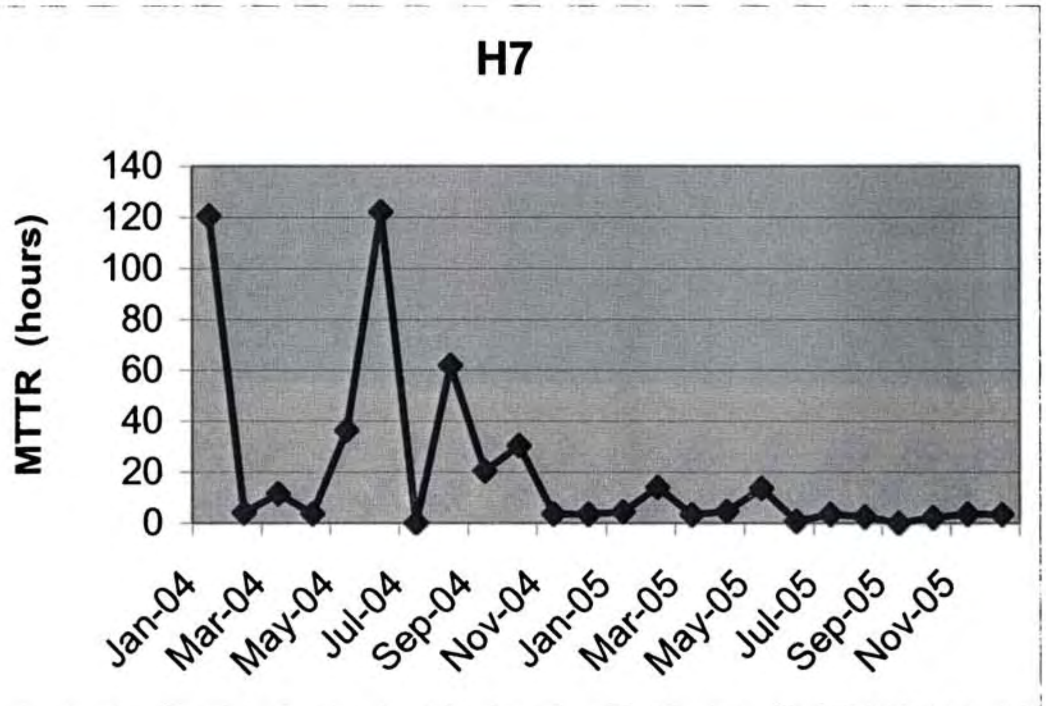



**Figure 8.69.** Variation of MTTR of H7 during 2004 and 2005

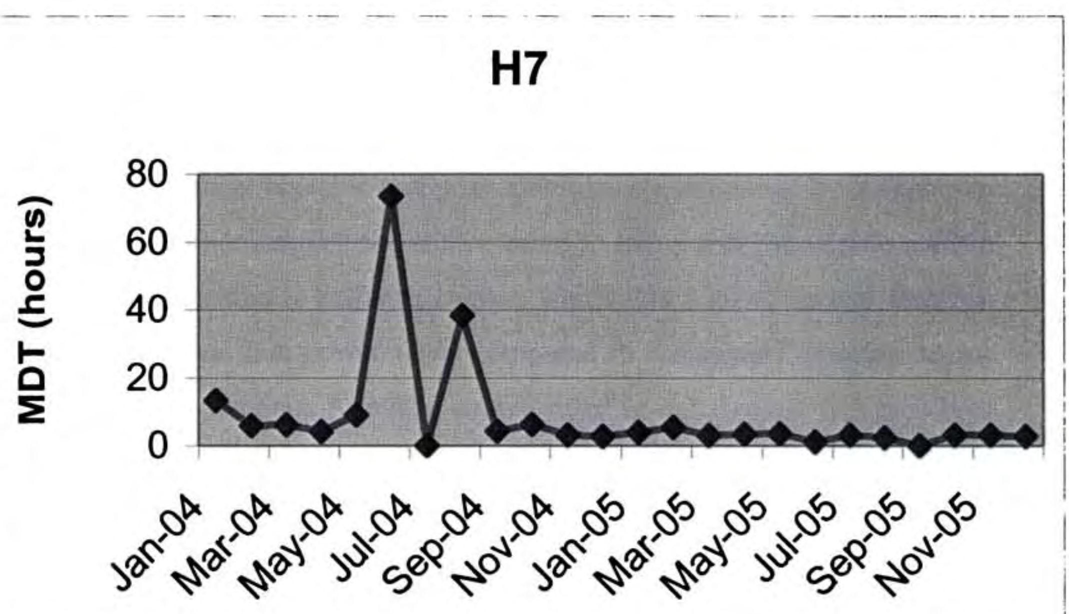



**Figure 8.70.** Variation of MDT of H7 during 2004 and 2005

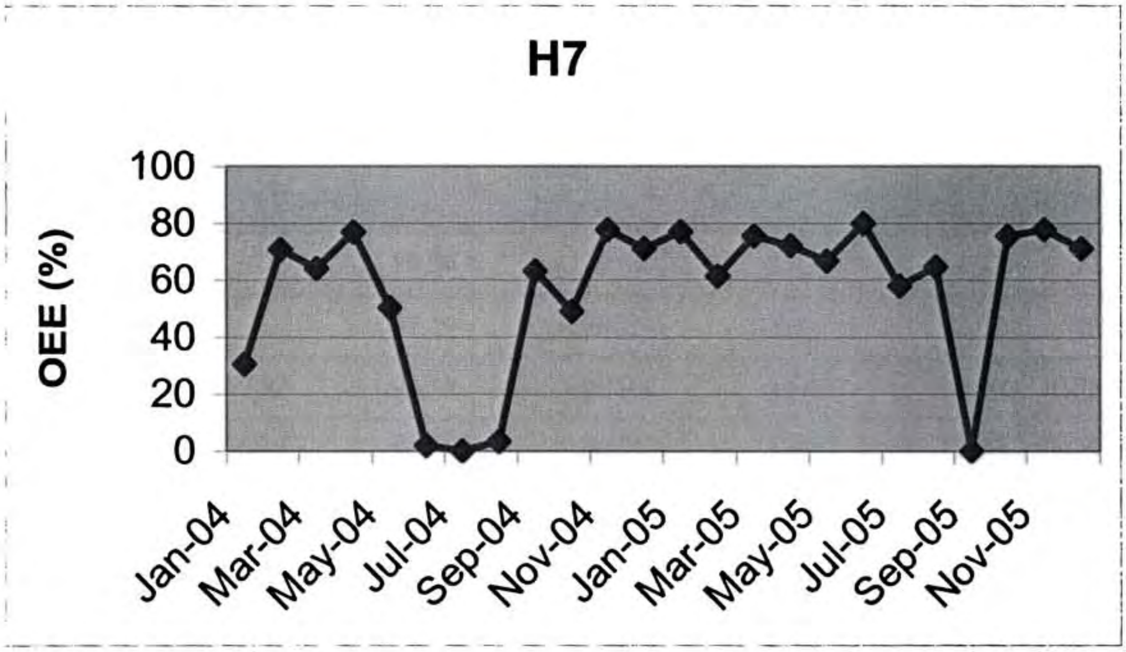



**Figure 8.71. Variation of OEE of H7 during 2004 and 2005**

### 8.7.5.8. Maintenance Quality Analysis of H8

The values of maintenance quality parameters pertaining to the equipment H8 are shown Table 8.28. The values are graphically depicted in Figures 8.72-8.76.

### Findings

This is the most unstable and unavailable machine among the dumpers in the mine. On further enquiry the author came to know that the engine used in this particular machine is komatsu engine, which has a lot of special features. However, but it has less power when compared to Kirloskar Cummins engine used in the other dumpers. Komatsu engine fitted in this dumper is a prototype developed by Bharath Earth Movers Limited and as a result, a number of teething troubles were noticed. This eventually made this vehicle a low available and performing vehicle.

**Table 8.28. Maintenance parameters of H8 during the years 2004 and 2005**

| Month | Availability (%) | MTBF (hours) | MDT (hours) | MTTR (hours) | OEE (%) |
|---|---|---|---|---|---|
| January 2004 | 89.94 | 20.56 | 3.43 | 4.33 | 72.62 |
| February 2004 | 97.79 | 69.25 | 2.98 | 2.67 | 78.97 |
| March 2004 | 94.58 | 23.93 | 4.15 | 3.00 | 76.37 |
| April 2004 | 98.00 | 60.25 | 3.60 | 2.50 | 79.14 |
| May 2004 | 99.35 | 182.75 | 3.59 | 2.50 | 80.23 |
| June 2004 | 94.20 | 21.30 | 1.04 | 2.18 | 76.07 |
| July 2004 | 95.61 | 28.31 | 2.68 | 2.13 | 77.21 |
| August 2004 | 29.42 | 13.33 | 19.31 | 91.17 | 23.76 |
| September 2004 | MAJOR OVERHAULING | | | | |
| October 2004 | | | | | |
| November 2004 | | | | | |
| December 2004 | | | | | |
| January 2005 | | | | | |
| February 2005 | | | | | |
| March 2005 | 28.35 | 14.50 | 15.21 | 103.00 | 22.89 |
| April 2005 | | | | | |
| May 2005 | | | | | 0.00 |
| June 2005 | 89.81 | 11.68 | 3.24 | 2.68 | 72.52 |
| July 2005 | | | | | |
| August 2005 | 63.08 | 10.56 | 2.29 | 7.50 | 50.93 |
| September 2005 | 96.14 | 11.33 | 7.05 | 2.25 | 77.64 |
| October 2005 | 68.48 | 16.66 | 2.59 | 8.95 | 55.30 |
| November 2005 | 82.44 | 18.07 | 2.73 | 4.79 | 66.57 |
| December 2005 | 93.92 | 31.83 | 2.41 | 2.75 | 75.84 |

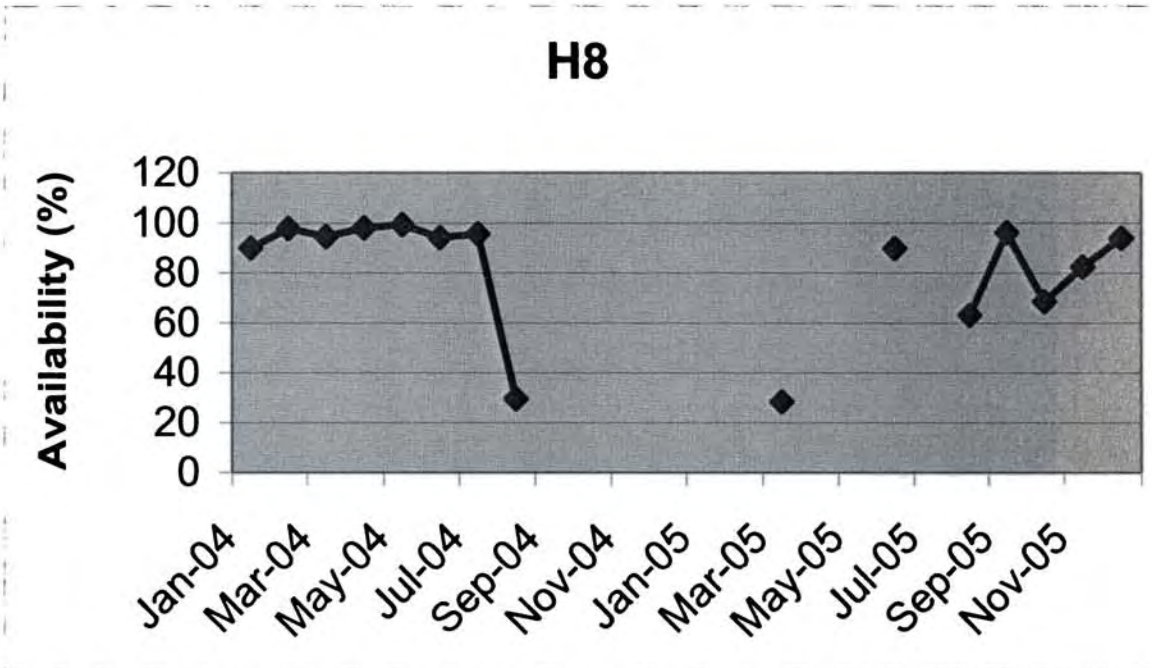



**Figure 8.72.** Variation of Availability of H8 during 2004 and 2005

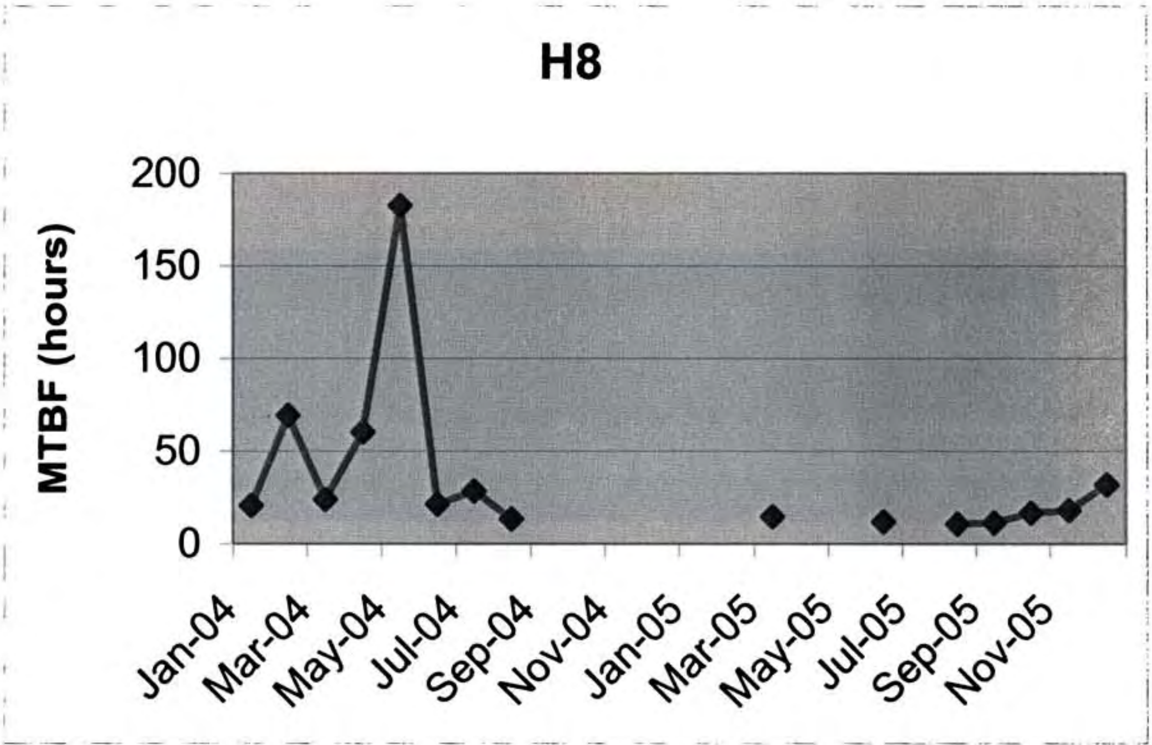



**Figure 8.73.** Variation of MTBF of H8 during 2004 and 2005

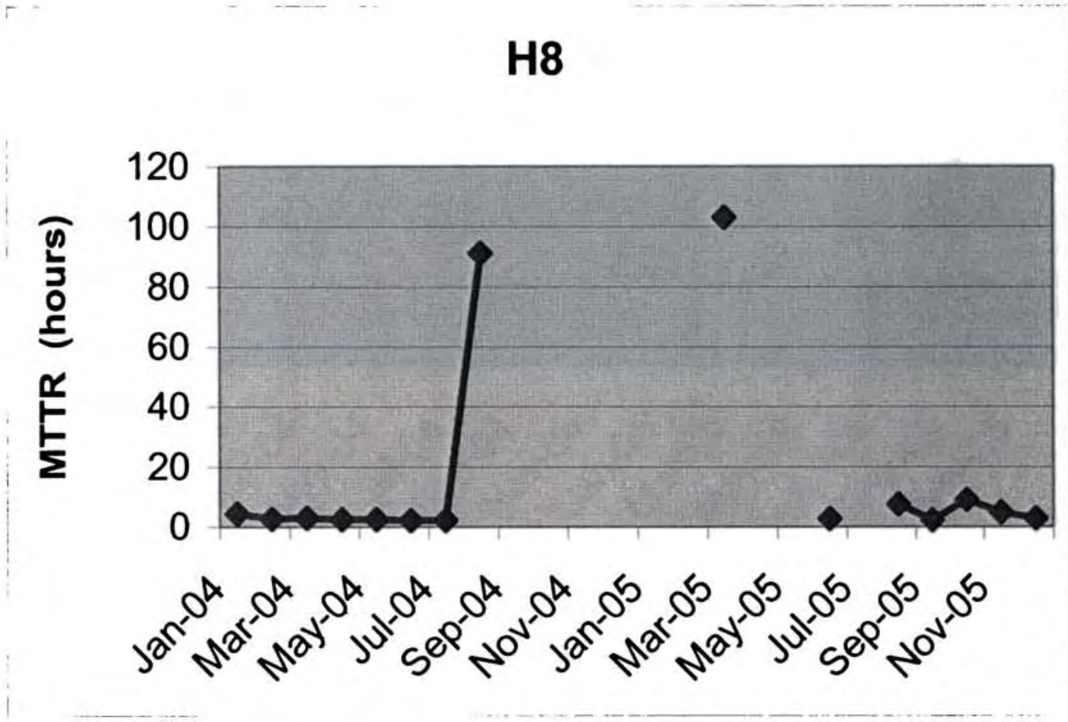



**Figure 8.74.** Variation of MTTR of H8 during 2004 and 2005

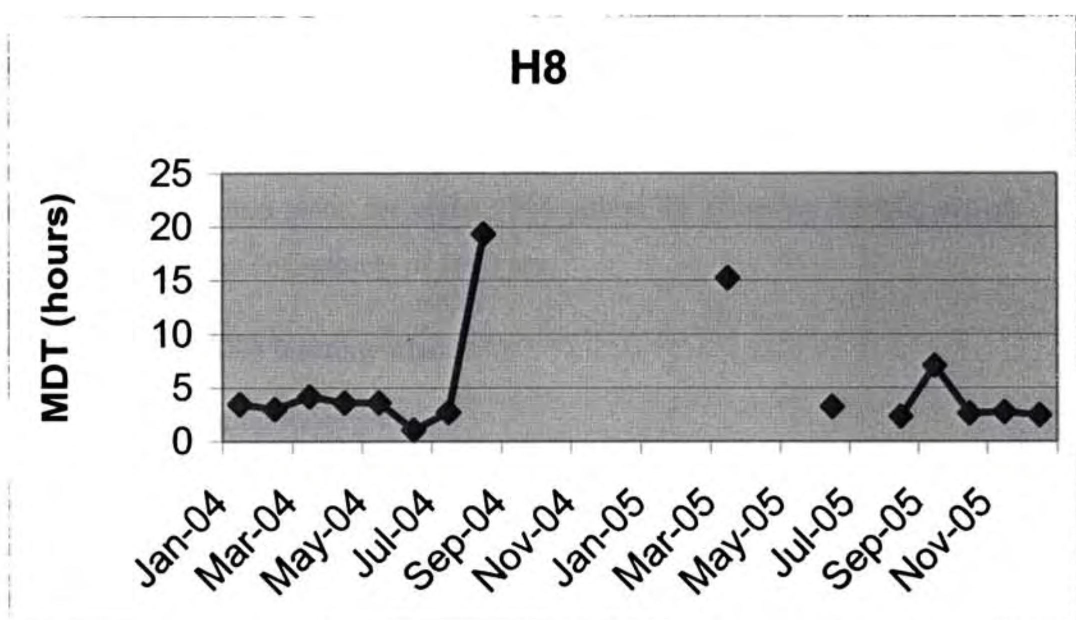



**Figure 8.75.** Variation of MDT of H8 during 2004 and 2005

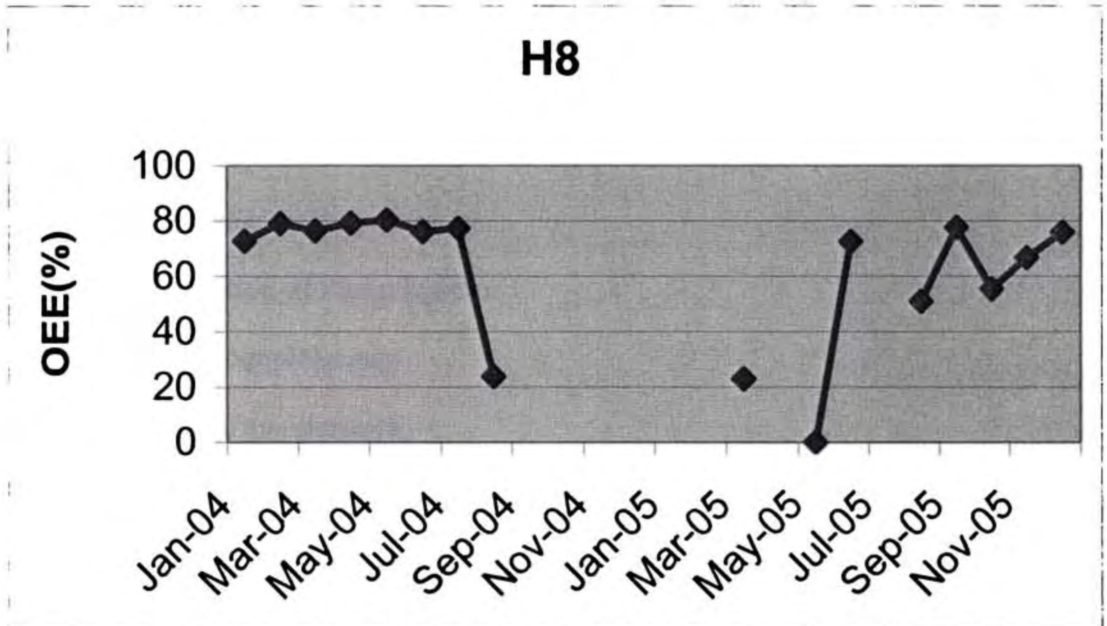



**Figure 8.76.** Variation of OEE of H8 during 2004 and 2005

**Suggestions**

The author suggested that in future purchases, units that have proved its reliability and worthiness must be considered. If this machine is more prone to failures, in future this machine must be decommissioned in future.

## 8.8. Implementation of TPM pillars

As mentioned in an earlier chapter, TPM is formed by eight pillars. This part deals with action plans for eight TPM pillars for directing the outputs of HoQ through them. The outputs of HoQ are

1. Scheduled blasting time
2. Tightening loose parts
3. Repair
4. Routine cleaning
5. Routine lubrication
6. Routine hydraulic Oil filling
7. Welding cracks

8. Tinkering
9. Replacement of damaged parts
10. Operator awareness
11. Leakage checking of diesel
12. Calibration of Pump/Injector
13. Periodic replacement
14. Routine maintenance
15. Training classes
16. Halogen lights
17. Leveling.

Strategic decision was made to categorize the above HoQ and outputs as required to pass through TPM pillars and those not required to pass through TPM pillars. The actions to be taken in this regard are tabulated in Tables 8.29 and 8.30.

**Table 8.29 Technical languages, which are not required to pass through the TPM pillars**

| Technical languages | Actions to be taken |
|---|---|
| Scheduled blasting time | A schedule has to be made for the time of blasting. This has to be decided by considering the present availability of loose material and the probability of getting loose material during each blasting. |
| Routine cleaning | Cleaning of the equipments in addition to the daily cleaning by the operators has to be carried out on a scheduled way. |
| Welding Cracks | Cracks, as soon as they are detected have to be welded. |
| Tinkering | Tinkering works have to be done at a regular interval. |
| Leakage checking of diesel | Diesel leak has to be checked frequently. |
| Calibration of pump/ injector. | Pumps/ injectors have to be calibrated at regular intervals. |
| Periodic replacement | Replacement of some specific parts of the equipments has to be carried out at regular intervals. |
| Routine maintenance | Maintenance of some typical parts has to be done on routine basis. |
| Halogen lamp | Halogen lamps have to be provided in the equipments. This will help them to work safely during night shifts. |
| Leveling | The place where the equipments are fixed for working should be leveled well. This will help them to do their functions efficiently. |
| Training Classes | People have to be deputed for the training classes. They should be trained about the basic principles and the activities at work places where they have to be attentive. It can be executed without the aid of TPM pillars. |

**Table 8.30. Technical languages, which are required to pass through the TPM pillars**

| Technical languages | Actions to be taken | |
|---|---|---|
| Tightening loose parts | Autonomous Maintenance (Jishu-Hozen - Pillar 1) | Operators should clean, lubricate and tighten the loose parts of their equipments. If any cracks or some abnormalities are observed, it should be informed to the maintenance wing at the earliest. Some orientation programs have to be conducted to set their mind in that direction |
| | Individual Improvement (Kobetsu Kaizen- Pillar 2) | Operators should be trained to clean, lubricate and tighten the loose parts. This has to become a culture. Some orientation programs have to be conducted to set their mind in that direction. In addition to that they should be motivated by suitable rewards. |
| | Planned Maintenance (Pillar 3) | Maintenance of the equipments has to be conducted in a scheduled way. It has to be done based on the recommendation of manufacturers and experience of the maintenance executives. |
| | Quality Maintenance (Pillar 4) | It has to be assured that the equipments leaving the maintenance shop are defect free to the extent possible. |
| | Office TPM (Pillar 5) | Spare procurement lead time is to be reduced to 48 hours from 60days. |
| | Education and Training (Pillar 6) | Employees should be motivated to pursue higher studies. They should be given suitable training in mechanical, electrical works and positive attitude. |
| | Safety, Health and Environment (Pillar 7) | Employees should be made aware of doing their work in a safe way. Some classes on safety aspects have to be conducted. They should be made health conscious. Environment has to be kept clean. Implementation of 5S principles can provide remarkable results in this direction. |
| | Initial Control/ Development Management (Pillar 8) | First the principles have to implemented for some selected machines. When this is achieved, the implementation has to be extended to other areas. |
| Repair | Autonomous Maintenance (Jishu- Hozen - Pillar 1) | The vehicles reaching the repair shops should be repaired under the strict control of the concerned diesel mechanic. If any work is done by assistants it should be known to him. Ultimately it has to be carried out under the attention of the concerned officer |
| | Individual Improvement (Kobetsu Kaizen- Pillar 2) | Mind setup of the people has to be developed for conducting the autonomous maintenance. This recommends for defining appropriate authority and responsibility hierarchies. Installation of an appropriate communication channel can provide remarkable results in this direction. |

Table Contd......

| | | |
|---|---|---|
| | Planned Maintenance (Pillar 3) | Maintenance of each equipment has to be done according to the recommendations of the manufacturer, observations of daily inspection, and life monitoring records. If some deviations have to be done, it should be checked in all aspects. |
| | Quality Maintenance (Pillar 4) | It has to be assured that the equipments leaving the workshop are defect free. |
| | Office TPM (Pillar 5) | Transactions concerning spare parts purchase, order placements, payments to suppliers etc have to be done at proper time. |
| | Education and Training (Pillar 6) | Maintenance personnel should be educated to carryout the maintenance works in a systematic way. They should attend sufficient classes in that direction. They should be motivated to pursue higher studies and for update knowledge level for acquiring knowledge on current modern maintenance practices carried out all around the world. |
| | Safety, Health and Environment (Pillar 7) | The maintenance shop has to be kept in a hygienic condition. Personnel should be trained to conduct their work in a safe way. Accident prone workers have to be identified and given only simple jobs. Besides 5S practices need to be implementated. |
| | Initial Control/ Development Management- (Pillar 8) | First actions have to be taken to ensure that some selected equipments are in good and perfect condition. Later it has to be expanded to other equipments. |
| Routine lubrication | Lubricants have to be applied on the equipments on a scheduled basis. This has to done by the operators. A colour coding has to be made to identify the lubrication spots and the lubricants. This will prevent the application of improper lubricants at the spots. | |
| | Autonomous Maintenance (Jishu- Hozen - Pillar 1) | Operators lubricate their equipments. |
| | Individual Improvement (Kobetsu Kaizen- Pillar 2) | Train the operators in that direction. They should have fundamental knowledge about the purpose of lubrication, grades of lubricants etc. |
| | Planned Maintenance (Pillar 3) | Prepare a schedule for lubrication interval of each machinery part and follow it. |
| | Quality Maintenance (Pillar 4) | This aims to assure proper (covering all points of lubrication scheduled), timely (exactly as per the periodicity) and effective (to ensure right quality of lubricant is fed) application of lubricants. |
| | Office TPM (Pillar 5) | Transactions for purchase of lubricants and order placements, have to be carried out quickly in regular manner. |

Table Contd......

| | | |
|---|---|---|
| | Education and Training (Pillar 6) | Technical training on tribology, grades and standards of lubricants and method of storing and handling needs to be implemented. |
| | Safety, Health and Environment (Pillar 7) | This aims for safe way of handling the lubricants. The godown should be hygienic. Lubricants should be stored at a safe place such that it should not be affected by dirt or moister. The chances of lubricants get mixed should be avoided. |
| Routine Hydraulic Oil filling. | Hydraulic oil has to be topped up at a fixed interval to make up the quantity lost through leakages. Proper checking intervals are to be fixed. | |
| | Autonomous Maintenance (Jishu- Hozen - Pillar 1) | Operators while cleaning has to identify the leaks if any at the joints. |
| | Individual Improvement (Kobetsu Kaizen- Pillar 2) | Attitudinal training to the operators has to be imported in this direction. |
| | Planned Maintenance (Pillar 3) | Hydraulic hoses and O-Rings are to be changed once in every 3000hours of operation of equipment |
| | Quality Maintenance (Pillar 4) | It has to be assured that the hoses and the O-rings are brought from the original equipment manufacturers. As it is a regular problem, it has to be consulted with the manufacturer. Sometimes they will be able to include some changes in the material structure or design and supply better. |
| | Office TPM (Pillar 5) | Equipment history keeping should be done usingan appropriate software for better data analysis as against the present manual record keeping |
| | Education and Training (Pillar 6) | Training on software based data management has to be imparted to the operators. |
| | Safety, Health and Environment (Pillar 7) | Removing the hoses and O-rings, fixing back etc has to be done in a safe way. It should be assured that oil should not get spreaded at the floor. |
| Replacement of damaged parts. | Damaged parts if any identified should be replaced immediately. | |
| | Autonomous Maintenance (Jishu- Hozen - Pillar 1) | Operators can change pin locks, bucket teeth and O-rings in non-critical areas. |
| | Individual Improvement (Kobetsu Kaizen- Pillar 2) | Operators mindset has to be tuned to carry out above jobs. |
| | Planned Maintenance (Pillar 3) | Plans have to be evolved based on the history of reconditioning / replacement of the components. |

Table Contd.......

| | | |
|---|---|---|
| | Quality Maintenance (Pillar 4) | Concept of Zero Break Down shifts for operation to be implemented |
| | Office TPM (Pillar 5) | Implementation of ERP (Enterprise resource programming) |
| | Education and Training (Pillar 6) | Training on ERP package to be imparted. |
| | Safety, Health and Environment (Pillar 7) | Assurance of clean hygienic garage floor |
| Operator awareness | Operators should be aware of keeping the condition of the equipments as good as new. They should be taught about the basic lessons and the chances and symptoms of malfunctioning of their equipments and emergency preventive measures. It has to be made as a culture in the organization. | |
| | Autonomous Maintenance (Jishu- Hozen - Pillar 1) | All periodic checking shall be carried out by the operators and if required, the assistance of diesel mechanics is to be sought. |
| | Individual Improvement (Kobetsu Kaizen- Pillar 2) | Training on team building and team work has to be imparted to the equipment operators. |
| | Planned Maintenance (Pillar 3) | All unrectified defects / malfunctions noticed during periodic checking shall be rectified during planned maintenance |
| | Quality Maintenance (Pillar 4) | Zero defect shifts |
| | Office TPM (Pillar 5) | Participation in Equipment history data upkeeping |
| | Education and Training (Pillar 6) | Technical training on maintenance aspects and hydraulics basics |
| | Safety, Health and Environment (Pillar 7) | Clean equipment, usages of personal protective equipments and safe working area |
| | Initial Control / Development Management (Pillar 8) | To improve material handling rate of machines in Tons Per Hour (TPH) |

## 8.9. Conclusion

In a public sector company like MCL, the importance of quality and cost reduction techniques play important roles. The implementation of the technique MQFD in its mines department will help them to achieve this in a very convenient and systematic way. The suggestions and the findings, if utilized in an effective way, will increase the equipments' OEE. MQFD has to be adopted as a program throughout the life time of the organization and it requires continuous improvement in every aspects. The author expects that MCL will implement MQFD in each and every department. Through this exercise, MCL will achieve its goals, thereby will attain excellency.

Chapter - 9

# IMPLEMENTATION OF MQFD IN MATTRESS MANUFACTURING

*Content*

# IMPLEMENTATION OF MQFD IN MATTRESS MANUFACTURING

## 9.1. Introduction

In order to examine the implementation aspects of MQFD in a non-conventional manufacturing company, an implementation study was carried out in a maintenance intensive mattress-manufacturing unit. This mattress-manufacturing unit is located at a place called Pampady at Kottyam District of India. This mattress-manufacturing unit is run by the Kerala state Government of India. This mattress-manufacturing unit was chosen for the study because of the intense maintenance engineering activities being carried out in it.

## 9.2. About the Company

The implementation study being reported in this chapter was carried out in the company by name Rubber Co-operative Limited (hereafter referred to as RUBCO). RUBCO has in a short span, redefined the way the cooperative sector functions and set the pace for the co-operative movement in Kerala state of India. RUBCO was setup in the year 1997 with the objective of effectively utilizing the abundantly available rubber resources of Kerala. RUBCO was started as a single unit company. Today RUBCO has grown into a conglomerate of value INR.280 Crore (US$560,000,00) with well-diversified operations. RUBCO's market has extended beyond the boundaries of Kerala. RUBCO manufactures and markets a variety of products such as mattresses, slippers etc. The implementation study being reported in this chapter was restricted to the application of MQFD in mattress manufacturing at RUBCO.

## 9.3. Types of mattresses

RUBCO manufactures a wide range of mattresses catering to the diverse segments of the market. The names and their charectoristics are enumerated below.

1. Dosth - Attractively priced mattresses that combine comfort and durability.

2. Safal - Attractively priced mattresses that combine comfort and durability.

3. Heaven and Heaven Plus - Premium mattresses offering best luxury and sleeping comfort

4. Hi-tech - Premium mattresses offering best luxury and sleeping comfort.

5. Yathri - A mattress ideal for hotels and tourist resorts.

6. Heal - A mattress suitable for hospitals.

7. Relief - A mattress specially designed for the Orthopedic patients.

During this implementation study, the product 'Heaven' was subjected to MQFD study as . its sales volume was high.

## 9.4. Study phases

The implementation study was carried out in four phases. The activities carried out under each phase are narrated in the following subsections.

### 9.4 .1. Phase1 – Data collection (Getting customer language)

During this phase, the voices of the customers were gathered. Here customers refer to the distributors to whom RUBCO supplies the mattresses. The structured questionnaire shown in Annexure D was prepared and distributed to the distributors. The list of distributers was given by RUBCO. The respondents were requested to provide their feedback, which were entered as the inputs of HoQ. During this stage, the information on consumers' complaints on RUBCO's products was collected.

### 9.4 .2. Phase 2 – Technical data collection

The second part of the study consisted of finding solutions to the complaints received from the customers in the form of technical languages. For this purpose, interviews and brainstorming sessions were held with the executives and the shopfloor workers. This helped to get the preliminary knowledge on the technical solutions against the complaints received from the customers. After that the relationships between customer and correlation between technical languages were established. Using all these data, HoQ shown in Figure 9.1was prepared.

### 9.4.3 Phase 3- Suggestion for implementing technical remedies through TPM

The HoQ matrix prioritizes these technical requirements. The decision regarding the outputs of HoQ to be either implemented directly or through the TPM pillars was made by consulting with the General Manager. These decisions were made based on the easiness and cost effectiveness of implementation.

### 9.4 .4 Phase 4- Action plans to implement technical remedies

After that, an action plan for implementing the technical remedies was prepared. Among the technical remedies, some have to pass through TPM and some can be implemented directly. Those, which have to pass through TPM, were sorted out and implementation plans against each pillar were formulated. Another set of action plans had to be prepared for those which need not pass through TPM pillars.

## 9.5. Survey

In order to gather knowledge on the drawbacks of the product/service from the customer point of view, the questionnaire shown in Annexure D was prepared in a structured format so that honest replies from the customers could be received. A likert's scale of range 0-9 was included with each questions for enabling the customers to answer precisely. Here 0 represents "not at all satisfied", 5 represents "somewhat satisfied" and 9 represents "fully satisfied". The sample size of the survey was little more that 50% of the population. That is, 11 out approximately 20 distribution centers were covered. The questionnaire was prepared encompassing seven dimensions. They were: 1. Essential product features, 2. Design parameters,

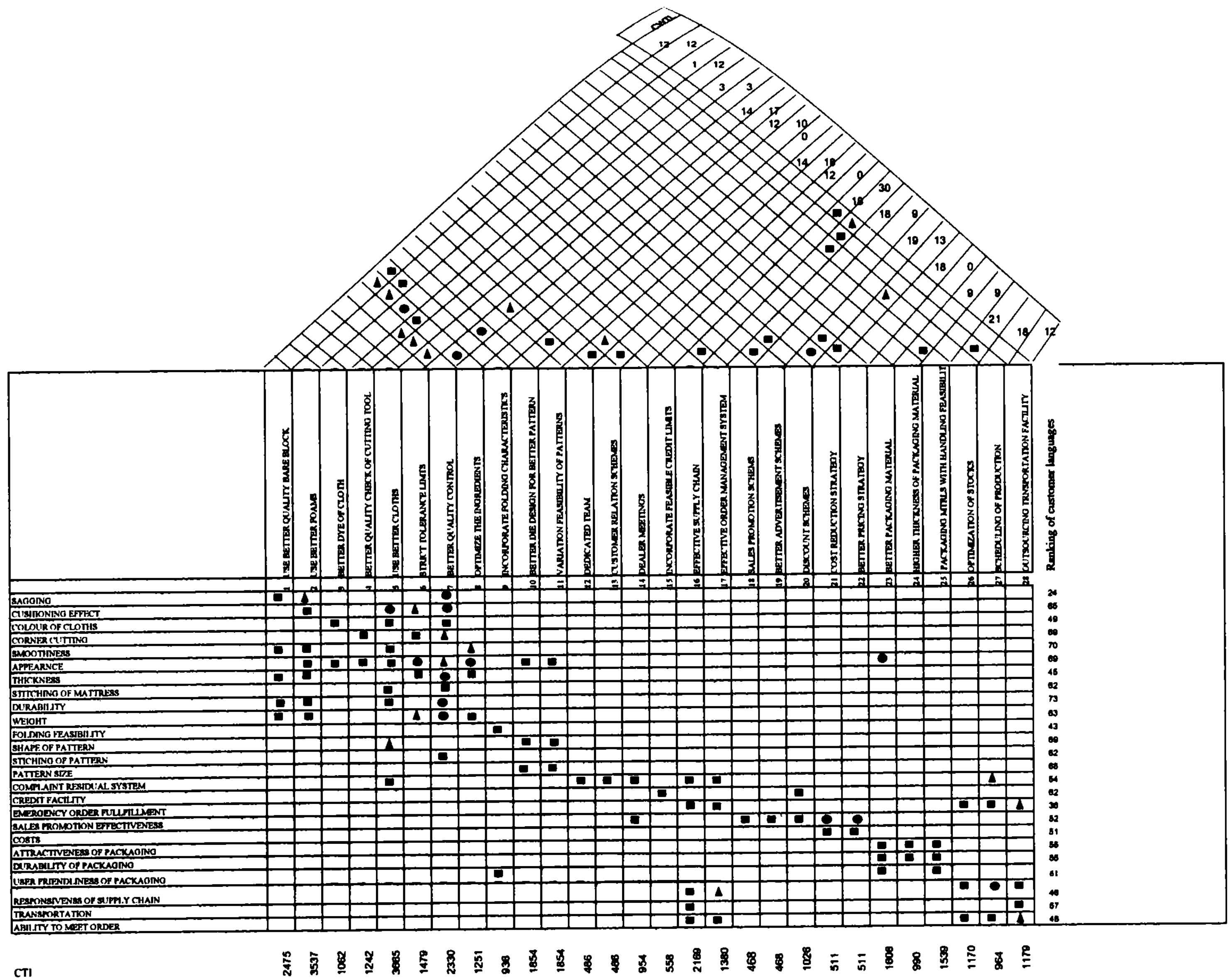



Figure 9.1.HoQ Matrix

## 9.6. Interpretation from the questionnaire

From the questionnaire based survey, a number of problems were identified. The most important among them are listed below.

i) The mattress sags, which will create ripples on them

ii) The emergency order fulfillment is very poor.

iii) The thickness of the mattress is varying from the specified limit

iv) The responsiveness of the supply chain is poor.

v) The colour of clothes does not have much variety.

vi) The sales promotion activities are not up to the mark.

The customers from outside Kerala state had some additional grievances regarding the sales promotion activities, the colour of clothes of the mattress, the thickness variation, advertisement promotions and order fulfillment.

## 9.7. HoQ construction

The problems identified were input into HoQ. After this, the technical languages numbering 28 were prepared by discussing with the competent personnel from the technical and production departments. The customers' reactions and the technical languages were entered in rows and columns of the correlation matrix of HoQ. In order to have a clear understanding of various terminologies connected with mattress manufacturing,

**Table 9. 2 Explanation of the technical languages**

| | |
|---|---|
| Use better quality bare block | The use of better quality bare block would prevent the sagging of mattress and thereby bending in the long run. |
| Use better foams | The use of better quality foams would result in good cushioning effect, prevent sagging, provide a good finish to the mattress and thereby more durability. |
| Better dye of cloth | The use of better dye of cloth would ensure better quality of colour of clothes of the mattress. |
| Better quality checking of cutting tool | This aspect would ensure that the thickness of the mattress do not vary, the corner cutting is as specified and thereby provide better finish. |
| Use better clothes | The use of better clothes would ensure good cushioning effect, attractive colour, and good quality of stitching. |
| Strict tolerance limit | This would provide better quality control and tolerance limits to all the aspects of the mattress. |
| Better quality control | The effective quality control of the process would ensure that all the characteristics of the mattress are maintained well. |
| Optimization of the ingredients | The proper mix of the ingredients would ensure that the mattress is 100% sufficient in weight and thereby the finish is maintained. |
| Incorporate folding characteristics | The folding characteristics of a mattress would ensure user-friendliness. |
| Better design of die for better patterns | The dies should be of good quality and their design should be optimum, to ensure that the patterns are excellent, both in shape and size. This would ensure that the appearance of the mattress is also attractive. |
| Dedicated team | There should be dedicated team to ensure that the complaint residual system is made effective. This helps to rectify the complaints immediately. |
| Customer relationship schemes | The customer relationship schemes should be made more effective so that a good ambient relationship exists between the company and the customer. |
| Effective supply chain | The supply chain should be made more effective so that the responsiveness, transportation and the ability to meet the order are met efficiently. |

Table contd....

| | |
|---|---|
| Effective order management system | The order management system should be made more effective to ensure that the order reaches the right customer at the right time. |
| Sales promotion schemes | There should be schemes for sales promotion so that sales efficiency is maintained and improved. |
| Better advertisement schemes | There should be better schemes for advertisement so that goodwill as well as the effectiveness in sales promotion are maintained. |
| Discount schemes | There should be sufficient number of discount schemes to counter the competition effectively. This would also help in sales promotion activities. |
| Cost reduction strategies | The cost reduction strategies should be such that the product quality is enhanced with reduction of cost as needed. |
| Better pricing strategy | The pricing of the product should be highly competitive friendly and should be able to maintain the increase in sales. |
| Better packaging materials | The packaging materials should be of good quality so that the mattresses are not damaged during transportation. The packaging material should be of a viable thickness as well as attractive. It should be user friendly and durable to the extreme conditions. |
| Optimization of stock | The stock should be optimized so that the orders are met according to the demand, effectively and efficiently. This would also alert the supply chain network to be effective. |
| Scheduling of production | The effective scheduling of production would help reduce the complaints by enabling the ability to meet the order and make the supply chain more responsive. |
| Outsourcing the transportation facility | Through the adoption of outsourcing, the transportation facility can be made more responsive and thereby more effective. As a result, it would be able to meet the order and keep the customers happy. |

a brief explanation of technical languages is presented in Table 9.2.The methodology explained in Chapter 6 was adopted to construct this HoQ. The calculated CTI, CTWL and other related terms are given in Table 9.3.

An example of computing customer technical interactive score for 'Use better quality bare block' is presented below.

CTI of 'Use better quality bare block' = 9×(24+ 70+45+ 73+63) =2475

Table 9. 3. Technical descriptors and their computed scores

| Serial Number. | Technical descriptors | CTI | Percentage normalized value of customers technical interactive score (2) | CTWL | Percentage normalized value of correlated weightage (4) | Sum of (2)+(4) |
|---|---|---|---|---|---|---|
| 1 | Use better quality bare block | 2475 | 6.49 | 12 | 3.59 | 10.08 |
| 2 | Use better foams | 3537 | 9.27 | 12 | 3.59 | 12.86 |
| 3 | Better dye of cloth | 1062 | 2.78 | 1 | 0.3 | 3.083 |
| 4 | Better quality check of cutting tool | 1242 | 3.26 | 12 | 3.59 | 6.848 |
| 5 | Use better cloths | 3665 | 9.61 | 3 | 0.9 | 10.5 |
| 6 | Strict tolerance limits | 1479 | 3.88 | 3 | 0.9 | 4.775 |
| 7 | Better quality control | 2330 | 6.11 | 14 | 4.19 | 10.3 |
| 8 | Optimize the ingredients | 1251 | 3.28 | 17 | 5.09 | 8.369 |
| 9 | Incorporate folding characteristics | 936 | 2.45 | 12 | 3.59 | 6.046 |
| 10 | Better die design for better pattern | 1854 | 4.86 | 10 | 2.99 | 7.854 |
| 11 | Variation feasibility of patterns | 1854 | 4.86 | 0 | 0 | 4.86 |
| 12 | Dedicated team | 486 | 1.27 | 14 | 4.19 | 5.465 |
| 13 | Customer relation schemes | 486 | 1.27 | 18 | 5.39 | 6.663 |
| 14 | Dealer meetings | 954 | 2.5 | 12 | 3.59 | 6.093 |
| 15 | Incorporate feasible credit limits | 558 | 1.46 | 0 | 0 | 1.463 |
| 16 | Effective supply chain | 2169 | 5.69 | 18 | 5.39 | 11.07 |

Table contd………

| | | | | | | |
|---|---|---|---|---|---|---|
| 17 | Effective order management system | 1380 | 3.62 | 30 | 8.98 | 12.6 |
| 18 | Sales promotion schemes | 468 | 1.23 | 18 | 5.39 | 6.616 |
| 19 | Better advertisement schemes | 468 | 1.23 | 9 | 2.69 | 3.921 |
| 20 | Discount schemes | 1026 | 2.69 | 19 | 5.69 | 8.378 |
| 21 | Cost reduction strategy | 511 | 1.34 | 13 | 3.89 | 5.232 |
| 22 | Better pricing strategy | 511 | 1.34 | 18 | 5.39 | 6.729 |
| 23 | Better packaging material | 1608 | 4.21 | 0 | 0 | 4.215 |
| 24 | Higher thickness of packaging material | 990 | 2.59 | 9 | 2.69 | 5.289 |
| 25 | Packaging materials with handling feasibility | 1539 | 4.03 | 9 | 2.69 | 6.728 |
| 26 | Optimization of stocks | 1170 | 3.07 | 21 | 6.29 | 9.354 |
| 27 | Scheduling of production | 964 | 2.53 | 18 | 5.39 | 7.916 |
| 28 | Outsourcing transportation facility | 1179 | 3.09 | 12 | 3.59 | 6.683 |

## 9.8. Strategic decisions

The outputs of the HoQ were subjected to strategic decision making to choose the technical descriptors which should be passed through TPM pillars and those to be implemented directly. According to the MQFD model, the action plansof TPM pillars for each technical languages were made after discussing with the General Manager. These details are narrated in Tables 9.4 – 9.26.

**Table 9. 4. Action plans of TPM pillars for the technical language 'use better quality bear block'**

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | Operators have to clean the machine by themselves. In addition to that they have to regularly check the machine. If any cracks or faults are found, they have to be rectified. This will improve the quality of bear block. |
| Individual improvement . | A mindset has to be developed among the employees to pursue autonomous maintenance. They should take interest to study the various functions of the bear block building machine and come out with the strategies to improve the utilization of the machine. |
| Planned maintenance | An advance planning has to be done on all the maintenance aspects and it has to be scheduled in such a way that it will not affect the production. This will prevent future breakedown. |
| Quality maintenance | The quality policy should be implemented effectively at all levels of the process. The quality has to be checked in accordance with the quality policy of the company. Allowable tolerance limits should be assigned and strictly followed. The proper mix of the coir and the latex should be decided and followed strictly. |
| Education and training | The employees should be trained about the TPM pillars and its importance. The training needs for each class of employees have to be identified in accordance with the future prospects of the company and training has to be given accordingly. Lectures have to be arranged for enabling them to understand the importance of the different aspects involved in mattress maufacturing |
| Safety, Health and environment | The shop floor has to be kept clean and better house keeping has to be followed to prevent any mishaps. People should be made aware of various safety aspects and the ways to perform the work safely. Oil, dirt etc from the shop floor should be removed. Safety principles in the work environment should be followed. Stress on the clean environment should be given due importance. Good hygienic conditions and better housekeeping principles should be kept in place. |
| Initial control/ Development management | This pillar aims to confirm whether the full capacity of the machine is utilized. The need of this approach is to ensure good quality of the bear block always available. In order to achieve this, first a target has to be fixed for the number of bear blocks to be manufactured in a week. After achieving this, the target has to be revised. In this way, company will have good quality bear blocks always available. |

**Table 9. 5. Action plans of TPM pillars for the technical language 'Use better quality foams'**

| TPM Pillars | Actions recommended |
|---|---|
| Individual improvement | The operator must be fully aware of the quality of the forms used for the manufacture of various mattresses. As the forms are purchased from outside, even if some small defects are there, operators should be able to identify them and inform to the concerned personnel. This will help the suppliers to aware of the quality aspects of the forms they have to supply. |
| Planned maintenance | Train the workers on the quality constraints of the different kinds of foams. Schedule the right kind of quality of foams after thorough inspection. |
| Quality maintenance | Company has to provide proper benchmarking on the quality of forms which are getting supplied by various suppliers. |
| Education and training | People should be motivated to pursue higher studies. This will indirectly help to enhance the quality of execution of this task. In order to achieve that, some training classes have to be conducted covering the various aspects of forms, methods of application, etc. |
| Safety, health and environment | Forms after purchase should be maintained well by proper house keeping. It should be stored and handled with care. The adoption of hygienic policies will help to prevent the form being covered by dirts during storage and handling. |

**Table 9. 6. Action plans of TPM pillars for the technical language 'Better dye of cloth'**

| TPM Pillars | Actions recommended |
|---|---|
| Individual improvement | The employees should be trained on the different classes of dye used for cloth and thereby made aware on the quality aspects. |
| Quality maintenance | Regarding this aspect, the quality of die and the cloths have to be taken into account. Certain quality aspects have to be put forward for both. The micron size for cloth thickness, intensity of threads, material used for clothes, (threads), ratio of colour compounding etc has to be fixed earlier and informed to the concerned people. In addition to that proper quality checking has to be done for clothes, dies colour mixing and methods of application. Ensure that the cloths produced are meeting quality requirements through stringent quality checks. Also ensure that the dye of cloth used is of superior quality |
| Education and training | The employees should be trained on the variety of cloths and dyes used, the quality aspects adopted for the selection and their chemical compositions. |
| Safety, health and environment | While selecting the die or compounds used for die, hazardous nature of dyes (poisonous, odor, allergic, etc) should be avoided to ensure the safe and healthy environment. |

**Table 9.7. Action plans of TPM pillars for the technical language 'Better quality checking of cutting tool'**

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | The employees should regularly check the condition of the operating machines to ensure that the tools are proper, both in condition and place. |
| Individual improvement | A mindset has to be created among the employees to take initaiative to find the various methodologies for detecting the troubles occurring. The employees should be trained about the different tools used, its properties, its efficiency criteria, etc. The employees should be trained about the different cutting tools used, the cutting speeds, efficiency, its effectiveness, etc. In addition to that, they should be made aware of various cutting tools used for each application, the selection of tools etc. |
| Planned maintenance | The condition of cutting tools should be checked regularly to prevent any disparities and for this, proper scheduling should be put in to place and strictly followed. |
| Quality maintenance | Stringent quality checks should be followed to ensure proper quality in working conditions. |
| Education and training | The employees should be trained about the different cutting tools used, the cutting speeds, efficiency, its effectiveness, etc. |
| Safety, health and environment | The scraps should be removed regularly. User friendly environment, should be maintained. The employees must be protected from any health hazards. |

**Table 9. 8. Action plans of TPM pillars for the technical language 'Use better cloths'**

| TPM Pillars | Actions recommended |
|---|---|
| Individual improvement | Employees minds should be tuned for checking the clothes. They should be motivated to gather the information regarding the various quality aspects of clothes and point out to the management in the case of finding any defects. |
| Quality maintenance | Ensure that each material meets the required quality standards to ensure a better variety and finish of mattress. |
| Education and training | Train the employees about the variety of cloths and threads used to ensure a better quality both in the process and in the product. |

**Table 9. 9. Action plans of TPM pillars for the technical language' Strict tolerance limit'**

| TPM Pillars | Actions recommended |
|---|---|
| Individual improvement | Create awareness among the employees about the effects of variation from the tolerance limit, and its importance towards the total quality of the finished product. |
| Planned maintenance | The maintenance should be scheduled effectively and efficiently in a planned way so that the variation in dimensions does not occur. |
| Quality maintenance | Identify the tolerance limits and strictly adhere to those limits. The tolerance limits set should be feasible enough for implementation. |
| Education and training | Train the employees about the quality aspects, the importance of tolerance and its limits, etc |
| Initial control/ development management | If the tolerance is found to be beyond the limits, then go for better design by allocating feasible tolerance limits in the new design. |

**Table 9. 10. Action plans of TPM pillars for the technical language 'Better quality control'**

| TPM Pillars | Actions recommended |
|---|---|
| Individual improvement | Employees' mind should be tuned to gather information regarding various quality aspects of the products, the quality policy, its importance and its necessity, both to the company as well as to themselves. They should be able to suggest better methods in scheduling, maintenance and quality control. |
| Planned maintenance | All the maintenance activities should be planned in advance in advance and scheduled as per the plans to ensure quality products. This will avoid the maintenance activities during the period of production. |
| Quality maintenance | All the quality elements should be thoroughly checked to confirm systematic order and strictly adhere to it. |
| Education and training | The employees should be trained about the modern quality philosophies, their purposes and relevance to the company. Training classes on SPC, TQM and Kaizens will be contributing a lot in this direction. The importance and necessity for the quality aspects to be followed in the company has to be convincing to all the employees. |

**Table 9. 11.** Action plans of TPM pillars for the technical language' Optimize the ingredients'.

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | Ensure that all the ingredients are properly mixed, in amount, quality and proportion. |
| Individual improvement | Employees should be trained about the right mix of ingredients to be put in to produce the final product. |
| Quality maintenance | Check for the quality of final output produced for a sample initially and hence ensure that a proper mix is there. This should be followed, if found suitable to the subsequent outputs. |
| Education and training | Employees should be trained about the different materials to be used, the right mix, the proper use of material, etc. |

**Table 9. 12.** Action plans of TPM pillars for the technical language 'Incorporate folding Characteristics'

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | Educate the employees about the need for folding characteristics in mattresses and inspire the employees to be creative in bringing out ideas for facilitating the betterment of the product. |
| Development management | Apply the folding characteristics in to the next design if found feasible and attractive. |

**Table 9. 13.** Action plans of TPM pillars for the technical language 'Better design of die for better pattern'.

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | Educate the need for better designs of patterns to be incorporated in to the mattress. If found feasible, also design the different sizes of the patterns. |
| Development management | Incorporate better die designs in the next manufacturing phase based on the scale of feasibility of the new designs. |

**Table 9. 14.** Action plans of TPM pillars for the technical language 'Variation feasibility of pattern'

| TPM Pillars | Actions recommended |
|---|---|
| Development management | The design variations in the patterns, both in size and shape to be incorporated in to the next manufacturing phase. |

**Table 9. 15.** Action plans of TPM pillars for the technical language 'Dedicated Team'

| TPM Pillars | Actions recommended |
|---|---|
| Individual improvement | Each individual in the team should be fully aware of the different constraints attached to the policies of the company. Sufficient training about subordination of the individual interest for the organizational goals should be given and stressed on |
| Education and training | The assigned team should be trained and educated on the different aspects attached and associated to the different departments and the different levels of the organization. |

**Table 9.16.** Action plans of TPM pillars for the technical language 'Customer relationship schemes'

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | Some training classes have to be conducted to the employees regarding the customers, customer behavior, aspirations and how customers evaluate the product. This will make them to enhance their part of work concentrating on customers. The employees related to the work should be given ample education and training on the feasibility and the acceptance of the different schemes allotted to the customer. |
| Office TPM | The merits and demerits of various schemes and packaging to be allotted for each class of customers can be analyzed. Softwares can be made use in this direction. In addition to that, sufficient planning has to be done for on time delivery, payment collection, discount schemes, free samples and gifts to various classes of customers. Periodic review of various schemes has also to be conducted to find out the best schemes during each business period. |
| Development management | The schemes should be reviewed then and there to avoid mistakes. This can also help to analyze for better schemes available and feasible to the company. |

**Table 9. 17.** Action plans of TPM pillars for the technical language 'Incorporate feasible credit limit'

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | Appropriate training has to be imparted to the employees working in the accounts department to evaluate various customers and benchmark their credit limits. In the current scenario, a lot of well-established techniques are available for this purpose. In addition to that, employees should be motivated to pursue suitable higher studies such as industrial psychology, marketing, and finance. |
| Office TPM | Using computer softwares, the worth of each credit schemes has to be evaluated. Computer based softwares can help to benchmark the credit limits of each client giving inputs from the client's organizational matters and warning signals when it approaches the limit and exceeds the limit. This minimizes the tasks of various decision making regarding credit. |

**Table 9. 18.** Action plans of TPM pillars for the technical language 'Effective supply chain'

| TPM Pillars | Actions recommended |
|---|---|
| Office TPM | Numerous varieties of software are available to manage the supply chain effectively and efficiently. So those should be put into effect with immediate effect. |
| Development management | The supply chain network should be designed and re-designed till a fully self-sustainable design is reached. Thus the company can ensure the effectiveness and efficiency of the network. Target fixation and their revisions in supply chains and continuous revise of the targets achieving each will enhance their efficiency and effectiveness. |

**Table 9. 19.** Action plans of TPM pillars for the technical language 'Effective order management system'

| TPM Pillars | Actions recommended |
|---|---|
| Office TPM | A computer based order management system has to be implemented. Automate order management system, monitor various order, its operating route, the time delays, the carrying capacity etc. |

**Table 9. 20** Action plans of TPM pillars for the technical language 'Sales promotion schemes'

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | Appropriate lectures/ tutorials have to be imparted to the workers on general aspects of marketing, sales, sales promotion and modern schemes available in that direction. The employees should be trained and educated on the schemes available as part of the sales promotion activities. |
| Development management | Redesign the schemes if required, analyze and re-analyze, till a feasible scheme is approvable, to both the company and the customers. |

**Table 9. 21** Action plans of TPM pillars for the technical language 'Better advertisement schemes'

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | Awareness programmes regarding the need of advertising, ineffectiveness and how its reflections and feedback have to be incorporated in production have to be conducted. Employees should be made aware of the schemes available and they should be induced for participation from all levels irrespective of their levels. |
| Development management | The design of the schemes should be analyzed thoroughly, checked for inconsistencies, and if any, should be redesigned, till an optimum and feasible scheme is reached which shall be acceptable to all. |

**Table 9. 22** Action plans of TPM pillars for the technical language 'Discount schemes'

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | The employees should be educated on the various schemes made available and induced to come up with ideas for designing new schemes. |
| Development management | Review the various discount schemes currently adopted by the company. If it is observed that some inadequacies are existing in the schemes, re-design the schemes till an optimum design is reached. |

**Table 9. 23** Action plans of TPM pillars for the technical language 'Scheduling the production'

| TPM Pillars | Actions recommended |
|---|---|
| Autonomous maintenance | The employee must be made aware of the machine capacity and should be able to meet the production schedule. |
| Individual improvement | The employees should be trained to understand and adhere to the schedule strictly. |
| Planned maintenance | Activities related to the maintenance should be planned in advance to minimize breakdowns. |
| Quality maintenance | There should be quality plans and policies, which should be adhered to, so that wastes are reduced and production is improved. |
| Office TPM | There are many softwares available for the purpose of keeping a check on planning and scheduling. The best among them should be incorporated for enhancing its effectiveness. |
| Education and training | The employees should be trained about the scheduling process, its need and importance, and the essence to stick to it. |

**Table 9. 24** Action plans of TPM pillars for the technical language 'Optimization of stock'

| TPM Pillars | Actions recommended |
|---|---|
| Individual improvement: | The various pros and cons of the existing inventory policies followed in the company and the best strategies to be adopted for the inventory reduction should be made known to the employees. Also, the hidden costs associated with improper utilization of the inventory should be exposed to the employees. They should be motivated to reduce inventory levels. |
| Education and training | Training classes have to be conducted on materials management. Principles like ABC analysis has to be taught to the employees. They should be imparted training on Six Big Losses and better inventory management methods. The employees should be trained about the different levels of optimum stock and its importance to the company. |
| Office TPM | Numerous softwares are available, to monitor the stock levels and re-order points for inventory. These should be incorporated to enhance the efficiency and effectiveness of stock management. |

**Table 9. 25** Action plans of TPM pillars for the technical language 'Better packaging material (with regard to both thickness and folding feasibility)'

| TPM Pillars | Actions recommended |
|---|---|
| Development management | The design changes related to packaging, if found feasible should be incorporated into the new schedule of production. As a trial basis, some better packing materials can be incorporated and tested. Based on the results, further refinements can be done. Incorporating low packing material makes the transformation easy. |
| Education and training | Employees should be trained on various packing methods, safe loading and unloading methods. Few classes and practical sessions have to be conducted for ensuring better utilization of chain blocks, hoists and max pullers. |
| Safety, health and environment | It should be made sure that the packaging material is eco-friendly and doesn't cause any health hazards. |

**Table 9. 26** Action plans of TPM pillars for the technical language 'Cost reduction strategy'

| TPM Pillars | Actions recommended |
|---|---|
| Education and training | Training has to be imparted to the employees on various cost aspects and their impacts to the company. They should also be trained on the various methods to reduce the cost. |
| Quality maintenance | In order to maintain the cost at the most optimum level, the rejection rate should be minimized to the lowest level. Company has to adopt strategies to prevent reworks. The wastages in men, money, material and machinery have to be analyzed in each process and actions have to be taken to minimize them. |
| Planned maintenance | The maintenance aspects should be planned to make sure that the maximum capacity of the plant is utilized. Most of the preventive maintenance activities will be held during off peak season. |

## 9.9. Success of the MQFD implementation

The technical requirements evolved out of the implementation study could not be implemented in this mattress-manufacturing unit. RUBCO being an Indian state government run public sector, the decision on implementing MQFD has to be made by the top level committee which has to adhere to long democratic procedures. Moreover, the competent personnel were not interested to spend time to forecast the chance of succesful implementation of MQFD in RUBCO. Hence, the chance of succesful implementation of MQFD could not be exactly assessed.

## 9.10. Conclusion

The implementation possibility of MQFD was checked in RUBCO, which is an Indian state government run public sector mattress manufacturing unit. Since TPM and QFD had not been implemented, the competent personnel of RUBCO could not nourish the implementation aspects of MQFD. However, the experience of developing HoQ and passing of technical descriptors through TPM pillars indicated the practical implementation feasibility of MQFD model even in non conventional manufacturing units like RUBCO.

Chapter · 10

# QUALITY IMPROVEMENT IN ENGINEERING EDUCATION THROUGH MQFD

*Content*

# QUALITY IMPROVEMENT IN ENGINEERING EDUCATION THROUGH MQFD

## 10.1. Introduction

The ever-rising global competitive waves keep invading all fields and geographical regions. This phenomenon has been pressing mankind to infuse higher degree of quality in all spheres of products, processes and services (Prendergast.et.al ,2001,Chong and Rundus, 2004). The knowledge required for attaining higher degree of quality originates from the brains of human resources. Hence a society can enjoy higher degree of quality of life, if its human resources are effectively groomed and developed. The responsibility for contributing highly useful human resources for the welfare of the society of all regions lies with educational institutions. Today globalization process progresses at a faster pace making the humans face common challenges irrespective of the societies and countries to which they belong (Irandoust And Sjoberg, 2001). In most of the societies these challenges are largely tackled by engineering professionals (Paten et.al, 2005). Hence, a large portion of social contribution originates from engineering educational institutions (Johnston,2001). Needless to mention, the engineering educational institutions have to contribute high quality human resources who are not only technocrats but also society-friendly individuals (Perez-Foguet et.al, 2005). While the business world has been reporting the adoption of different continuous quality improvement models (Kaye and Anderson,1999), the examination of their application feasibility for infusing higher degree of quality in engineering education will lead to useful contribution to all kinds of societies over the globe(Johnston,2001).

Total quality management (TQM) models have revolutionized the organizations of all types (Chong and Rundus, 2004, Hoque, *2003*,Montes.et.al,2003). Presumably due to this reason, during the recent years, some engineering educationalists and researchers have been striving to apply TQM and its techniques in engineering education (Sahney et.al,2004). Some engineering educational institutions have started practising TQM

(Jaraiedi and Ritz,1994, Prendergast.et.al ,2001,Swift,J.A, 1996). These efforts are getting focused on attaining specific strategies. For example, the engineering educational institutions are becoming quality system conscious since many of them have implemented ISO 9001: 2000 quality system standard. Likewise Hwarng and Teo, (2001),and Lam and Zhao, (1998) have reported the pilot implementation of quality function deployment (QFD) in engineering education. These efforts have yielded in achieving higher degree of quality in administering engineering educational institutions, testing the students' capabilities to meet the requirements of their employer and building excellence in the learning of engineering advancements (Ferrer-Balas et.al, 2004). These favorable results indicate that, on application of well-proven quality engineering and management models, the quality level of engineering education would raise. In this context, this chapter brings into focus the contribution of total productive maintenance (TPM) and QFD in practising environments.

Both TPM and QFD have played valuable roles in achieving continuous quality improvement in organizations (Emiliani, 2004). Both researchers and practitioners have reported a large number of successful case studies on TPM (Chan. et.al, 2005,Eti. et.al, 2004) and QFD (Hwarng and Teo, 2001). Because of their success in practical environments, the research on the application of TPM and QFD engineering education promises valuable outcome. In this background, the author was motivated to examine the roles of TPM and QFD in attaining higher degree of quality in the engineering educational scenario. Besides, a careful study indicated that the synergising effect of implementing TPM and QFD together would trigger a significant stride in attaining higher degree of quality in engineering education. However, it appears that no researcher or practitioner has so far attempted to link these two techniques and apply them in the engineering educational scenario. This chapter reports a research project through which the author attempted to makeup for this deficiency. First, the author is presenting the salient features of applying TPM and QFD in engineering education with the anticipated impacts. Next, the author is describing the design of a model called "Maintenance Quality Function Deployment"(MQFD). This model combines TPM and QFD principles. Followed by that, the author has presented a survey in which he has examined the receptivity of applying MQFD in Indian Engineering Educational scenario.

## 10.2.Quality of engineering education

The various quality eras which have been revolutionalising the organizations of all types and sizes during the past five decades (Kaye and Anderson,1999) have their foundation on the preaching of quality gurus (Bendell et.at,1995). But quality gurus have attributed different meanings and definitions to quality. For example, Juran has referred to quality as 'fitness for use'. Taguchi has viewed quality as the loss that it imparts to the society. Upon drawing inferences from these definitions, the author interpreted that quality of engineering education would refer to the production of human resources who are capable, contributive and adaptive in required to the advancements and usefulness to the society (de Graaff and Christensen,2004).The engineering educational institutions failing to understand this definition will be fading away from the modern competitive scenario (Veltz, 2001). This shows the need for rigorous application of continuous quality improvement concepts in engineering educational institutions. Besides achieving higher degree of quality levels, recent researchers have been appraising the need for sustaining engineering education (Ashford, 2004, Ferrer-Balas et.al, 2004). The sustainability of engineering education is ensured by maintaining the quality of engineering education. TPM provides a way for bringing out such kind of changed scenario in engineering education. Another requirement of engineering education is to react according to its customers. In practical application, the technique QFD is found to meet this requirement. Hence the application feasibility of QFD in engineering educational scenario has to be studied. However both TPM and QFD cannot be applied in their present forms in engineering education since they are compatible with applications only in manufacturing and service organizations. In order to accomplish this process, both QFD and TPM have to be remoulded in a systematic way, so that they are made suitable for application in engineering educational scenario.

## 10.3.TPM and engineering education

TPM originated in Japan during 1970 (Cooke 2002, Ireland and Dale 2001). Before the evolution of TPM, the field of maintenance engineering had been adopting technology oriented approaches like condition monitoring, preventive maintenance and reliability centered maintenance (Deshpande and Modak,2002, Eti.et.al, 2004,). Presumably, on realizing the absence of human and totality components in the maintenance engineering field, the principles of TPM were promoted by Japanese Institute of Plant Maintenance (JIPM) (Bamber et.al 1999). Later it spread to different parts of the world. Fundamentally TPM encompasses various elements of TQM and maintenance engineering. Besides there have been researches linking TPM with quality (Ben-Daya and Duffuaa, 1999). Because of the shadowing of TQM, TPM envisages the total involvement of employees for enhancing the maintenance quality of equipments (Cooke 2000, Ireland and Dale, 2001). Several definitions and approaches of TPM have so far been brought out (Bamber et.al, 1999) in the literature arena. A bird's eye view of those literatures would indicate that eight-pillar approach of implementing TPM is the most exhaustive one (Yamashina, 2000; Cigolini and Turco, 1997). Maintenance engineering and total quality control form the foundation of TPM programme. After laying this foundation, TPM programme is developed by constructing the eight pillars (Ahmed et.al, 2005). Hence, the examination of applying TPM in the engineering educational scenario is to be carried out by studying the implementation of the eight pillars in it. But, TPM pillars are highly biased towards manufacturing aspects and hence cannot be adopted in their current form into the engineering educational scenario. Therefore TPM pillars need to be suitably moulded for implementing them in the engineering educational scenario. The modalities of transferring TPM pillars from the manufacturing context to the engineering educational context are briefly appraised in the following subsections.

### 10.3.1. Autonomous maintenance

In the manufacturing scenario, this pillar envisages the development of a sense of ownership among workers of the equipment operated by them. The transfer of this pillar into engineering educational scenario would emphasize the empowerment of the employees and students over the curriculum they study and the infrastructure they use. This means that the employees and students have to participate in curriculum development. Also, during the course of teaching-learning process both communities are to be facilitated to explore the theory and practice of curriculum in engineering application. Likewise the ownership rights on infrastructure of both employees and students should be distributed and both communities should strive to use the infrastructure for imbibing engineering skills and knowledge (Gelfand,2005). This process would lead to the generation of enormous creative ideas. The development and management of knowledge through creative ideas are the hallmarks of today's competitive scenario. Hence the building up of this pillar would ensure the enhancement of the quality of engineering education.

### 10.3.2. Individual improvement

In the manufacturing scenario, this pillar motivates the worker to improve himself/herself in such a way that he/ she attains capability to attend independently to the maintenance failures. He/she must also learn to analyze the cause of maintenance failures using tools like why-why analysis and performance measurement analysis (Malina and Selto,2004). These aspects translate into the engineering educational scenario in the form of helping both employees and students to develop required skills of knowledge of their own. In other words, this pillar of TPM envisages the development of self-learning capabilities of not only students but also employees. This is a valuable exercise in today's context, because even after a student completes the course of study and leaves the engineering educational institution, enormous developments take place in the engineering profession (Perkins, 2002). In this situation, the same student, after getting employed, is also required to learn further (Horvath et.al,2003). At that point of time, the individual improvement of capabilities acquired through self-learning will prevent him/her from becoming an obsolete person in the society. The condition is the same in the case of employees. The employees with certain knowledge and skill-sets recruited at an early time need to be exposed to the latest advancements in future. However, it is the arduous task in practice to conduct a number of educational and training programmes for the employees for keeping them updated with knowledge and skill-sets. In this situation, the employees possessing self-learning traits will be able to exhibit individual improvement capabilities. This kind of individual improvement capability of employees will be of use in providing the students of engineering educational institutions with updated knowledge and skill sets.

### 10.3.3. Planned maintenance

In the manufacturing scenario, this pillar is built by drawing maintenance schedule in advance. Besides, this pillar envisages the allotment of sufficient resources to meet the planned schedule. The translation of this aspect into the engineering educational scenario would mean the development of a calendar containing not only the routine activities, but also the developmental activities such as field visits, expert lecturers, conduct of conferences and demonstration of new products. However, such a calendar of activities must be prepared in accordance with the resources that the management is prepared to invest. Further in the manufacturing scenario, the planned maintenance needs to control maintenance costs and estimate equipment losses. The enumeration of these losses and translation of them into the engineering educational scenario are prescribed in Table 10.1. The elimination or reduction of these losses would lead to the enhancements of the quality of education in engineering educational scenario.

**Table 10.1** Six Big Losses in engineering educational scenario

| | Equipment losses | Six Big Losses in engineering educational scenario |
|---|---|---|
| 1 | Breakdown losses | Cancellation of classes, Field visits etc. |
| 2 | Setup and adjustment losses | Newly enrolled students get admission into some other courses leave the present course |
| 3 | Minor idling stoppage losses | Infrastructure is not adequate and strengthened to ensure that the classes and the practice sessions are held without interruption. |
| 4. | Reduced speed losses | The coverage of syllabus and technical sessions are not at the pace planned. |
| 5. | Defect/ Rework | Conduct of extra and special classes for the students who have failed in theory and practice tests and examination. |
| 6. | Startup losses | Students not exposed to fundamental principles and language skills fail to perform in written tests and examinations |

### 10.3.4. Quality maintenance

In the manufacturing scenario, the building of this pillar is made possible by inculcating the zero defect philosophy in the organization. The translation of this aspect in the engineering education scenario envisages the succesful completion of the course by all the students within the prescribed stipulated time and all of them being offered suitable jobs by the companies even before they complete the course.

### 10.3.5. Education and Training

In the manufacturing scenario, this pillar emphasizes the imparting of education and training to all levels of employees. This corresponds in the engineering educational scenario to the development of educational and training programmes for all levels of employees. For example, a teacher handling topics on welding technology should be provided with practical training on welding. Likewise the laboratory assistants in the welding department should be educated on the theoretical principles of welding. The merging of theory and practice through engineering education and training would enhance the quality of education in the engineering educational scenario.

### 10.3.6. Office TPM

As the title implies, this pillar envisages the attainment of a higher degree of quality in office administration. The adoption of this pillar will be very useful in the engineering educational scenario because engineering educational institutions are dominated by administrative activities like admission of students, fee collection, conduct of tests, evaluation of answer scripts and consolidation of marks. (Ko and Cheng, 2004). According to this pillar, the employees and students of engineering educational institutions should be relieved of the burden that arise due to the administrative hurdles. In fact, the administration must be supportive in enhancing the quality of the products produced by engineering educational institutions.

### 10.3.7. Initial control/Development management

In the manufacturing scenario, this pillar emphasizes the review of designs for preventing further mistakes, use of manufacturing process data and establishment of equipment startup times. This aspect in the engineering educational scenario translates into the reviewing of curriculum, use of the feedback received from both students and employees and establishment of administrative practices and teaching-learning process for ensuring the delivery of quality products. These data have to be referred to while developing and managing appraisal programmes and upgradation activities.

### 10.3.8. Safety, health and environment

Current researchers are attributing greater value to the synergy of Safety, Health and Environment (SHE) (Cowing et.al, 2004,Deshpande and Modak,2002, Abe and Starr, 2003, Atherton,2002, and Duarte, 2004). Appropriate implementation of safety aspects can enhance the sustainability of the whole system (Graber, 2004). This enunciation has given rise to the modern manufacturing concepts like green manufacturing and cleaner manufacturing. In the absence of safety and health, accidents will occur, which can result in catastrophic and irrecoverable failures causing large financial, human, and environmental losses. Therefore SHE has to be in built as a culture (Farrington-Darby et al,2005) in organization of all types. For this purpose, as envisaged by the researchers like Allen-Gil,et.al, (2006), Ashford et.al, (2004) Fenner et.al , (2005), Lundholm, (2005), Lourdel, et.al, (2005), and Bryce.et.al, (2004), the students of engineering educational institutions should be taught the ethics of preventing the environmental degradation as a result of their contributions. Further the consciousness of safety and health has to be instilled in to the minds of the students. Further, this pillar envisages the setting up of safety devices and teaching of safety principles while undergoing practice sessions by these students. This pillar also insists on installing medical facilities in engineering educational institutions. In order to ensure the psychological health of both employees and students, counseling centers have to be installed in engineering educational institution (Rajan, 2005).

## 10.4.QFD and Engineering Education

Ideally, soon after the completion of courses, students should be capable of working in companies (Andersen, 2004). But, this is not happening in practice (Zairi, 1992, Sardana and Arya, 2003). Engineering education has traditionally concentrated on preparing students for professional careers in manufacturing and construction, but now those industries employ fewer engineers than ever before (Wei,2005). In order to meet this deficiency, the engineering educational system has to be modified to suit the requirements of its customers, who are primarily the companies employing the engineering students. In this context, the voice of the customers plays an important role. The voice of the customers will be in the form of their wants and needs, which shall have to become drivers of engineering educational development. These drivers shall have to envisage the engineering education to produce the products, which are acceptable to the customers. However, this challenging task has to be accomplished in accordance with the desires of the customers of engineering education in an economical manner. In this background, the usefulness of the technique QFD for enabling the accomplishment of the above engineering educational challenges is appraised here. For this purpose, the QFD matrix shown in Figure 10.2 has been developed by observing the current engineering educational scenario and drawing inferences from general and engineering educational environment. The contents of six sections of QFD matrix (Zairi and Youssef,1996, Chein and Zu,2003) developed to evolve solutions in response to the customers' voice in the engineering educational scenario are briefly described in the following subsections.

### 10.4.1. Section 1:Customer requirements (Voice of Customers)

The QFD matrix development process begins by considering customer requirements as inputs. An engineering educational institution has to find the potential customers, and determine their tastes and views (Sardana and Arya,2003, Irandoust. and Sjoberg.,2001). By gathering the necessary data regarding the desires of customers, technical remedies can be found out. The aspirations and expectations of the students joining the engineering educational institutions, their parents and the companies appointing the engineering graduates have to be ascertained. This has to be carried out by employing questionnaire based surveys, personal interviews and brainstorming sessions. This section of QFD shown in Figure 10.1 has been incorporated with possible outcomes of this exercise.

### 10.4.2.Section 2:Technical languages

This section shows how the customers' vague languages can be interpreted in terms of technical languages. As shown in Figure 10.1, in the engineering educational scenario, this has to be achieved through the employment of highly qualified and experienced employees, enhancement of qualification and experience of existing employees, development of value based curriculum, and conduct of industrial visits, in plant training etc.

### 10.4.3.Section 3:Relationship matrix

This matrix shows the relation between sections 1 and 2. Such relationships are graded as strong, moderate and weak. As shown in Figure 10.1, they are represented using three symbols. For the purpose of analyzing further, they are assigned values. The relationship symbols used and the values assigned are shown in Table 10.2. (Lu and Kuei, 1995, Perk, 2003).

**Table 10.2** Symbols representing the relationships and their values

| Relationship | Symbol | Value |
|---|---|---|
| Strong | ■ | 9 |
| Moderate | ▲ | 3 |
| Weak | ● | 1 |

### 10.4.4.Section 4: Prioritizing customer requirements

Among all customer requirements, one of the most crucial has to be considered for further analysis. Hence it is necessary to prioritize the customer requirements using a suitable quantification methodology. In the section 4 of QFD shown in Figure 10.1, the 21 customer requirements are prioritized in the descending order. Accordingly, the highest prioritized customer requirement is given the number 21.The lowest prioritised customer requirement is given the number 1. As shown in Figure 10.1, the customer requirement "Technical knowledge" is given the maximum priority value 21 and the customer requirement "Fees structure" is given the value 1.

### 10.4.5. Section 5. Prioritizing Technical remedies

Like in the case of customer requirements, due to several type of constraints, all the technical remedies cannot be considered for implementation in the engineering educational scenario. This is a very crucial point because engineering education is several decades old and has spotted a niche in almost all societies of the world (Wei,2005). Therefore, many technical remedies cannot be promulgated within a short period. Therefore the technical remedies have to be prioritized based on their importance and feasibility of implementation. The section 5 of QFD shown in Figure 10.1 provides a means to carryout this task. As shown, the highest prioritized technical remedy is 'motivation' and the lowest prioritized technical remedy is 'attractive brochure'. However, prioritizing of technical remedies has to be made by considering the correlation and the relationship metrices.

### 10. 4.6. Section 6: Correlation Matrix

This matrix is developed with a view to showing the correlation between different technical requirements. Many technical requirements will have relationships among other with different degrees of correlation. The degree of correlation is categorized as strong, moderate and weak, depending on their intensity. The same symbols and values used for denoting relationships have been used to compile section 6 of the QFD shown in Figure 10.1.

In order to quantify the relationships and correlate using numerical values, the pattern followed by Lu and Kuei (1995) for quantifying the relationships was used. Accordingly, the values 9, 3 and 1 were assigned to strong relationship/ correlation, medium relationship/ correlation, and weak relationship/ correlation respectively. No values were assigned against blank cells. These values were used to compute Customer-technical interactive scores and weighted correlated values. As a sample, the method of calculating Customer-technical interactive score is illustrated here by considering the technical language "motivation". The relationship of customer voices namely 'technical knowledge', against 'motivation' is indicated by the symbol ■ whose value is 9. While the relationship of 'repeated breakdown' with 'good result' is denoted by the symbol, ● whose value is 1.The customer technical interactive scores have been calculated as follows:

Formula:

$$\text{Customer technical interactive score} = \sum_{i=1}^{n} \text{Relationship values between customer voice and technical languages} \times \text{Expected value of customer voice}$$

Where 'n' refers to the number of customer voices.

Example: Customer technical interactive score for 'qualified and experienced staff' = $9\times57 + 3\times10 + 1\times4 = 547$

In order to visualize the relative weightages, the percentage normalized value of customer technical interactive scores has been computed as follows.

Formula: Percentage normalized value of customers' technical interactive score

$$= \frac{\text{Customer technical interactive score}}{\text{Sum of customer technical interactive score}} \times 100$$

Example: Percentage normalized score of customers technical interactive score against the technical voice 'qualified and experienced staff' = $(547/3832)\times 100 = 14.27$

These computed scores are displayed in Table 10.3. The weighted correlated value is calculated by summing the values of correlations. As shown in Figure 10.1, the weighted correlated value against the technical parameter "excellent coaching" is 12.03.

In order to visualize the relative weightages of technical correlation, the percentage normalized value of correlated weights has been calculated using the following formula.

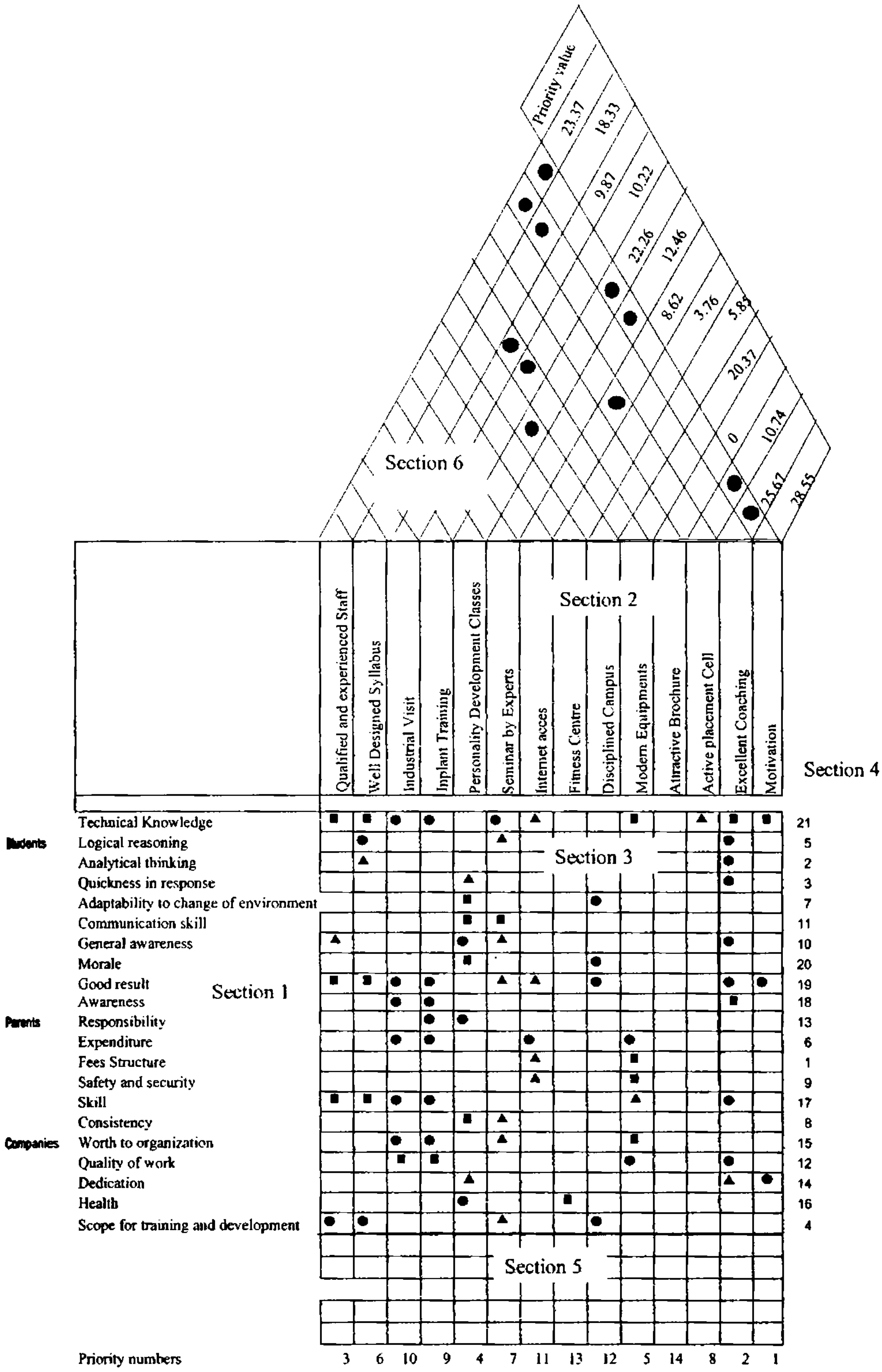



Figure 10.2 House of Quality Matrix

Percentage normalized value of correlated weightage =

$$\frac{\text{Correlated weightage of the technical language}}{\text{Sum of Correlated weightages}} \times 100$$

Example: Percentage normalized correlated weightage against the technical parameter 'motivation'= 5/22 × 100 =22.73

**Table. 10.3. Computed scores of technical parameters of house of quality**

| Serial Number | Technical descriptors | Customer technical interactive score (1) | Percentage normalized value of customers technical interactive score (2) | Correlated weightage of the technical language (3) | Percentage normalized value of correlated weightage (4) | Priority value (2)+(4) |
|---|---|---|---|---|---|---|
| 1 | Qualified and Experienced employees | 547 | 14.27 | 2 | 9.1 | 23.37 |
| 2 | Well designed curriculum design | 528 | 13.78 | 1 | 4.55 | 18.33 |
| 3 | Industrial visits | 204 | 5.32 | 1 | 4.55 | 9.87 |
| 4 | In plant training | 217 | 5.67 | 1 | 4.55 | 10.22 |
| 5 | Personality development classes | 504 | 13.16 | 2 | 9.1 | 22.26 |
| 6 | Seminar by experts | 303 | 7.91 | 1 | 4.55 | 12.46 |
| 7 | Internet access | 156 | 4.07 | 1 | 4.55 | 8.62 |
| 8 | Fitness center | 144 | 3.76 | 0 | 0 | 3.76 |
| 9 | Disciplined Campus | 50 | 1.3 | 1 | 4.55 | 5.85 |
| 10 | Modern equipments | 432 | 11.27 | 2 | 9.1 | 20.37 |
| 11 | Attractive brochure | 0 | 0 | 0 | 0 | 0 |
| 12 | Active placement cell | 63 | 1.64 | 2 | 9.1 | 10.74 |
| 13 | Excellent coaching | 461 | 12.03 | 3 | 13.64 | 25.67 |
| 14 | Motivation | 222 | 5.82 | 5 | 22.73 | 28.55 |

Both percentage normalized score of customer technical interactive score and percentage normalized value of correlated weightage have been added and entered in the correlation matrix (section 6) of QFD shown in Figure 10.1 and are termed as total normalized values. The inference drawn from the QFD presented in Figure 10.1 is that the technical requirements shown in Table 10.4 are to be fulfilled in response to the customers voice according to the indicated order of priority values.

**Table 10.4** Technical requirements of Engineering education

| Technical requirements | Priority numbers | Priority value |
|---|---|---|
| Motivation | 1 | 28.55 |
| Excellent coaching | 2 | 25.67 |
| Qualified and Experienced staff | 3 | 23.37 |
| Personality development classes | 4 | 22.26 |
| Modern equipments | 5 | 20.37 |
| Well designed syllabus | 6 | 18.33 |
| Seminar by experts | 7 | 12.46 |
| Active placement cell | 8 | 10.74 |
| In plant training | 9 | 10.22 |
| Industrial visits | 10 | 9.87 |
| Internet access | 11 | 8.62 |
| Disciplined Campus | 12 | 5.85 |
| Fitness center | 13 | 3.76 |
| Attractive brochure | 14 | 0 |

## 10.5. Synergizing TPM and QFD through MQFD

The previous sections dealt with the power of TPM in enhancing quality of products and the capability of QFD in translating customer languages into technical languages in the engineering educational scenario. However, both TPM and QFD principles lack linking mechanisms to avail the synergic power of them. In order to fill this lacuna, the author proposes here a model called MQFD. Its conceptual features are depicted in Figure 3. As shown, the performance of an institution will be heard through the voice of customers. Those voices of customers are used as the inputs to develop the house of quality. The house of quality has to be built by the QFD team. The outputs of house of quality, which are in the form of technical languages, are submitted to the top management for making strategic decisions. This step becomes necessary because researchers have established the need for applying strategic approach in both QFD (Lu and Kuei 1995) and TPM (Tsang 1998; Murthy et.al.,2002) projects for ensuring their success. The technical languages which are concerned with enhancing maintenance quality are strategically directed by the top management for applying eight TPM pillars on them. The TPM characteristics evolved through the development of eight pillars are fed into the production system, where their implementation focuses on increasing the values of the maintenance quality parameters. The outputs from production system are required to be reflected in the form of improved maintenance quality, increased profit, upgraded core competence, and enhanced goodwill (Al-Najjar, 1996). All the quantified values of these outputs are used for developing another house of quality and comparing with set targets. Now the next cycle begins. Thus implementation of MQFD model is a never-ending continuous improvement process. A unique feature of MQFD model is that it does not envisage any change or dismantling of the existing structure of house of quality and TPM. Therefore, even if an organization has already been applying TPM and QFD, it is possible to superimpose MQFD on its environment. Thus MQFD model enables the tactical marriage of QFD and TPM.

## 10.6. MQFD in Engineering Education

MQFD in an engineering educational institution has to begin by forming a team of seven to eight teaching and supporting employees from different departments. This MQFD team shall be headed by a senior teaching employee. The responsibility of MQFD team is to find out the voice of customers through different media and convert them into technical languages. This is accomplished by building the house of quality. The output of the house of quality will be submitted to the decision makers of the engineering educational institution to make decisions at the strategic level. Some outputs of house of quality would be so simple that they could be implemented without any difficulty. For example, making the time schedule for conducting any course does not require much strategical effort. Such kind of outputs of house of quality can be implemented at this stage. However while implementing them, close watch will have to be kept to examine whether they align with the goals of the engineering educational institution. If required, some modifications will be done based on the suggestions at tactical level. Some of the outputs of house of quality are so complex that they would require critical thinking and analysis at the strategic level. Those outputs shall have to be directed towards the eight TPM pillars of MQFD model. The results obtained have to be processed by the production module of MQFD model. Production can be equated with the teaching learning process in engineering education. As shown in Figure 10.2, this process has to be designed to fulfill the following requirements of engineering education.

- Increasing the percentage of engineering students getting employed before and after completing their courses
- Increasing the percentage of students passing engineering
- Increasing the number of companies aspiring to recruit students
- Increasing the performance quality of employed students
- Decreasing the percentage of students giving up / stopping the course of study before completion and
- Increasing the availability of qualified and experienced teachers.

One cycle of MQFD implementation will lead to the sustained development of engineering educational institution the results of which will be reflected in the following forms:

- Higher accreditation score
- Raising of surplus funds
- Increased core competencies (Irandoust And Sjoberg, 2001) and
- Enhanced goodwill of engineering education.

The rationale behind the achievements of the above are narrated here. Today in many societies accreditation system is installed to assess the performance of engineering educational institutions. These systems make use of scoring scheme. Higher score indicate higher degrees of quality of education offered by the engineering educational institution. When the quality of employees and students improves, students are willing to pay higher fees for the courses offered by the engineering educational institution. Likewise, companies will also be seeking the help of students and employees to solve practical problems and execute the project by paying the fees. These developments will lead to the raising of surplus funds, which can be used for further development of the engineering educational institution. On the application of MQFD, the hidden talents will be reflected in the form of core competencies of the engineering educational institution. Achievement of these excellences will lead to higher reputation of the engineering education offered by the institution among its customers. Thus MQFD would help the engineering education achieve success, which is found eluding in the societies of various parts of the world (Zairri, 1992). The attractive aspect of MQFD implementation in engineering education is that its implementation does not require much financial investments. Rather, many refinements are possible with slight modifications in the currently followed practices to make the products of engineering education acceptable to their customers.

## 10.7. Implementation Strategies

Successful implementation of MQFD model in engineering education needs the wholehearted cooperation of all personnel in the institution. In order to accomplish this task, a step-by-step approach has to be adopted. After witnessing the emergence of several technological and management models during the last three decades, today the global community examines the reasons for their failures. This implies that many models have suffered failures. In some cases they have even met the fate of extinction. Hence a foolproof set of implementation steps pertaining to MQFD application in the engineering educational scenario is presented in the following subsections. The rationale behind suggesting these steps is also narrated in these subsections.

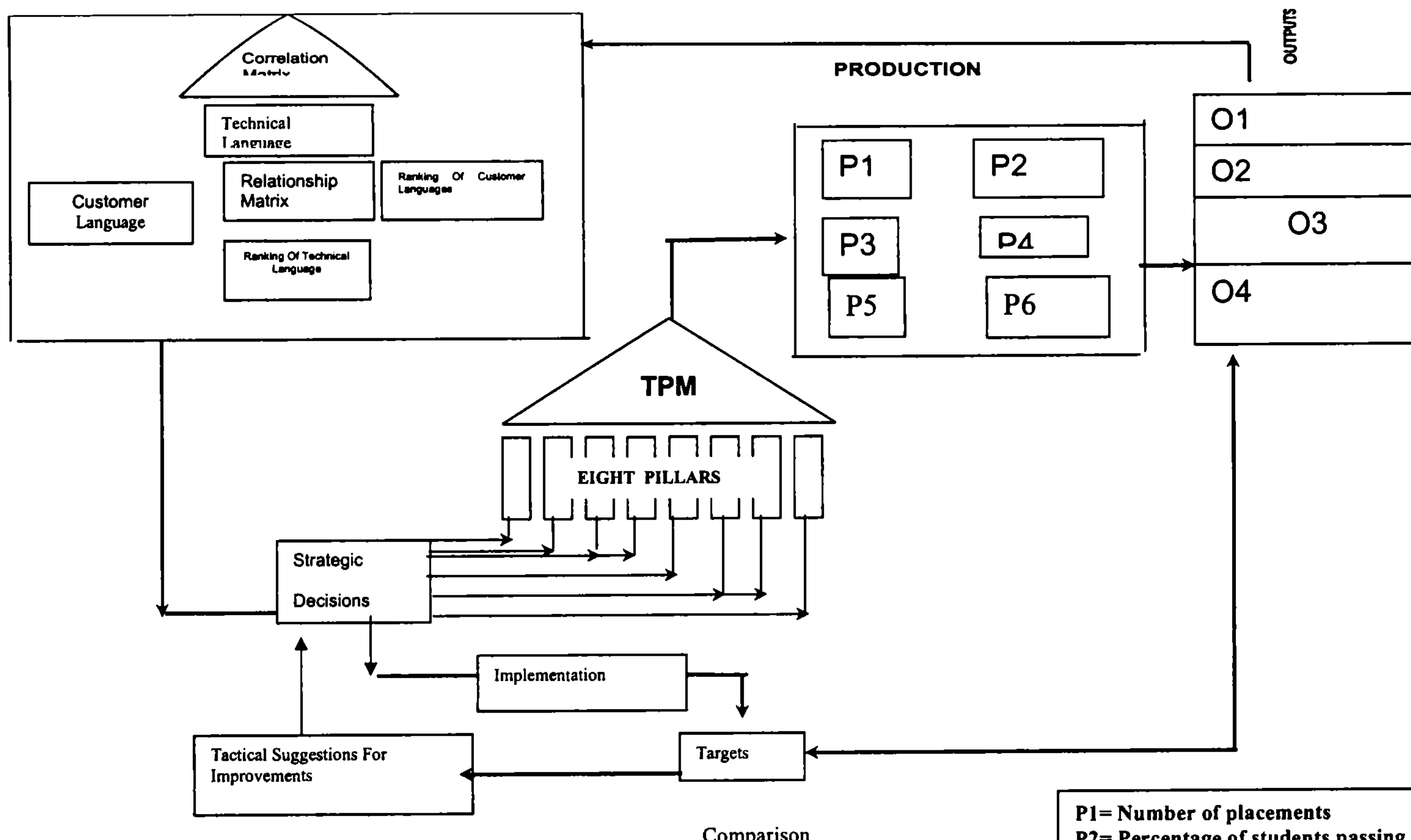



Figure 10.2

**MQFD Model for Engineering Education**

**O1=Higher accreditation score**
**O2=Increased Surplus Fund**
**O3= Increased Core competence**
**O4=Enhanced Goodwill**

**P1= Number of placements**
**P2= Percentage of students passing**
**P3= Number of companies visiting**
**P4= Performance quality**
**P5= Number of students leaving course**
**P6= Availability of qualified and experiencedteachers**

### 10.7.1 Step 1

MQFD experts have to convince the management and the Principal/ Director of the engineering educational institution of the benefits that can be reaped through its implementation. This exercise has to be carried out by organizing seminars and brainstorming sessions with the involvement of management personnel, representatives and the Principal.

#### 10.7.1.1 Rationale

The vitality of top management support and commitment for the successful implementation of both TPM and QFD models have been well established in literature (Emiliani, 2005; Kaye and Andersen, 1999; Cooke, 2000; Kathawala and Motwani, 1994). The core requirement of the above seminar and brainstorming sessions is to convince the top management of the benefits to be achieved by implementing MQFD and to ensure their commitment and ownership to it. Similar emphasis is made in Chan et.al (2005) while enumerating the twelve steps for the TPM implementation programme. As many seminars and brainstorming sessions are being held in an engineering educational institutions by different professional bodies, this exercise would not be a difficult task. However, convincing the decision makers of the implementation of MQFD in the engineering educational scenario depends on the competencies of MQFD experts.

### 10.7.2. Step 2

Management and the Principal have to announce the implementation of MQFD as a policy. They have to state the objectives so that they can reach all personnel in the institution. Different types of educational campaigns have to be conducted for the personnel at different levels in order to make them fit to attain MQFD objectives.

#### 10.7.2.1.Rationale

The rationale of this step is that top management personnel become cautious while embarking on any new programme. At the same time, they will be attracted to the models, which will lead to sales and revenue increase. The same approach has been adopted by Ghobadian and Terry (1995) while describing the implementation of QFD in a company by name Alitalia. A similar step is envisaged under the name 'focus group brainstorming' in Pun et.al (2000) and Chin et.al (2001). During this stage, the problem of resistance to change can be sensed. This has to be tackled using appropriate change management approaches (Ferrer-Balas et.al, 2004). There will be another bottleneck which has to be overcome. Conducting different types of educational campaigns for different categories of people will be expensive. Hence a suitable educational campaign has to be designed which is economical and reachable to as many personnel as possible.

### 10.7.3 Step 3

A MQFD team consisting of 7-8 members of different departments may have to be formed. They have to meet once in a week and draw out plans for the implementation.

#### 10.7.3.1 Rationale

The individual knowledge will be too narrow and self centered for adoption in real time environments. A team effort is required to make superior decisions (van der Wall and Lynn , 2002). When members from different departments join, practically compatible continuous improvement results will emerge (Chan. et.al, 2005). The synergic combination of multi-disciplinary efforts will lead to very valuable decisions(Ollero, et.al., 2002). Quite interestingly, the formation of a team is envisaged while implementing both TPM and QFD principles (Ireland, and Dale ,2001, Rahim, and Baksh, 2003, Tsang, and Chan, 2000). Hence the team shown above is formed while implementing MQFD, which has to be done with care (Balthazard, and Gargeya, 1995).

After the formation of MQFD team, the management shall support its effective functioning by providing the required resources. One among them is the management's willingness to allot a certain time during the working hours for conducting MQFD meetings. In order to fulfill this requirement, while implementing MQFD, the management shall help by earmarking one or two hours in a week for MQFD members' meeting. Similar appraisal has been made by Bamber et.al (1999) who has cited 'time allocation' as one of the factors affecting successful implementation of TPM. When MQFD gains momentum, a section of the management and employees may feel sceptic about its fruitful results. This feeling may emerge in the form of resistance to change. In order to mitigate these reverberations on MQFD, a seminar explaining its features and expected benefits to be reaped by the institution is required to be conducted. Similar observations have been reported by Ireland and Dale (2001). Also, the step like the above has been suggested with regard to the implementation of TPM in a company in T Sang et.al (2000). This is a feasible exercise in engineering educational institutions. As members from different departments join, many new ideas will emerge. The synergic effort will lead to very valuable decisions that would aid in effecting continuous quality improvement of engineering education.

### 10.7.4. Step 4

Customer languages in engineering educational scenario have to be identified. For this purpose the feedback of parents, alumnis and the employers who have employed aluminis has to be rigorously and regularly entertained.

#### 10.7.4.1. Rationale

Identifying customer language is a difficult exercise. The different sources and channels are to be tactically tapped and traced to gather customer languages. MQFD team has to adopt suitable methodologies to identify the above customer languages. For this purpose the MQFD team may refer to the methodologies reported in article like Chin.et.al (2001), Kumar and Midha (2001), Ghobadian and Terry.(1995) and Pun et.al(2000). The difficulty of carrying out this exercise in the engineering educational scenario is multifarious. The customers of engineering education are large in numbers and varied in types. Hence interviewing them to gather the customer languages of engineering education will be a cumbersome exercise. If necessary, some other suitable methods will also have to be evolved.

### 10.7.5. Step 5

Customer languages shall have to be ranked based up on their importance. This can be done by making use of the experience and views of the management and employees.

#### 10.7.5.1. Rationale

Prioritization has been an accepted practice in several fields. For example, Juran and Gryna (1997), recommend the use of Parato analysis to identify the vital few quality problems. Likewise, the field of inventory management uses ABC analysis to prioritise the materials as A, B and C categories (Zomerdijk, and Vries, 2003). Hence, MQFD implementation would be more result oriented if customer languages are ranked and considered according to their priorities. However, the choosing of appropriate metrics and scales for ranking customer languages of engineering education would be a challenging task because, meeting the requirements of varied types of customers is a difficult task in the engineering educational scenario. However, the technical skills and experience of MQFD experts and members may come in handy to overcome this difficulty.

### 10.7.6. Step 6

House of quality shall have to be built to convert customer languages into technical languages.

#### 10.7.6.1. Rationale

This exercise results in systematic conversion of customer languages (requirements) into technical languages (descriptors). In addition to that, house of quality matrix shows a clear picture of the ranking and relationships between customer and technical languages. Besides, correlations among the technical languages are revealed. Hence the above step utilizing these features is a core aspect of MQFD programme. In the engineering educational scenario also, many factors are interrelated. For example, a company interested in recruiting graduates from an engineering educational institution desires to introduce a technology in the curriculum. The administrative procedures of that engineering educational institution may not permit the addition of this topic in the curriculum to fulfill the requirements of this company. Hence the relationships among these contradicting factors shall have to be studied.

## 10.7.7. Step 7

Management and the Principal have to take strategic decision to choose the outputs of house of quality, which have to be passed through eight TPM pillars.

### 10.7.7.1 Rationale

A few vital problems damage the systems to the maximum possible extent. Hence solving these problems would help overcome the major malfunctioning of the systems (Logothetis, 1997). Therefore, when technical language with the highest priority is chosen, it would lead to the solving of major deficiencies and trading off minor deficiencies Besterfield,et.al(2004). The outputs of house of quality have to be studied and then passed through appropriate TPM pillars. A good understanding of TPM pillars and their influence on the engineering educational system are very essential for carrying out this step.

## 10.7.8. Step 8

The chosen outputs of house of the quality has to be sent through eight pillars of TPM

### 10.7.8.1 Rationale

As mentioned earlier, TPM pillars have been found to be powerful. In fact, they serve as gateways for achieving the goals of TPM. The power of TPM pillars in enhancing the quality in the engineering education has been well explained in one of the previous sections. Hence this step is playing a vital role in applying MQFD in the engineering educational institution.

### 10.7.9. Step 9

The results of implementing the eight pillars of TPM have to be used for refining the curriculum.

#### 10.7.9.1 Rationale

Since traditionally curriculum based education is enforced in the engineering educational scenario, improving its contents using the reliable inputs will play a powerful role in improving the quality of engineering education. Engineering educationalists seldom use rationalised data for refining curriculum. This step makes up this deficiency.

### 10.7.10. Step 10

The results have to be evaluated based on suitable parameters which include the number of students recruited by companies, the number of students who have completed the course, the number of companies recruiting students, the performance quality of engineering students, the number of students dropping out of the course and the availability of expertise among both the teaching staff and students.

#### 10.7.10.1 Rationale

Many authors have claimed that the overall equipment effectiveness (OEE) is the most effective measure of the maintenance quality (Chan et.al, 2005). However engineering educational institutions cannot use OEE for measuring maintenance quality because it is designed for use in industrial environments. Hence engineering educational institutions have to measure their maintenance quality from different perspectives (Ferrer-Balas et.al, 2004). This is made possible by measuring the other parameters cited above.

### 10.7.11. Step 11

The results shall have to be compared with the set targets of the engineering educational institution.

#### 10.7.11.1 Rationale

Researchers have stated the importance of comparing the integrity of TPM benefits with business performance (Ahmed,et.al,2005, Seth and Tripathi, 2005).In engineering educational institutions, the implementation of MQFD cycle may result in business performance improvement. However, its level has to be checked with that of the target (Grygoryev and Karapetrovic, 2005, Shen, 2004). This will enable the engineering educational institution to reap the ultimate benefits of implementing MQFD. In other words, this will enable the engineering educational institution, to climb one step towards in meeting the requirements of its customers.

### 10.7.12. Step 12

The deviation of the results, if any, has to be identified.

#### 10.7.12.1 Rationale

The findings and results of MQFD have to be used for engineering educational institution's sustained and continuous improvement. Hence, strategic decisions are required to be made for implementing the outcomes of MQFD. Since management holds the key, the task of making strategic decisions in this direction has to be carried out by the management (Madu, 2000). During recent years, the sustainability of engineering education has been largely debated. This step is necessary to achieve the sustainability of engineering education.

### 10.7.13. Step 13

The tactical suggestions have to be proposed to the management and the Principal, who have to make strategic decisions to implement them.

#### 10.7.13.1. Rationale

The engineering educational scenario is largely driven by external forces and traditional practices. For example, the educational system adopted in the United States of America is considered as the 'world-class education' by the engineering educationalists of most of the other countries. Hence, the engineering educational scenario prevailing in those countries are driven by the American educational system. In this context, restructuring engineering education is a challenging task. Therefore the decision in this regard has to be made by the management and the Principal and those decisions will have to be strategic in nature.

### 10.7.14. Step 14

Recommended actions evolved after MQFD proceedings will have to be implemented.

#### 10.7.14.1 Rationale

Since the suggestions have to yield value and results (Ireland and Dale, 2001), they have to be implemented in the engineering educational system. For ensuring succesful implementation, all departments and personnel have to be prepared themselves and tune their minds to accept the changes and improvements.

### 10.7.15. Step 15

The target, which has been achieved, will have to be revised along with the house of quality matrix. If there are changes in customers' languages, that also have to be considered while revising the matrix.

#### 10.7.15.1 Rationale

Due to the rapid changes taking place in technologies and management fields, the demands of the customers of engineering education have been dynamic. Therefore a continuous revision of the house of quality has to be carried out to cope with this dynamics. In fact, the engineering educational system has never been so critical due to the dynamic demands of customers. Hence, MQFD exercise needs to be continued further and new targets have to be set to meet customers' dynamic demands.

### 10.7.16. Step 16

The working of MQFD programme as a whole has to be reviewed. During its progress, the views of the management and the Principal will have to be studied. The effect of experimenting the MQFD for continuously enhancing the quality of engineering education has to be examined.

#### 10.7.16.1 Rationale

Currently the world is shrinking in size due to the globalization process.(Cravens,et.al, 2003 Rose-Ackerman, 2002, Soudien, 2002,Czinkota and Ronkainen,2005).Hence, the engineering education has to meet the dynamic requirements of customers at the global level (Johnston,2001). Hence, it is necessary that the management and principal have to ensure that the developments taking place in various departments are directed towards attaining its core competence in the global market.

## 10.8. Reactions

After exploring the methodology of implementing MQFD in the engineering educational scenario, engineering educationalists were approached to sense their reactions The profiles of these educationalists are presented in Table 10.5. These engineering educationalists were personally approached by the author and appraised about the features of MQFD and its application in the engineering educational scenario. Then the questionnaire as depicted in AnnexureE enabling them to assess the extent of applying each step of MQFD in the engineering educational scenario was given to them. The decisions and questions supplied and the reactions of the respondents pertaining to MQFD implementation steps are shown in Table 10.5. As shown, the respondents had to tick any one of the response Yes- Surely, Yes- Partially, Yes-Feebly, and Not Possible. Also the respondents had the option of writing their comments against each question. The frequency table of the responses of the respondents is also given in Table 10.6. As indicated, against most of the steps, the respondents' reactions were favorable. The responses are summarized and pictorially depicted in Figure 10.3. As shown, only 1.1% of the total respondents were pessimistic about implementing MQFD steps in the engineering educational scenario.

**Table 10.5** Profiles of Engineering Educationalists who responded to the survey.

| Serial Number | Name of the Respondent | Positions and locations in India | Years of service in Engineering Education (approximate) |
|---|---|---|---|
| 1 | Dr.M.C.Philipose | Principal,TKM College of Engineering, Kollam. Kerala state | 25 |
| 2 | Professor. R.V.Shenoy | Principal, Musaliar College of Engineering & Technology. Kerala state | 30 |
| 3 | Professor. P.Nizzar | Director, TKM Institute of Technology, Karuvelil, Kollam Kerala state | 35 |
| 4 | Professor. P.A.Abraham | Professor, Department of Mechanical Engineering, TKM College of Engineering, Kollam, Kerala state | 30 |
| 5 | Professor. K.Bala Chandra Sharma | Principal, Balas Elias Mathew II College of Engineering, Kollam, Kerala state | 30 |
| 6 | Dr.George vargese | Professor & HOD, Department of Electronics and Communication Engineering, TKM College of Engineering, Kollam, Kerala state | 25 |

Table Contd......

| | | | |
|---|---|---|---|
| 7 | Professor. K Gangadharan | Chairman& HOD, Department of Information Technology, Amrita Viswa Vidyapeetham, Coimbatore,Tamil Nadu State | 35 |
| 8 | Professor. Joshi C Haran | Professor, Department of Mechanical Engineering, Amrita Viswa Vidyapeetham, Coimbatore, Tamil Nadu State | 25 |
| 9 | Professor. R.Govindan Kutty | Dean and Vice Principal, Park College of Engineering and Technology, Coimbatore, Tamil Nadu State. | 35 |
| 10 | Professor. A.K.Balakrishnan Nair | Chairman and HOD,Department of Mechanical Engineering, Amrita Viswa Vidyapeetham, Coimbatore, Tamil Nadu State | 35 |
| 11 | Dr.P.G.Bhaskaran Nair | Director, Mount Zion Engg. Collge, Pathanamthitta., Kerala state | 40 |
| 12 | Dr.V.Balakrishna Panicker | Retired Pricipal, NSS College of Engineering, Palakkad, Kerala state | 40 |
| 13 | Professor.SitaLekshmi Amma. B | Professor & Head, Instrumentation and Control engineering NSS College of Engineering, Palakkad, Kerala state | 25 |
| 14 | Dr.M.R.Vikraman | Professor & Head, Department of Electronics and Communication Engineering, NSS College of Engineering, Palakkad, Kerala state | 25 |
| 15 | Professor. V.Girija Devi | Professor & Head, Department of Electrical and Electonics Engineering, NSS College of Engineering, Palakkad, Kerala state | 25 |
| 16 | Professor. P. Govindan Nair | Retired Professor & Head, Department of Mechanical Engineering, NSS College of Engineering,Palakkad, Kerala state | 35 |
| 17 | Dr.V.P. Sukumaran Nair | Professor & Head, Department of Mechanical Engineering, NSS College of Engineering,Palakkad, Kerala state | 30 |
| 18 | Professor. C.Somasekharan | Retired Principal, NSS College of Engineering,Palakkad. Kerala state | 30 |
| 19 | Professor. R.Ravichandran | Lecturer, Department of Humanities, PSG College of Technology, Coimbatore, Tamil Nadu State | 15 |
| 20 | Professor..T.Divakaran | Professor & Head, Department of Civil Engineering, NSS College of Engineering, Palakkad. Kerala state | 30 |
| 21 | Kalpana.N | Lecturer, Department of Humanities, PSG College of Technology, Coimbatore, Tamil Nadu State | 10 |
| 22 | Anonimous | | |

**Table 10.6. Reactions of Engineering Educationalists**

| Step number | Description and question | Yes Surely | Yes Partially | Yes feebly | Not Possible | No Response |
|---|---|---|---|---|---|---|
| 1 | MQFD experts have to convince the top management and the principal/ director of the engineering educational institution about the benefits that can be reaped by the implementation of MQFD. This exercise has to be carried out by organizing seminars and brainstorming sessions. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 13 | 8 | 1 | 0 | 0 |
| 2 | Management and the principal have to announce the implementation of MQFD as a policy. They have to state the objectives such that it will reach all personnel in the institution. Different types of educational campaigns have to be conducted for personnel at different levels in order to make them fit to attain MQFD objectives. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 4 | 15 | 3 | 0 | 0 |
| 3 | Form an MQFD team consisting of 7-8 members of different departments. They meet once in a week and draw out plans for the implementation. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 9 | 11 | 2 | 0 | 0 |

Table Contd.........

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | Identify the customer languages of education. For this purpose the feedback of parents, alumnis and the employers who have employed aluminis has to be rigorously and regularly gathered. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 7 | 10 | 5 | 0 | 0 |
| 5 | Customer languages shall have to be ranked based upon their importance. This can be done either by using previous experience and the views of management and personnel. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 7 | 11 | 2 | 1 | 0 |
| 6 | Construct the House of Quality (HoQ). To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 6 | 10 | 3 | 0 | 3. |
| 7 | Management and principal have to take strategic decision to choose the outputs of HoQ, which have to be passed through eight TPM pillars.<br>The eight TPM pillars are<br>1.Autonomous maintenance<br>2.Individual improvement<br>3.Planned maintenance<br>4.Quality maintenance<br>5.Development Management<br>6.Education and Training<br>7. Office TPM<br>8.Safety, Health and Environment<br>To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 5 | 15 | 1 | 1 | 0 |

Table Contd.........

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | Send the chosen outputs of HoQ through eight pillars of TPM. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 6 | 11 | 3 | 0 | 2 |
| 9 | Direct the results to the curriculum. To which extent do you believe that this exercise can be carried out given the prevailing engineering scenario? | 9 | 11 | 0 | 1 | 1 |
| 10 | Evaluate the results based on the parameters namely (Number of students placed, Percentage of students passed, Number of companies visited for campus interview, Overall performance quality of students, Number of students dropping the course and Availability of competent faculty and supporting staff). To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 14 | 7 | 1 | 0 | 0 |
| 11 | Compare the results with the set targets. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 12 | 9 | 0 | 1 | 0 |
| 12 | Identify the deviation of the results, if any. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 14 | 6 | 2 | 0 | 0 |
| 13 | The tactical suggestions have to be exposed to the management and principal, who will take strategic decisions to implement them. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 11 | 8 | 3 | 0 | 0 |

Table Contd.........

| | | | | | | |
|---|---|---|---|---|---|---|
| 14 | Implement the recommended actions evolved after MQFD proceedings. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 7 | 12 | 3 | 0 | 0 |
| 15 | After achieving the target, revise the target and HoQ matrix. If there is change in customers' languages, that also has to be considered while revising the matrix. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 9 | 9 | 2 | 0 | 2 |
| 16 | Review the working of MQFD Program as a whole and incorporate the top management's and principal's views while experimenting the MQFD for enhancing continuously the maintenance quality of engineering education. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario? | 10 | 9 | 3 | 0 | 0 |
| Total | | 143 | 162 | 34 | 4 | 9 |

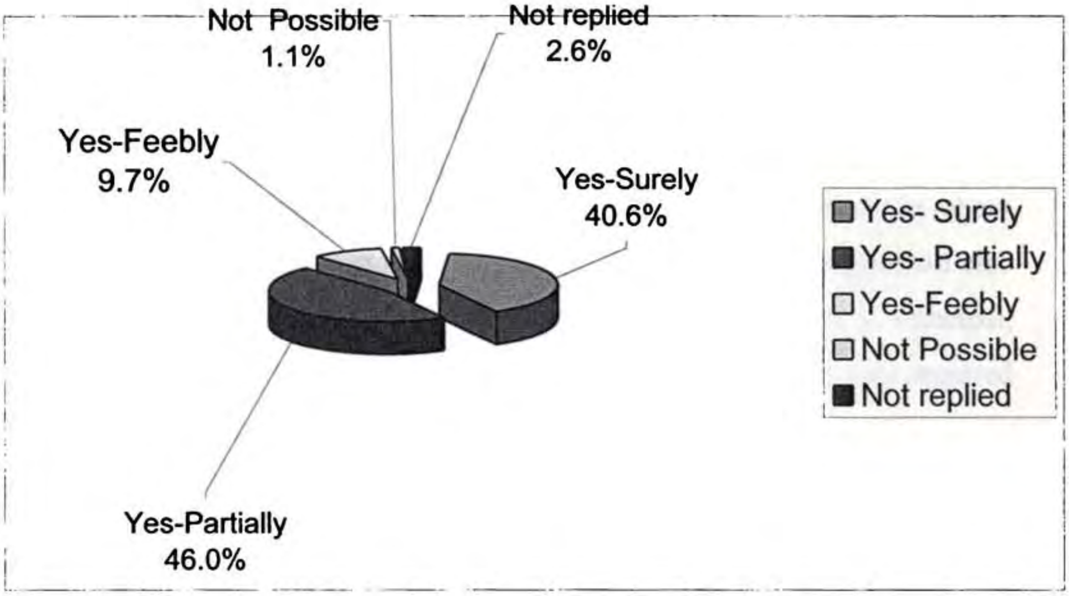



**Figure 10.3** Receptivity from experts

## 10.9. Major Reactions

The questionnaire based survey on MQFD helped to bring out the following interesting views, opinions and observations of Indian engineering educationalists.

- Many engineering educationalists expressed difficulty in convincing the top management about implementing MQFD in the engineering educational scenario.
- Refinement of curriculum is not foreseen as a difficult task by the engineering educationalists. Particularly with more and more engineering educational institutions being granted autonomy, the refinement of curriculum is fast becoming a reality in the engineering educational scenario.
- Some engineering educationalists opined that it is feasible to implement MQFD because many data requirements are fulfilled in the present job recruitment system. However, MQFD programme has to begin initially by involving a small-dedicated group.

- Some respondents felt that "resistance to change" and "reluctance to cooperate" due to lack of motivation would be the major challenges to be overcome for the successful implementation of MQFD.

- One of the respondents, who is a director, expressed doubt about gathering factual customer languages. An anonymous respondent also expressed the same view. Another respondent, who is a Principal, expressed the difficulty in gathering the large volume of data required for implementing MQFD.

- One of the respondents envisaged that All India Council of Technical education (AICTE), which is monitoring the engineering education, will have to set norms for the successful implementation of MQFD.

- Some respondents had claimed that top management attitude would determine the degree of success or failure of MQFD programme.

- Some respondents pointed out that the university affiliation system prevailing in most parts of India will make it difficult to effect the changes required for implementing MQFD.

- Some respondents pointed out the need for developing the environment conducive for engineering education before embarking on MQFD programme. They are particularly critical of some activities that take place in certain Indian engineering educational institutions with the support of political parties.

- Some respondents pointed out that the existing facilities like placement cell and parent teachers association, would be supportive of MQFD implementation in the engineering educational system.

On the whole, the reactions of the respondents led to an impression that MQFD could be successfully implemented in the engineering educational system with the help of the available facilities and by removing the loopholes and hindrances in the system.

## 10.10. Conclusion

The ever-increasing competition and changing tastes of customers have been forcing the companies to produce outputs whose characteristics would match that of the customers' desires. To cope with this trend, engineering education has to mesh with the requirements of the competitive market. Rapid changes are occurring in the industrial scenario. In the majority of societies, engineering educational institutions play key roles in molding products suitable for application in the industrial world (Gelfand, 2005). The companies in industrial world employ students trained and educated in this way. But the reality is that, the products of today's engineering educational systems are not directly usable in the industrial world. Rather, they need to be trained by their employers before they become contributors. This situation has compelled certain professionals to declare that engineering education has failed to deliver authentic products (Zairi, 1995). In this context, this chapter is brought out to deliberate on the feasibility of applying two world's proven principles namely, TPM and QFD in engineering education. In order to utilize the synergic power of these principles, the model MQFD has been proposed with reference to the engineering educational scenario. The feasibility of implementing MQFD in the engineering educational scenario is to be appraised by dissecting MQFD process into 16 steps.

In order to examine the feasibility of implementing MQFD in the engineering educational scenario, the reactions of engineering educationalists were surveyed using a questionnaire. Their reactions indicated the prevalence of favorable situations in the engineering educational scenario for the successful implementation of MQFD. These engineering educationlists hail from Indian engineering educational system. But this fact does not limit the scope of the interpretations of the questionnaire-based survey to Indian engineering educational system. This is due to the reason that Indian engineering educational system mimics the global engineering educational scenario and the scope of these interpretations shall be extended to the global engineering educational scenario. These favorable reactions and conditions enable us to believe that MQFD implementation in the engineering educational scenario would be a success. However, this belief has to be strengthened by practically implementing MQFD in the engineering educational scenario by plugging the loopholes and gathering the support of all stakeholders. It appears that some of such exercises can become a reality because of the increasing number of engineering educational institutions being granted autonomy in various societies of the world.

Chapter - 11

# STRATEGIC RECEPTIVITY OF MAINTENANCE QUALITY FUNCTION DEPLOYMENT ACROSS HETEROGENEOUS ORGANIZATIONAL CULTURES

*Content*

# STRATEGIC RECEPTIVITY OF MQFD ACROSS HETEROGENEOUS ORGANIZATIONAL CULTURES

## 11.1. Introduction

The implementation of MQFD model is a never-ending continuous improvement process. A unique feature of MQFD model is that it is not necessary to change or dismantle the existing process of developing HoQ and TPM projects, which may be in practice in the company concerned. Thus MQFD model enables the tactical marriage of QFD and TPM. Since this process demands strategic changes, a strategic procedure is to be employed for its succesful implementation. The Strategic steps to be followed to implement MQFD are highlighted in Table 11.1(Pramod et al., 2006a).A careful study of MQFD (Figure 4.2) and its strategic implementation steps (Table 11.1) would indicate that a concrete strategic change management approach is vital for their succesful adoption in real time practice. In order to create such a strategic change management approach, the receptivity of MQFD among its prospective users has to be assessed. But this task will be challenging because MQFD has to be applied across heterogeneous cultures prevailing in inter and intra organization. Hence, the need of conducting a research on strategic receptivity of MQFD across heterogeneous organizational cultures becomes necessary. The module of the research work reported in this chapter was carried out to fulfill this imperative.

## 11. 2. Structure of the questionnaire

The module of the research work being reported in this chapter was accomplished by conducting a questionnaire-based survey. The questionnaire used for carrying out the strategic receptivity analysis of MQFD and its implementation steps comprised three sections. The first section contained questions, which aimed to gather the background information about the company. The second section contained questions, which facilitated the respondents to foresee the outcome of MQFD. The third section contained questions, which aimed to asses the respondents' confidence over the succesful implementation of MQFD steps. Thus the questionnaire was systematically designed to estimate the receptivity of the strategic changes that are required to occur in organizations. These strategic changes are vital for successfully implementing and deploying MQFD and achieving business prosperity.

**Table 11. 1. Strategic steps for MQFD implementation**

| Step Number | Actions |
|---|---|
| Step 1 | MQFD experts have to convince the top management about the benefits that can be reaped by the implementation of MQFD. This has to be done by conducting seminars and brainstorming sessions. |
| Step 2 | Top management has to announce the implementation of MQFD as a decision. They have to state the objectives either in the company newsletter or through similar media such that it will reach all in the company. Different types of educational campaigns have to be conducted for personnel at different levels in order to make people fit to attaining objectives. |
| Step 3 | A MQFD team consisting of 7-8 members of different departments has to be formed. This team meets once in a week and plans for the implementation. |
| Step 4 | Customer languages have to be identified and enumerated. |
| Step 5 | Customer languages have to be ranked. This can be done either by using Analytical Hierarchy Process (AHP) or any other similar techniques. |
| Step 6 | HoQ has to be developed to translate customer languages into technical languages. |
| Step 7 | Top Management has to take strategic decision to choose the outputs of HoQ, which have to be passed through eight pillars. |
| Step 8 | The chosen outputs of HoQ have to be sent through eight pillars of TPM. |
| Step 9 | The results of building eight pillars have to be directed to the production system. |
| Step 10 | The results have to be evaluated based on the six parameters (OEE, MTBF, MTTR, Performance quality, MDT and Availability). |
| Step 11 | The results have to be compared with the set targets. |
| Step 12 | The deviation of the results from the targets have to be enumerated |
| Step 13 | The tactical suggestions have to be exposed to the top management, who will take strategic decisions to implement them. |
| Step 14 | The results recommended through the conduct of MQFD proceedings have to be implemented. |
| Step 15 | After achieving the target, the same has to be revised. Followed by that, the HoQ has to be revised. If there are changes in the customers languages, that also have to be considered while revising the HoQ. |
| Step 16 | The working of MQFD Programme has to be reviewed as a whole and the top management's view has to be incorporated while experimenting the scope of MQFD in different directions of copmpany's strategic journey. |

## 11.3. Survey

This questionnaire was given to 50 managers of whom only 15 responded. The profiles of the respondents are given in Table 11.2. As hinted, these respondents are managers possessing different levels of experiences and hailing from different types of organizations ranging from electronics to pharmaceutical industries. The responses of these respondents were useful in assessing the strategic receptivity of MQFD and its implementation procedure in heterogeneous cultures. The details of this analysis are presented in the following four section in stages. This aspect is depicted in Figure 11.1.

**Table 11.2. Respondents profile and their organization's turnover**

| Serial Number | Name of the Respondent | Positions and locations in India | Approximate experience in Years | Turnover of the Company | |
|---|---|---|---|---|---|
| | | | | INR | US Dollars approximate |
| 1 | Pious Mathew | Proprietor, Classic Art Lamps, Vazhappally,P.O, Changanachry, Kerala, India | 40 | 20 lakhs | 4000 |
| 2 | K.O.Markose | Assistant manager (QMS), Transformers and Electricals Kerala Limited, Kerala, India | 35 | 100 Crores | 20 Millions |
| 3 | S. Rajendran | Factory Manager, BPL Limited, BPL Works, Chanrdra Nagar.P.O, Palakkad, Kerala, India | 27 | 65 Crores | 130 Millions |
| 4 | Raj Kumar.P | Manager, Steel and Industrial Forgings, Ahani, Thirssur, Kerala, India | 15 | 50 Crores | 100 Millions |
| 5 | A.Remesh | Manager(Mechanical), Arya Vidya sala, Kottkkal, Malappuram Dist, Kerala, India | 12 | 90 Crores | 180 Millions |
| 6 | D.Rejith | Hindustan Organic Chemicals, Ambalamugal, Ernakulam, Kerala, India | 19 | 400 Crores | 800 Millions |
| 7 | N.K.Sasidharan Pillai | Research coordinator, Parishath production Center, Muntoor, Palakkad, Kerala, India | 5 | 10 Lakhs | 0.2 Millions |
| 8 | Raj Mohan Nambiar | Ex.DGM, Instrumentation Ltd, Kanjikode, Palakkad Kerala, India | 28 | 45 crores | 90 Millions |

Table Contd......

| | | | | | |
|---|---|---|---|---|---|
| 9 | D.Rajanayagam | Manager, Quality Assurance, Salzer electonics Limited, Samichetty Palayam, Coimbatore, Tamilnadu, India | 10 | 14 Crores | 28 Millions |
| 10 | P.Suresh Babu | Manager, Indian Telephone Industries Ltd, Kanjikode, Palakkad , Kerala, India | 19 | 235 Crores | 470 Million |
| 11 | Sursh.P.K | Chief Research engineer, Fluid Control Research Institute, Kanjikode, Palakkad ,Kerala, India | 16 | 5 crores | 10 Millions |
| 12 | A.N.Balaji, | Technical Manager, Texmo Indusries, Coimbatore, Tamilnadu,India | 0.5 | 150 Crores | 300 Millions |
| 13 | G.Kannan | Manager, R&D, ELGI equipments Ltd. Coimbatore Tamilnadu, India | 20 | 325 Crores | 650 Millions |
| 14 | E.K.Surendranath | PartnerKumar Industries, Edathara, Palakkad, Kerala, India | 25 | 4.5 crores | 9 Millions |
| 15 | K.U.Baby | Manager(Design), Hindustan machine tools Limited, Kalamassery, Ernakulam, Kerala, India | 21 | 60 Crores | 120 Millions |

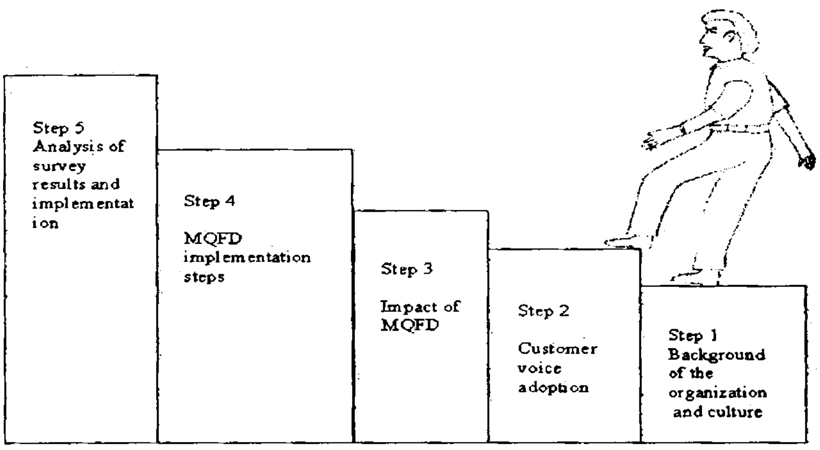



**Figure 11.1.** Research methodology

## 11.4. Background of the organizations and the cultures prevailing in them

As mentioned earlier, the first section of the questionnaire aimed to recognize the background of the organizations and the cultures prevailing in them. The responses gathered against these questions have been summarized in Tables 11.3 , 11.4 and 11.5. As seen in Table 11.2, the annual turnover of the companies of the respondents varied from as less as INR 10 lakhs (US $ 200) to as high as INR 325 crores (US $ 650 million).This indicates the various volumes of business carried out in the respondents' organizations. As shown in Table 11.3, maximum number of the organizations were started during 1980s. Therefore the average age of the organizations represented by the managers was 20 years. As indicated in Table 11.4, many of them have been implementing TPM and TQM principles. Thus the cultures prevailing in them are conducive to applying world-class manufacturing strategies. This is a very encouraging scenario. However, the nature of responses against these questions are scattered and non-uniform, which indicate the heterogeneous cultures prevailing among them. This is depicted in Tables 11.5 and 11.6.

**Table 11.3.** Year of inception of respondents organization.

| Year of inception | Before 1950 | 1950-1960 | 1961-1970 | 1971-1980 | 1981-1990 | 1991-2000 |
|---|---|---|---|---|---|---|
| Number of organization | 1 | 2 | 4 | 2 | 5 | 1 |

**Table 11.4.** Statistics on World-Class Management strategies applied in organization

| Number of Organizations | | | | | | |
|---|---|---|---|---|---|---|
| Exporting products/services to customers | Implementing TQM related activities | Implementing TPM related activities | Using customer feedback | Ranking customer languages | Ranking technical remedies | Correlating technical remedies |
| 12 | 11 | 8 | 14 | 9 | 10 | 10 |

**Table 11.5. Methods employed for collecting customer feedback**

| Name of the Respondent and organization | Methods Employed foe collecting customer feedback |
|---|---|
| Pious Mathew, Classic Art Lamps | Personnel contacts |
| K.O.Markose, Transformers and Electricals Kerala Ltd. | During the visit of service personnel to customer sites/Customer representatives to the organization, By sending the prescribed format to the respective customers |
| S. Rajendran, BPL Ltd | Survey through questionnaire |
| Raj Kumar.P, Steel and Industrial Forgings | Customer Response report, Customer inspection reports |
| A.Remesh, Arya Vidya sala, Kottakkal | Discussion |
| D.Rejith, Hindustan Organic Chemicals | Questionnaire |
| N.K.Sasidharan Pillai, Parishath Production Centre | Direct contact during get together |
| Raj Mohan Nambiar, Instumentation Limited | Regular questionnaire sent to customer, Customers request the presence of inspectors at the time of commissioning |
| D.Rajanayagam , Salzer Electonics Ltd | Customer satisfaction analysis format sent to collect feedback. Few customers provide feedback in their own format and through letter, email etc. |
| P. Suresh Babu, Indian Telephone Industries Ltd | Through feedback forms |
| Suresh.P.K, Fluid Control Research Institute | Direct interaction, Email |
| K.U.Baby, Hindustan machine tools Limited | Field visits by the sales staff |
| E.K.Surendranath, Kumar Industries | Direct feedback from the sales representatives |

**Table 11.6 Current practices influencing MQFD adoption**

| Serial Number | Organization | Factors considered while ranking customer languages | Factors considered while ranking technical remedies | TQM related activities | TPM related activities |
|---|---|---|---|---|---|
| 1 | Classic Art Lamps | Severity, Frequency of occurrence, Financial Loss | Easiness of implementation, Cost, Customer attraction | | |
| 2 | Transformers and Electricals Kerala | Functional, Performance, Reliability/ Durability/ serviceability, Physical appearance, Quality of service rendered, Experience gained during customer visits | As appropriate to meet the needs of the customers/ relevant to the business tasks. | Quality Circles, 5 S | |
| 3 | BPL Limited | Reliability of products, Functional use of products, Service provided, Features of product,Response, On time delivery, Price, Appearance. | Special requirements, Improvements, Corrective actions, Pricing. | | |
| 4 | Steel and Industrial Forgings, | Metallurgy and Heat treatment, Chemistry of alloys, Dimensional accuracy, Physical properties of Row materials and forgings, Appearance | Improve reduction ratio, Job design, Heat treatment, Alloying elements are recalculated, Die design, tolerance and process improvement, Reheat treatment after re calibration, Avoid scaling and EDM engraving | ISO9001: 2000 certification + periodical audit, DGA certification + periodical audit, DGAA certification + periodical audit, Failure Mode Effect Analysis (FMEA) | Preventive maintenance, Quality reviews, Customer complaint analysis, Contract review, Calibration of equipment, Documentation, Quality audit |

Table Contd.....

| | | | | | |
|---|---|---|---|---|---|
| 5 | Arya Vidya sala, Kottakkal | | | | Autonomous maintenance, Documentation of maintenance |
| 6 | Hindustan Organic Chemicals, | Quality, Delivery, Communication, Cost | Adherence of quality in container, Adherence of quality in customer, Response time, Timely delivery | ISO 9000 and 14000 | |
| 7 | Parishath production Center, | Convincing the customers, Local production strengthening, Local economy strengthening, Reduction of manufacturing cost, Generation of local employment, Utilize local resources/ products for production | Quality improvement, New ingredients, New methodology, New appearance, Awareness creation Contacting the customers, Confidence buildup, Sharing experience, Interaction with successful producers | Quality assessment | |
| 8 | Instrumentation Ltd, | Adhere to timely supply,After sales service, Supply of free spare kits, Lifelong maintenance service, Supply of spares,Ready to supply any buried type | Schedule production and planned delivery, Better maintenance, Training some contractors, Regular customer training, Regular customer meeting | Quality Circles, Employee empowerment schemes, Employee involvement schemes, ISO 9001 | Scheduled maintenance, Employee training, Quality maintenance, Subcontractor motivation/ Empowerment, Safety rules observed strictly, Periodic calibration of Gauges |

Table Contd...

| | | | | | |
|---|---|---|---|---|---|
| 9 | Salzer Electronics | Meeting Technical specification, Identification/ Labeling packaging, Accommodation of urgent requests, Restoring of customer complaints, Product range, Consistency of quality, On time delivery, Value for money, Response to special requests, Response to customer communication. | | ISO 9000, Quality Circle, Value Engineering, 5S, TPM | Autonomous Maintenance, Individual improvement, Planned Maintenance, Quality maintenance, Initial control |
| 10 | Indian Telephone Industries Ltd, | Quality ,Delivery, Response from the technical department, Personnel when contacted, Cooperation from workforce, | | ISO 9000, ISO 14000, Quality Circle, Six Sigma | Improvement, Process Validation |
| 11 | Fluid Control Research Laboratories | | | NABL accreditation and related activities | Internal auditing, International inter comparison study of test results for a standard product which is also termed as round robin test, Assessment of customer feed back, Constant up gradation of equipments, Validation of test results through replicate testing, Quality improvement discussions, Sending employees through quality programmes |

Table Contd............

| | | | | | |
|---|---|---|---|---|---|
| 12 | Texmo Industries, | Price, Competitiveness Functional and performance requirements, Delivery adherence, Appearance | | ISO 9001 | Performance related, Appearance related |
| 13 | ELGI equipments Ltd. | | | ISO 9000, Six Sigma, Quality Circles | Availability, Performance Quality, Product quality, Overall equipment efficiency, Planned maintenance |
| 14 | Hindustan machine tools Ltd. | | | Quality circles | |

## 11. 5. Customer voice adoption

As shown in Table 11.4, majority of the organizations are found to adopt customer voice adoption either explicitly or implicitly by gathering the customer feedback. As seen in this table, but for one, all respondents have responded to the questions related to the customer voice adoption. Thirteen of them could pinpoint the methods employed for collecting feedbacks. Their responses in this regard are presented in Table 11.5. Further the respondents were asked to indicate the current practices that are adopted in their organizations, which would influence MQFD adoption. The responses against these questions are shown in Table 11.6. Eleven of them implement TQM related activities. These activities range from 5S to six sigma. Seven of them have been implementing TPM related activities. The technique adopted in this direction ranged from conventional scheduled maintenance to modern TPM pillar like autonomous maintenance. All the seven of them implement TQM principles as well. This observation reinforces our earlier statement in which we have claimed that in parallel with TQM, organizations have started to implement TPM. The factors considered while ranking customer languages and technical remedies are also listed in Table 11.6. Most of the factors considered are related to money and quality. In this stage also, the observations indicate that heterogeneous natured cultures prevail in the respondents' organizations.

## 11. 6. Impact of MQFD

As mentioned earlier, the second section of questionnaire facilitated the respondents to foresee the impacts of MQFD with reference to the maintenance quality parameters. The respondents were asked to quantify the impacts of MQFD with respect to the various maintenance quality parameters. The unique feature of the questions asked in this stage was that, it enabled the respondents to foresee the performance even in the negative direction. For this purpose, a Likert's scale of range –10 to +10 was utilized. For example, a respondent could expect the outcome of OEE as a result of MQFD implementation either to decline or improve. In case it seems to decline, the respondent could choose the negative value. In case it seems to improve, then respondent could choose the positive value. The number of respondents who chose negative and positive values are summarized in Table 11.7. The values entered by them were consolidated and shown pictorially in Figure 11.2. As shown, except in case of MDT, in the view of the respondents, the maintenance quality parameters and the business prosperity indicators are going to increase significantly. As shown in Figure 11.3, 67% of the opinions of the respondents indicate the confidence in achieving the targets through the implementation of MQFD. One of the questions asked was about the strategic decisions that have to be made to achieve the targets of MQFD. The eight respondents' responses are enumerated in Table 11.8. Another two open ended questions asked the respondents to write the expected favorable and unfavorable conditions. The responses are also enumerated in Table 11.8. As shown, these conditions varied from organization to organization.

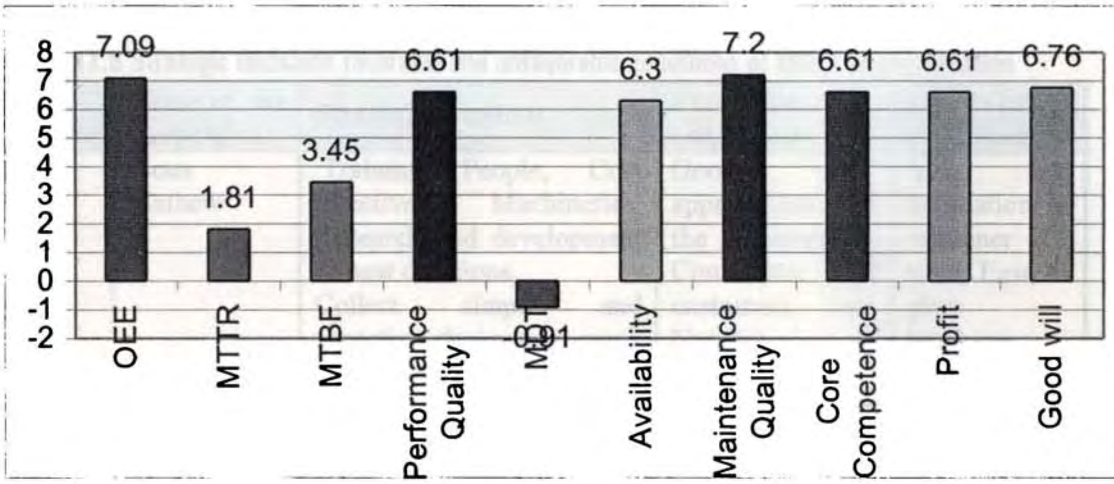



**Figure 11.2.** Average ratings of MQFD's impact on maintenance Quality Parameters

**Table 11.7** Impact of MQFD with reference to maintenance quality parameters

| | Number of respondents who choose | | |
|---|---|---|---|
| **Maintenance quality parameters** | **Negative values** | **Positive values** | **No change/ Not responded** |
| OEE | 0 | 9 | 4 |
| MTTR | 3 | 8 | 4 |
| MTBF | 3 | 8 | 4 |
| Performance quality of the organization | | 13 | 2 |
| MDT | 6 | 5 | 4 |
| Availability | | 12 | 3 |
| Maintenance Quality | | 13 | 2 |
| Core competence | | 13 | 2 |
| Profit | | 13 | 2 |
| Good will of the company | | 13 | 2 |

**Table 11.8 Strategic decisions favorable and unfavorable conditions of MQFD implementation**

| Serial Number | Name of the Respondent | Strategic decisions | Favorable conditions | Unfavorable conditions |
|---|---|---|---|---|
| 1 | Pious Mathew | Training People, Cost effective Machineries, Research and development of new decisions, Collect simple and attractive designs as much as possible | Good appreciation of the customers, Confidence of customers, Less Number of competitors, Easy to adopt new designs | Very fast fluctuation of customer taste, Ease of glass breakage, Difficult to cope with foreign items, Difficulty in storage. |
| 2 | S. Rajendran | Form team, Review in detail, Brainstorming, Action plan and implementation. | Skill and experience, Management support, Infra structure | Non willing ness , Inadequate resources |
| 3 | Raj Kumar.P | Modernizing Plant by installing forging press, Using CNC machines (Heavy duty) for die making, Supply value added finished components in place of forgings | Good market reputation, Monopoly in development of import substitution jobs, Good technical team and quality system, Company was making good profit since last twelve years | Political interference, Subsidiary of sick company, It is not an autonomous company, They have to take approval for major policy decision from Government. |
| | A.Remesh | Empowerment of personnel, Continuous training and improvement on all fronts,. Continuous feedback, discussion and corrective action, Education and enlightment of people at all level | Minimum Down time of equipments, Zero breakdowns, Zero rejections, Increased application of company and increased morale of personnel | Time consuming and costly, Can be achieved only on graded and continuous basis, Market fluctuation and decreasing top line, Lack of awareness among top classes of organizations. |

Table Contd...

| | | | | |
|---|---|---|---|---|
| 5 | N.K.Sasidharan Pillai | Awareness creation, Campaigns to Monologue the idea, Leaflets, Advertisements | Local trust and acceptance, Avoiding the unnecessary marketing expenses | Customer performance to high quality advertisements, Taboos and believes, Lack of perception for local production |
| 6 | Raj Mohan Nambiar | Company's' commercial department with inspectors are present at the time of commissioning, Necessary accessories and spares promptly supplied, All order delivered timely, After sales service is very prompt | Employee cooperation, Customer support, Project Consultant's support Nation wide, Past customers recommend to new customers | Attitudinal resistance, Price fluctuation, Emergence of new technology, Sudden change of duties (Government based) |
| 7 | D.Rajanayagam | Implementation of solution based remedies through team efforts, Employee Empowerment/ Involvement to produce results, Reviewing the results periodically and recording to motivate | Team work, Work culture, Conducive work environment, Employee satisfaction | Disturbance in routine task in very few situation, Extra documentation |
| 8 . | K.U.Baby | Implement the suggestions stage by stage, Evaluate the improvement | High productivity, Better appearance, Better Profit, Increase sale | Lack of technical skill of employee, Lack of availability of material, Market acceptability Price |

## 11. 7. MQFD implementation steps

The respondents were shown the 16-implementation steps of MQFD and asked to indicate their implementation feasibility. They were asked to quantify this aspect in the Likert's scales of range 0-10. The values entered by them are consolidated and shown pictorially in Figure 11.4. As shown, on an average, the implementation feasibility of all steps are found to be more than 6 in the Likert's scale of range 0-10 and the range between the highest and the lowest values is also found to be narrow. This result indicates the feasibility of MQFD implementation steps among heterogeneous cultures prevailing in intra and inter organizations. In addition to this quantification, the respondents were asked to write their comments against each step. These responses were valuable in carrying out qualitative assessment of MQFD implementation steps.

The qualitative assessments enabled the respondents to freely express their opinions and judgments. Against each step, three to eight respondents reacted. The comments/remarks appeared in these questionnaires are reproduced in Tables 11.9 to 11.24. As in the previous responses, in the majority of cases, it was not possible to pinpoint any common findings. However, one commonality found was the emphasis on management support for implementing many of the MQFD steps. Subsequently, these qualitative assessments were converted using the measurement metrics used in QFD literature (Lu and Kuei, 1995) are shown in Table 11.25. The values derived using the matrices have been denoted in brackets in Tables 11.9 to 11.24. In each case, the values were consolidated into an average value and entered in the Likert's scale of range 0-10.

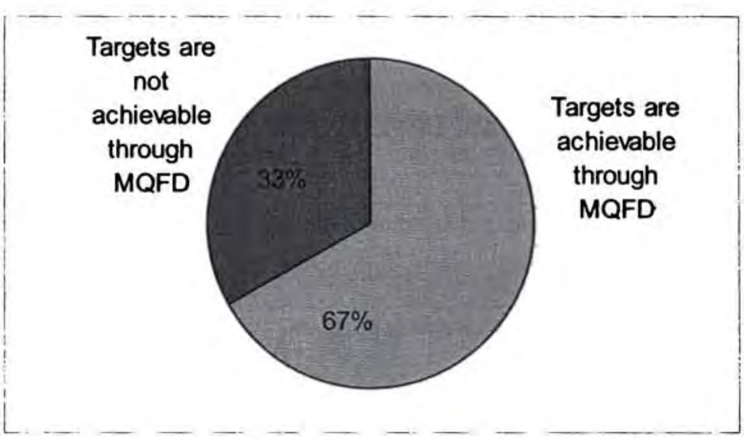



**Figure 11.3** Ratings on achieving targets through MQFD

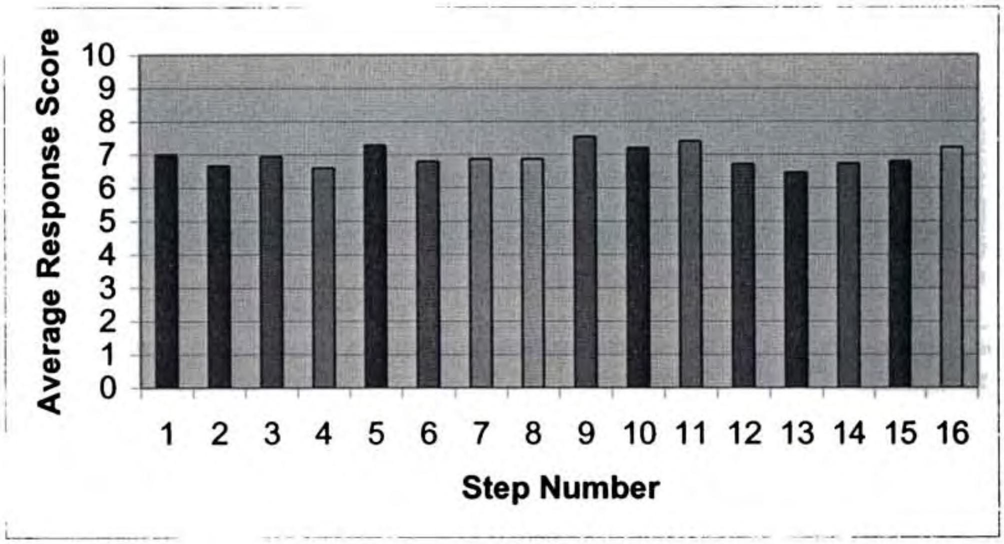



**Figure 11.4** Average response score against MQFD implementation steps

**Table 11.9** Respondents comments against Step 1

| **Step 1:** MQFD experts have to convince the top management about the benefits that can be reaped by the implementation of MQFD. This has to be done through seminars and brainstorming sessions. | | |
|---|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) | |
| Pius Mathew | In a self-owned company like classic lamps, this is possible to a large extent. Especially company is welcoming modern technologies. Provided company convinces that it will be profitable, it will think of implementing it **(9)** | |
| K.O.Marcose | In order to convince the top management, a consistent effort is required **(3)** | |
| A.Ramesh | The perfection in this step varies from industry to industry. Organizational factors play a major role for this. **(3)** | |
| N.K.Sasidharan Pillai | As it is a creative idea, companies will be willing to accept it and there will be vast feasibility of accepting this **(9)** | |
| R.M.Nambiar | The implementation can be enhanced by full time expert consultant **(3)** | |
| D.Rajanayagam and E.K.Surendranath | Through proper convincing only management will show interest **(3)** | |
| K.U.Baby | Awareness of problem gives a motivation. Proper communication of the idea is also essential in this direction **(3)** | |
| Average Receptivity in Likert's scale of range 0-10<br>(9+3+3+9+3+3+3+3)/8 = 5 | | Assessment:<br>Moderate receptivity |

**Table 11.10 Respondents comments against Step 2**

| **Step 2:** Top management has to announce the implementation of MQFD as a decision. They have to state the objectives either in company newsletter or through similar media such that it will reach all in the company. Different types of educational campaigns have to be conducted for personnel at different levels in order to make people fit to attain objectives. | |
|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) |
| Pius Mathew | In small companies mutual cooperation of management and employees is sufficient for improvement ideas. Therefore there is good feasibility of this step **(9)** |
| S.Rajendran. | The success of this step depends upon commitment between top management and MQFD team. **(3)** |
| A.Ramesh | For that enlightment at top levels is a must. **(3)** |
| N.K.Sasidharan Pillai. | Company used to conduct some get together periodically. This step will help to communicate the ideas in a rational way. **(9)** |
| R.M.Nambiar | This step has to be implemented only after motivation and training all employees to understand the importance of MQFD for profitability of the company and employees improved life condition. **(3)** |
| D.Rajanayagam | As any policy or objective has to be discriminated to all the levels as the employee involvement is mandatory to implement a change and reap benefits out of it. **(3)** |
| K.U.Baby | Easy way of communication to lower levels is to conduct an awareness programme. Conducing an awareness programme is not an easy step**(1)** |
| Average Receptivity in Likert's scale of range 0-10 (9+3+3+9+3+3+1)/7= 4 | Assessment: Poor receptivity |

**Table 11.11 Respondents comments against Step 3**

| **Step 3:** A MQFD team consisting of 7-8 members of different departments has to be formed. They meet once in a week and plans for the implementation. | |
|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) |
| Pius Mathew | Generally small organizations will be well disciplined. Forming of a team is feasible their. Every achievements can be made possible by mutual cooperation **(3)** |
| K.O.Marcose | This needs a sincere and continuous approach **(3)** |
| R.M.Nambiar | Team members should collect before meeting sufficient data regarding the present problems and some ideas for how to solve it. In addition to that they should think to have better suggestions for further improvements **(3)** |
| D.Rajanayagam | This is a nice idea. But the feasibility of meeting once in a week is difficult **(9)** |
| K.U.Baby | This is very good step. Decisions can be enhanced further **(9)** |
| Average Receptivity in Likert's scale of range 0-10 (3+3+3+9+9)/5= 5 | Assessment: Moderate receptivity |

**Table 11.12 Respondents comments against Step 4**

| Step 4: Customer language have to be Identified and enumerated. (Receptivity in Likert's scale of range 0-10 is indicated in bracket) | | |
|---|---|---|
| **Respondent** | **Comments** | |
| Pius Mathew | Vast feasibility is there for this step. If the customers are in close contact, it is easy to get their feedback (9) | |
| K.O.Marcose | Customer languages are very important. It has be collected judiciously focusing company's future needs (3) | |
| A.Ramesh. | Even though it may take some extra time and effort, this step is of great importance. (9) | |
| N.K.Sasidharan Pillai. | We are doing accordingly (9) | |
| R.M.Nambiar | Questionnaires should be checked with customers operation department also (3) | |
| (D.Rajanayagam | Identifying customer languages helps us to know what exactly he requires. It is a must also. Perfect identification has practical difficulties such as communication gap (3) | |
| K.U.Baby | Unfiltered customer languages and economic aspects also have to be considered (3) | |
| Average Receptivity in Likert's scale of range 0-10 (9+3+9+9+3+3+3)/7= 6 | | Assessment: Moderate receptivity |

**Table 11.13 Respondents comments against Step 5**

| Step 5: Customer languages have to be ranked. This can be done either by using Analytical Hierarchy Process (AHP) or other similar techniques. | | |
|---|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) | |
| Pius Mathew | Ranking of customer languages can be done by experience (3) | |
| A.Ramesh | Ranking of customer languages is possible but it will take time(3) | |
| N.K.Sasidharan Pillai | Previous experience helps a lot in this regard. But periodic assessment has to be done (3) | |
| R.M.Nambiar | Customer is to be judged properly. This judgment has to be done according to their exact modes of operation is to be decided to satisfy customer demands in all aspects (3) | |
| D.Rajanayagam | Ranking/ Prioritizing customer languages is a must. But in actual arena, it is too difficult to execute. A company will have several customers and their requirements may not be the same (1) | |
| K.U.Baby | Ranking of the customer languages is also very essential. This helps to attack each customer related problems on a priority basis by technical means. By the support of top management it can be implemented also (3) | |
| Average Receptivity in Likert's scale of range 0-10 (3+3+3+3+1+3)/6= 2 | | Assessment: Poor receptivity |

**Table 11.14 Respondents' comments against Step 6**

| **Step 6:** HoQ has to be developed to convert customer languages in technical languages. | | |
|---|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) | |
| Pius Mathew | This helps to have a scientific basis for the analysis of customer needs and their solutions **(3)** | |
| K.O.Marcose. | Prior to this step support from the top management has to be checked **(3)** | |
| A.Ramesh. | The scope of this step is high **(9)** | |
| R.M.Nambiar | This requires proper coordination of production and marketing departments **(3)** | |
| D.Rajanayagam | Development of HoQ is very important as it has a lot of scope in clarity or perfectly converting customer language into technical language. It is essential to meet customer requirements **(9)** | |
| K.U.Baby | This will help for root cause analysis of the problem **(9)** | |
| Average Receptivity in Likert's scale of range 0-10<br>(3+3+9+3+9+9)/6= 6 | | Assessment:<br>Moderate receptivity |

**Table 11.15. Respondents' comments against Step 7**

| Step 7: Top Management has to take strategic decision to choose the outputs of HoQ, which have to be passed through eight pillars. | | |
|---|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) | |
| A.Ramesh,<br>R.M.Nambiar | An intelligent approach is needed for this step. The easiness of implementation has also taken under consideration. Enlightment of top management is prerequisite for this step (3) | |
| D.Rajanayagam | The possibility of passing the outputs through eight TPM pillars has some practical difficulty (1) | |
| K.U.Baby | This needs the role of an expert. Top management has greater role in this regard (3) | |
| Average Receptivity in Likert's scale of range 0-10<br>(3+1)/2= 2 | | Assessment:<br>Poor receptivity |

**Table 11.16 Respondents' comments against Step 8**

| Step 8: The chosen outputs of HOQ have to be sent through eight pillars of TPM. | | |
|---|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) | |
| Pius Mathew | Financial aspects have to be taken into account in this regard (3) | |
| A.Ramesh | This needs the wholehearted support of top management. Proper convincing is essential (3) | |
| R.M.Nambiar | One member of the MQFD team has to take an active role for proper coordination amongst all departments. (3) | |
| D.Rajanayagam | But practical feasibility of this step is very less (1) | |
| K.U.Baby | This requires the help of an expert for successfully sending the output of HoQ through appropriate TPM pillars (3) | |
| Average Receptivity in Likert's scale of range 0-10<br>(3+3+3+1+3)/5= 3 | | Assessment:<br>Poor receptivity |

**Table 11.17. Respondents' comments against Step 9**

| Step 9: The results of building eight pillars are directed to the production system. | |
|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) |
| Pius Mathew | These decisions evolving after TPM will be of high value (9) |
| R.M.Nambiar | This shows the huge feasibility of this step. This step has to be implemented and it is expected that result will be most satisfactory (9) |
| D.Rajanayagam | Directing the results to production system is partially possible. This is due to the rigidity of Indian production system (3) |
| E.K.Surendra nath. | Cost effectiveness of production system has to be considered in this regard (3) |
| Average Receptivity in Likert's scale of range 0-10<br>(9+9+3+3)/4 =6 | Assessment:<br>Moderate receptivity |

**Table 11.18. Respondents' comments against Step 10**

| Step 10: The results have to be evaluated based on the six parameters (OEE, MTBF, MTTR, Performance quality, MDT and Availability). | |
|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) |
| Pius Mathew and E.K.Surendra nath. | Evey result can be evaluated on a quantified basis. Each parameter is a good indication of the quality of maintenance (3) |
| A.Ramesh. | It can be improved further once it is essential (3) |
| R.M.Nambiar | Success of any methodology will reflect the system parameter. By watching the changes in parameter, it is possible to asses the value of the methodology in the organizational environment (3) |
| D.Rajanayagam | Evaluating the results based on 6 parameters is possible only to a less extent as man-machine-method linkages are not as strong as they are required (3) |
| Average Receptivity in Likert's scale of range 0-10<br>(3+3+3+3)/4= 3 | Assessment:<br>Poor receptivity |

**Table 11.19. Respondents' comments against Step 11**

| Step 11. The results have to be compared with the set targets. | |
|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) |
| Pius Mathew | It is always better to first fix a target. This can help the company to have an analysis of the total effectiveness and to remove the barriers for attaining the targets one by one (3) |
| A.Ramesh | This can help the company to have a continuous evaluation and improvement (9) |
| R.M.Nambiar | This step is of vital importance. The implementation can help the company to increase the productivity and target (9) |
| D.Rajanayagam | It is always better to set a target first. Comparing the results with the set targets can help to locate the barriers for achievement .this will help the company to adopt better technologies and assurance of management commitment etc (9) |
| Average Receptivity in Likert's scale of range 0-10<br>(3+9+9+9)/4 = 8 | Assessment:<br>Good receptivity |

**Table 11.20. Respondents' comments against Step 12**

| Step 12: The deviation of the results from the targets has to be enumerated | |
|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) |
| Pius Mathew | Deviations are clear indications are clear indications of barriers. They have to be analyzed carefully and preventive measures have to be taken accordingly (3) |
| A.Ramesh | This will have long standing effects. Continuous effects in this direction will lead to good improvements (9) |
| N.K.Sasidharan Pillai | This will be used as a tool to assure customer satisfaction. (9) |
| R.M.Nambiar | If the deviations can be projected exactly, the barriers of achieving the targets can be found out and the results can be achieved by eliminating the barriers. (3) |
| D.Rajanayagam | Identification of deviation is well possible if the results are clear and expressed in measurable terms (3) |
| Average Receptivity in Likert's scale of range 0-10<br>(3+ 9+9+3+ 3)/5= 5 | Assessment:<br>Moderate receptivity |

**Table 11.21 Respondents' comments against Step 13**

| Step 13: The tactical suggestions have to be exposed to the top management, who will take strategic decisions to implement them. | |
|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) |
| Pius Mathew | Top management support is required for implementing new methodologies (3) |
| A.Ramesh | Once top management convinced, the implementation can be done easily (3) |
| N.K.Sasidharan Pillai | Group discussion can help in convincing top management (3) |
| R.M.Nambiar | Everybody has got some potential to suggest some good ideas. These ideas have to be scrutinized by top management. They have to take initiative to implement good ideas (3) |
| D.Rajanayagam | Some times tactical suggestions will be out of policies and flexibility boundaries. Therefore decisions of the top management is very essential in this regard (3) |
| Average Receptivity in Likert's scale of range 0-10<br>(3+3+3+3)/4 =3 | Assessment:<br>Poor receptivity |

**Table 11.22** Respondents' comments against Step 14

| Step 14: The results recommended through the conduct of MQFD proceedings have to be implemented. | | |
|---|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) | |
| Pius Mathew | As the recommendations of the MQFD teams are of high value, they have to be implemented (9) | |
| A.Ramesh | Management has to take appropriate actions in this regard. The reliability of the ideas of MQFD teams ishigh. Therefore they have to be implemented at any cost (9) | |
| R.M.Nambiar | The implementation of the suggestions ultimately enhances productivity (9) | |
| D.Rajanayagam | Implementation of the recommended actions is possible where employee involvement and management commitment are clearly visible (3) | |
| Average Receptivity in Likert's scale of range 0-10<br>9+9+9+3)/4 = 8 | | Assessment:<br>Good receptivity |

**Table 11.23** Respondents' comments against Step 15

| Step 15: After achieving the target, the same has to be revised. Followed by that, HoQ has to be revised. If there are changes in customers languages, that also have to be considered while revising the HoQ. | | |
|---|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) | |
| Pius Mathew | Targets have to be varied frequently. Customer languages are dynamic. They have to be analyzed and changes have to be made accordingly (3) | |
| A.Ramesh. | PDCA cycle can help in this regard | |
| D.Rajanayagam | This is possible to some extent as change in customer need and pace of implementation of these changes may vary from case to case. (3) | |
| R.M.Nambiar | Continuous changes are occurring for customer languages. In such a scenario, this step has high value (9) | |
| K.O.Marcose | This can help to have continual improvement (9) | |
| Average Receptivity in Likert's scale of range 0-10<br>(3+3+9+9)/4 =7 | | Assessment:<br>Good receptivity |

**Table 11.24** Respondents' comments against Step 16

| Step 16: The working of MQFD Programme has to be reviewed as a whole and the top management's view has to be incorporated while experimenting the scope of MQFD in different directions of copmpany's strategic journey. | | |
|---|---|---|
| Respondent | Comments (Receptivity in Likert's scale of range 0-10 is indicated in bracket) | |
| D.Rajanayagam | MQFD results will have reflections in various dimensions. The totality has to be considered for the token of this achievement (9) | |
| R.M.Nambiar | The aim of this step should be to achieve the ultimate goal of productivity (9) | |
| Average Receptivity in Likert's scale of range 0-10<br>(9+9)/2 = 9 | | Assessment:<br>Very good receptivity |

Table 11.25 Matrices used for quantitative assessment

| Sl.No | Description | Score |
|---|---|---|
| 1 | Strong influence towards the implementation of the concerned steps | 9 |
| 2 | Moderate influence towards the implementation of the concerned steps | 3 |
| 3 | Weak influence towards the implementation of the concerned steps | 1 |

## 11. 8. Strategic receptivity scorecard of MQFD

The questionnaire-based survey carried out in this research project was finally subjected to four stage evaluation pattern. These patterns are shown below.

1. Quantitative analysis of MQFD's strategic receptivity
2. Qualitative analysis of MQFD's strategic receptivity
3. Quantitative analysis of MQFD's implementation strategic receptivity
4. Qualitative analysis of MQFD's implementation strategic receptivity

These four patterns have been used to design the strategic receptivity scorecard of MQFD shown in Table 11.26. As shown, the overall strategic receptivity of MQFD model in the Likert's scale of range 0-10 is 6. As seen, the strategic receptivity of MQFD in the four patterns varies between moderate and good. The strategic receptivity of MQFD in Likert's scale of range 0-10 varies from 5 and 7.These scores indicate the feasibility of implementing MQFD in heterogeneous cultures. These scores can also be used to further explore ways of enhancing the strategic receptivity of MQFD concept.

## 11. 9. Conclusion

Over the years, the scope of TPM and QFD have been enlarging and invading all fields and all types of applications, (Ahmed , et.al, 2005; chan and Wu, 2002) Hence, MQFD's application is also prone to cover all type and sizes of organizations. Therefore MQFD should be implementable across heterogeneous organizational cultures. In this context, the questionnaire-based research reported in this paper has considered the responses of managers hailing from heterogeneous inter and intra organizational cultures. After the responses

**Table 11.26. Strategic receptivity scorecard of MQFD**

<table>
<tr><td>

**MQFD Model : Quantitative Analysais**

Consolidated scores

| | |
|---|---|
| MQFD's impact on OEE | 7 |
| MQFD's impact on MTBF | 2 |
| MQFD's impact on MTTR | 3 |
| MQFD's impact on MDT | 1 |
| MQFD's impact on Performance quality | 7 |
| MQFD's impact on Availability | 7 |
| MQFD's impact on Improved maintenance quality | 1 |
| MQFD's impact on Increased profit | 7 |
| MQFD's impact on Upgraded core competence | 7 |
| MQFD's impact on Enhanced goodwill | 7 |

Avreage rating in the Likert's scale of range 0-10: 5

Scope for improvement MTTR

Strategic Receptivity: Moderate

</td><td>

**MQFD Model: Qualitative Analysis**

Targets achievable through MQFD 67%

Average rating in the Likert's scale of range 0-10: 7

Strategic Receptivity: Good

</td></tr>
<tr><td>

**MQFD implementation steps: Quantitative Analysis**

Average receptivity of steps in the Likert's scale of range 0-10: 7

Strategic Receptivity: Good

</td><td>

**MQFD implementation steps: Qualitative Analysis**

Average opinion of the judgment of The respondents: 4.6

Average rating in the Likert's scale of range 0-10: 5

Strategic Receptivity: Moderate

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Overall strategic receptivity in Likert's scale of range 0-10 = 6

Overall strategic receptivity: Moderate

</td></tr>
<tr><td colspan="2">

Less than 4: Poor; Between 5 and 7: Moderate; Between 7 and 9: Good; Between 9 and 9.5: Very Good; Between 9.5 and 10: Excellent

</td></tr>
</table>

to the questions were gathered, they were subjected to analysis. Finally, an instrument called strategic receptivity scorecard was designed to assess the strategic receptivity of MQFD. This study revealed that the strategic receptivity of MQFD concept is found to be 6. The study has been conducted among the managers who were attached to the organizations, amidst various world class concepts like TQM, 5S, six sigma and TPM. Hence, the interpretations drawn from this research project can be generalized and claimed to be applicable to all types and sizes of healthy, organizations functioning in any part of the world. The questionnaire employed in this research would also enable the organizations to identify the required the change agents for improving the strategic receptivity MQFD concept in the society in which it will be implemented.

Chapter - 12

# MULTI-CRITERIA DECISION MAKING IN MAINTENANCE QUALITY FUNCTION DEPLOYMENT THROUGH ANALYTICAL HIERARCHY PROCESS

*Content*

# MULTI-CRITERIA DECISION MAKING IN MAINTENANCE QUALITY FUNCTION DEPLOYMENT THROUGH ANALYTICAL HIERARCHY PROCESS

## 12.1. Introduction

As appraised in the previous chapter, one of the challenges of implementing MQFD is that it needs to fit into varied organizational cultures. For this purpose, the practicality of MQFD's components has to be studied. While implementing these components, numerous decision alternatives have to be considered. This will be a tedious task. In order to ease this task, the need for an appropriate tool is realized. In this context, the contribution of the tool 'analytical hierarchy process' (AHP) is noticed with interest. AHP has been used as a tool to solve crucial decision-making problems. (Chin, et al, 1999). During the module of the research work reported in this chapter, the method of making MQFD suitable for a typical organizational culture using AHP was examined.

## 12.2. Overview on AHP

AHP is a quantitative method devised by Saaty and adopted for ranking decision alternatives based on the sensitivity of the critical factors and sub-factors on the system under study (Chin et al, 2002,Taha. 2003, Haj ShirMohammadi and Wedly, 2004). The AHP methodology begins by decomposing the system under study into distinct components. Then the factors critical for successfully implementing these components are identified. If possible and necessary, these critical factors are divided into sub-factors. This structuring of decision alternatives ends in the decision hierarchy of the system under study. Followed by this, each factor and sub-factor are assigned values using numerical scores on the basis of their contribution towards achieving the goals of the system under study. The scores are analyzed to determine the sensitivity of each factor and sub-factor.

Based on the results of sensitivity analysis, the factors and sub-factors are ranked. This ranking enables the decision makers to prioritize their decisions for making the system under study a practically compatible one. The AHP is one of the most frequently addressed contemporary tools in literature. Table 12.1 shows the various natures of AHP applications, which are reported in the literature. Readers interested in acquiring deep knowledge on AHP are advised to refer Troutt and Tadisina, (1992), Pavlikakis, and Tsihrintzis, (2003), Ossadnik, and Lange, (1998),Drake, (1998), Chiang, and Lai, (2002), Yedla and Shrestha, (2003),and Karapetrovic,and Rosenbloom, (1999). Readers will also be able to understand the working of AHP by reading the sample application study presented in the next section of this chapter.

**Table 12.1. Multifarious applications of AHP**

| Serial Number | Nature of application | Researchers |
|---|---|---|
| 1. | Measure for business excellence | Cheng and Li (2001) |
| 2 | Personal evaluation | Taylor III,et.al,(1998) |
| 3 | Determination correlation of product issues to profit | Muller and Fairlie-Clarke (2001) |
| 4. | Prioritizing customers and other stakeholders | Jackson (2001) |
| 5 | Marketing | Davies, (2001) |
| 6 | Manufacturing | Rangone, (1996) |
| 7 | Cellular manufacturing | Chan.and Abhary, (1996) |
| 8 | Safety management | Chan et.al,(2004) |
| 9 | Multi-attribute analysisof ISO 9000 registration | Crowe ,et.al, (1998) |
| 10 | Evaluation of success factors for implementing ISO 14001-based EMS | Chin,et.al (1999) |
| 11 | Tourism | Ramos, et.al .(2000) |
| 12 | Higher education | Badri and Abdulla (2004) |
| 13 | Facility location selection | Yang and Lee, (1997) |
| 14 | Supplier selection | Kahraman,et.al , (2003) |
| 15 | Study of TQM benefits | Lewis, et al, (2005 ) |
| 16 | Environmental quality | Bender, et al, ( 2000, ) |
| 17 | Pavement maintenance | Ramadhan, et al, (1999) |
| 18 | Centralization/Decentralization | HajShirmohammadi andWedley (2004) |
| 20 | Aircraft maintenance | Cheung,et.al, (2005) |
| 21 | Negotiation and resolution of conflict | Al-Tabtabai, and Thomas.,( 2004) |
| 22 | Determining an appropriate equity risk premium | Palliam (2005) |
| 23 | Assessment of the ISO 14001 environmental management system | Pun, and Hui, (2001) |
| 24 | Selecting optimal order | Choi,et.al (2004), |
| 25 | Maintenance decision making | Triantaphyllou,et.al (1997) |
| 26 | Evaluation of airline service quality | Tsaur, et.al (2002) |

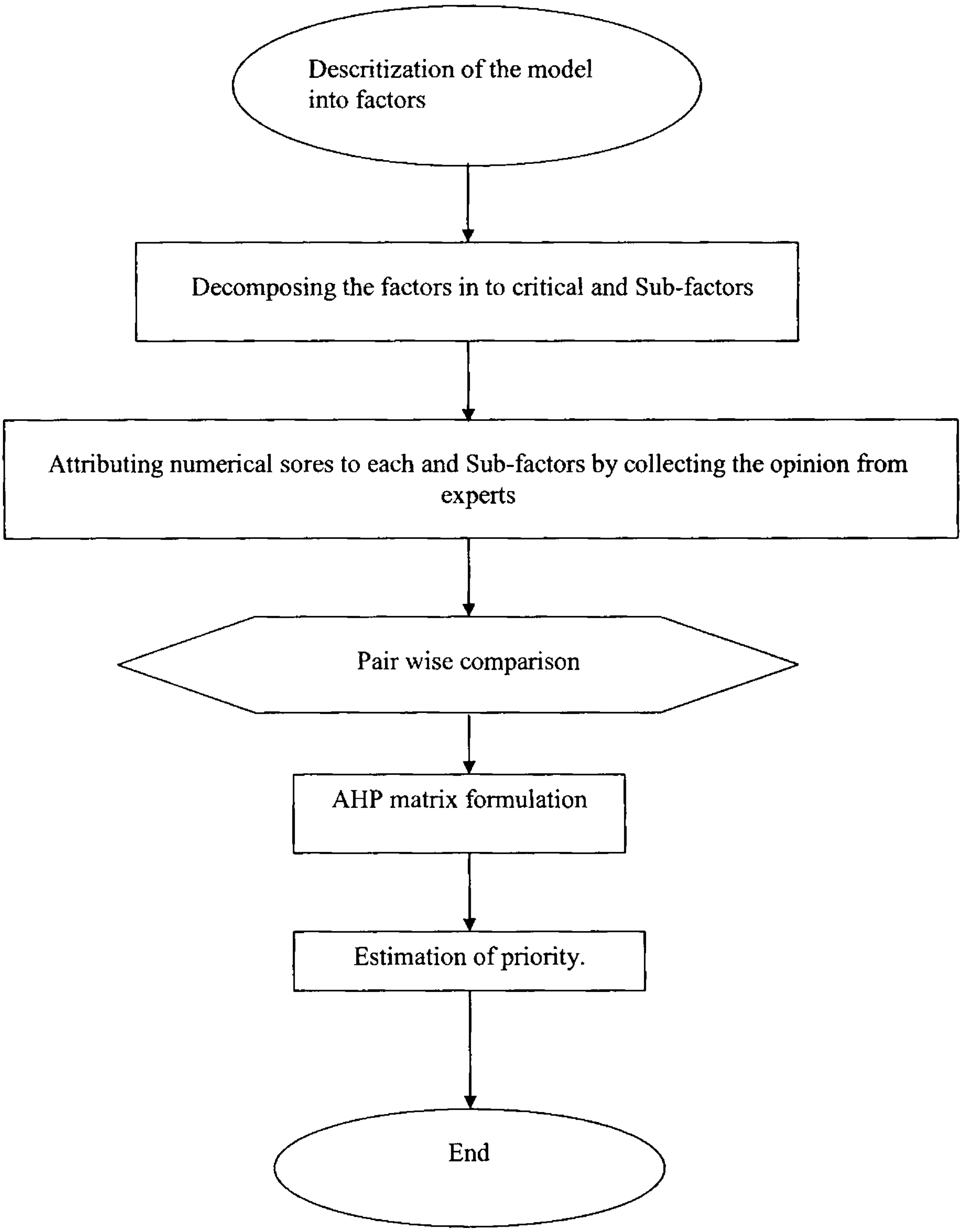


**Figure 12.1** Seven phase activities of AHP

The study was conducted in seven phases as per the following sequence. They are pictorially depicted in Figure.12.1.

1. Descritization of the model into factor
2. Splitting the factors in to critical and Sub-factors
3. Attributing numerical scores to each by collecting the opinion from experts and further data analysis.
4. Pair wise comparison
5. AHP matrix formulation
6. Estimation of priority.
7. Checking the consistency

## 12.3. Sample application study

In order to examine the practicality of applying AHP in MQFD, a sample application study was conducted in a maintenance intensive automobile service station. This service station is located in the city of Coimbatore, India. This service station is run by the Tamil Nadu state Government, India. This service station is required to cater to the maintenance requirements of Tamil Nadu state Government's vehicles.

### 12.3. 1. Survey

To begin with, the discretization hierarchy of MQFD shown in Figure 12.2 was developed. As shown, the MQFD was decomposed into its five components namely, House of Quality, Decision system, TPM, Maintenance parameters, and Quality parameters. Further, the factors critical to their implementation were identified. These factors have also been divided into sub-factors. The entire set of components, critical factors and sub-factors may be seen in Table 12.2. Followed by this discretization, it was found necessary to carryout paired comparisons among them. (Ramanathan,2001). The scores of comparisons are denoted using a 9-point scale (Yurdakul,M and Tansel.Y ,2003).The propositions recommended by the researchers for this purpose are shown in Table 12.2.As shown, this scale is known as Saaty's 1-9 scale. In the case study considered here, these scores should depict the practical experiences of the competent personal. The competent personal refers to the employees of the company possessing significant knowledge. In order to meet these conditions, ten such employees were recognized as competent personal.

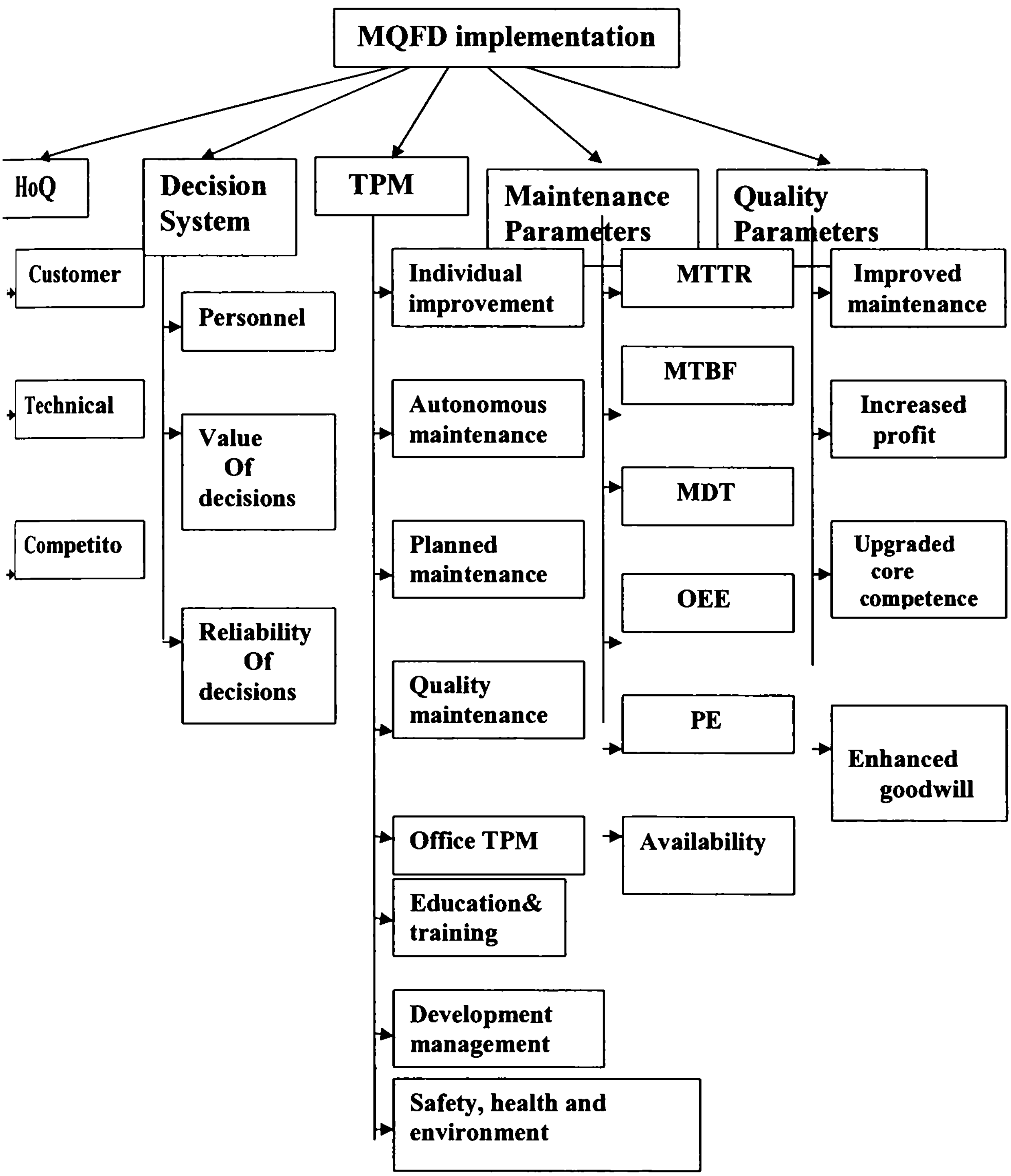


**Figure 12.2** Descritization hierarchy of MQFD

Table 12.2. Saatys 1-9 scale for multi-criteria decision making

| Judgment | Explanation | Score |
|---|---|---|
| Equally | Two attributes contribute equally to the upper level criteria | 1 |
| Moderately | Judgment slightly favours one over other | 3 |
| Strongly | Judgment strongly favours one attribute to another | 5 |
| Very strongly | An attribute is very strongly favoured and its dominance demonstrated in practice | 7 |
| Extremely | The evidence of extremely favouring one attribute over another is of highest possible order of affirmation | 9 |
| Intermediate values for finer resolution | | 2, 4, 6, 8 |

In order to gather relevant data from them, a questionnaire as shown in Annexure was prepared. The practical knowledge gained by the author during an earlier MQFD study was exploited while preparing the questionnaire. As shown, Likerts scale 1-9 has been used. This questionnaire was distributed to those competent personal. After collecting the filled in questionnaires, the average values were computed against each factor and sub-factor. These values were converted into Saaty's scales by using the following equivalent ratio scale formula:

$$Y=1+ [(x-x_{min}) \text{ X } 8 / (x_{max} - x_{min})]$$

Where, Y- Equivalent score in Saaty's 1-9 scale. X- Average value specified by the respondents.

$x_{min}$ – Minimum value specified by the respondents.

$x_{max}$ – Maximum value specified by the respondents.

These scores computed are shown in Table 12.3.

As a sample, the computation of the method of computing the score in Saaty's scale for the sub factor 'Frequency of vehicle Breakedown' listed under the critical factor 'customer' is illustrated here. As shown in Table 12.3,

**Table 12.3. Weighatage of parameters in Saaty's scale.**

| Component | Critical Factors | Sub-factors | Average value | Score in Saaty's Scale |
|---|---|---|---|---|
| HoQ | Customer | | 7.9 | 9 |
| | | Frequency of vehicle breakdown | 6.4 | 4 |
| | | Cultural background | 5.3 | 1 |
| | | Duration of maintenance | 6 | 3 |
| | | Emergency/necessity | 6.5 | 5 |
| | | Quality of spare parts | 7.9 | 9 |
| | | Cost of spare parts | 6.2 | 4 |
| | Technology | | 7.3 | 5 |
| | | Infrastructure | 7.7 | 7 |
| | | Skill of the personal | 8.2 | 9 |
| | | Employer employee relationship | 7.3 | 5 |
| | | Organizational climate | 6.4 | 1 |
| | | Maintenance methods | 6.8 | 3 |
| | Competitors | | 6.5 | 1 |
| | | Financial power | 8 | 9 |
| | | Performance of competitors. | 7.4 | 8 |
| | | Customer relationship | 7.7 | 8 |
| | | Strategies of competitors | 5.7 | 5 |
| | | Change management scheme | 3.9 | 1 |
| | | Quality parameters | 7.4 | 8 |
| | | New technology | 7.4 | 8 |
| Decision system | Personnel Factor | | 8.1 | 9 |
| | | Authority of personal | 7 | 1 |
| | | Responsibility of Personal | 8.3 | 9 |
| | | Initiatives of personal | 7.4 | 3 |
| | | Motivation of personal | 8 | 7 |
| | Value of Decisions | | 6.3 | 1 |
| | Reliability of Decisions | | 7 | 4 |
| TPM | Autonomous Maintenance | | 7.7 | 9 |
| | | Attitude of workers | 7.1 | 7 |
| | | Attitude of management | 7.1 | 7 |
| | | Motivation schemes | 5.5 | 1 |
| | | Incentive of salary | 7.8 | 9 |
| | | Financial benefits | 7.2 | 7 |
| | | Lubrication management | 6.3 | 4 |
| | | Daily maintenance of data | 6.9 | 6 |
| | Individual Improvement | | 7 | 5 |

Table Contd...

| | | | |
|---|---|---|---|
| | Reputation of individual | 7.3 | 4 |
| | Kaizen's principle | 8.5 | 9 |
| | Employee's suggestion scheme | 6.8 | 2 |
| | Employee involvement scheme | 7 | 3 |
| | Daily maintenance of machinery | 6.6 | 1 |
| | Interpersonal relationship | 7.3 | 4 |
| | Employee's wish | 7 | 3 |
| | Planned Maintenance | 7.6 | 6 |
| | Schedule of maintenance | 7.5 | 8 |
| | Frequency of breakdown | 7.7 | 9 |
| | Idleness of machine | 6.3 | 2 |
| | Repetition of same problem | 6.8 | 5 |
| | Quality Maintenance | 7.5 | 8 |
| | TQM tools | 6.7 | 7 |
| | Sampling | 2.4 | 1 |
| | Data management | 7.9 | 9 |
| | Education And Training | 7.5 | 8 |
| | Feasibility for higher studies | 6.3 | 1 |
| | Training facility | 7.4 | 7 |
| | Employee's own interest | 7.4 | 7 |
| | Motivation for training | 7.1 | 5 |
| | Rewards for better performance | 7.9 | 9 |
| | Development management | 6.6 | 2 |
| | Target setting | 7.5 | 9 |
| | Job scheduling | 6.7 | 8 |
| | Production planning | 2.9 | 1 |
| | Maintenance schedule | 7.3 | 9 |
| | Office TPM | 5.4 | 1 |
| | New technology | 8.1 | 9 |
| | Training | 7.5 | 7 |
| | Motivation | 6.8 | 5 |
| | Proximity of customer | 5.2 | 1 |
| | Proximity of supplier | 5.8 | 3 |
| | Data processing speed | 7.7 | 8 |
| | Safety Health And Environment | 7.5 | 8 |
| | Hospital | 5 | 1 |
| | Gymnasium | 5.4 | 2 |
| | Pollution | 7.3 | 8 |
| | Safety rules | 7.8 | 9 |
| | Green belt concepts | 6.7 | 6 |
| | Safety training | 7.1 | 7 |
| | Display for safety | 7 | 7 |
| | Periodic medical checkup | 6.5 | 6 |
| Maintenance Parameters | Overall equipment effectiveness | 7.3 | 7 |
| | Mean time between failure | 5.6 | 1 |
| | Mean time to repair | 6 | 2 |
| | Performance efficiencies | 8 | 9 |
| | Mean down time | 7 | 6 |
| | Availability | 7.1 | 6 |

| | | | |
|---|---|---|---|
| Quality parameters | Improved Maintenance | 8 | 9 |
| | Increased Profit | 3.3 | 1 |
| | Upgraded Core Competence | 5.5 | 5 |
| | Enhanced goodwill | 8 | 9 |

the average values of the 'customer' are 6.4, 5.3, 6, 6.5. 7.9 and 6.2. Among them the minimum average value is 5.3, which is denoted as $x_{min}$ in the above formula. The maximum average value is 7.9, which is denoated as $x_{max}$ in the above equation. The average of the average value is 6.4. The substitution of these values in the above formula is presented below.

**Y=1+ [(6.4 - 5.3) X 8 / (7.9 – 5.3)] =4.385** = rounded off to 4

The conversion of values into scores of Saaty's scale is necessary for the purpose of pursuing AHP (Ramanathan, 2001, Yedla and Shrestha 2003, Karapetrovic and Rosenbloom, 1999, Chin, et al, 2002). The scores in Saaty's scale were later substituted in pairwise comparison matrices. These matrices are shown in Tables 12.4-12.8. Followed by that, normalization of critical factors has been carried out. Through this process, the normalized values and local sensitivity were calculated. Normalized values represent the fraction of pairwise contribution of critical factors against each

**Table 12.4.** Pairwise degree comparison matrix of critical factors of Critical factors of the component 'House of Quality'

| Critical factors of the component 'House of Quality' | Customer | Technology | Competitor |
|---|---|---|---|
| Customer | 1 | 2 | 9 |
| Technology | $^1/_2$ | 1 | 5 |
| Competitor | $^1/_9$ | $^1/_5$ | 1 |
| Sum | 1 $^3/_5$ | 3 $^1/_5$ | 15 |
| Consistency Parameters | $\lambda_{max}$ = 3.0012 CI=0.58 RI= 0.58 CR =0.00103 CR < 0.1 | | |

**Table 12.5** Pairwise degree comparison matrix of critical factors of Critical factors of the component 'Decision making'

| Critical factors of the component 'Decision making' | Personnel | Value of decisions | Reliability of decisions |
|---|---|---|---|
| Personnel | 1 | 7 | 2 |
| Value of decisions | $^{1}/_{7}$ | 1 | $^{1}/_{4}$ |
| Reliability of decisions | $^{1}/_{2}$ | 4 | 1 |
| Sum | 1 $^{2}/_{3}$ | 12 | 3 $^{1}/_{4}$ |
| Consistency Parameters | $\lambda_{max}$ = 3.002 CI=0.006 RI= 0.58 CR = .00172 CR < 0.1 | | |

**Table 12.6.** Pairwise degree comparison matrix of Critical factors of the component 'TPM'

| Critical factors of the component 'TPM' | Autonomous maintenance | Individual improvement | Planned maintenance | Quality maintenance | Education and Training | Development management | Office TPM | Safety Health Environment |
|---|---|---|---|---|---|---|---|---|
| Autonomous maintenance | 1 | 1 | 1 | 1 | 1 | 2 | 9 | 1 |
| Individual improvement | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1 |
| Planned maintenance | 1 | 1 | 1 | 1 | 1 | 2 | 9 | 1 |
| Quality maintenance | 1 | 1 | 1 | 1 | 1 | 2 | 8 | 1 |
| Education Training | 1 | 1 | 1 | 1 | 1 | 2 | 8 | 1 |
| Development management | $^{1}/_{2}$ | 1 | $^{1}/_{2}$ | $^{1}/_{2}$ | $^{1}/_{2}$ | 1 | 5 | $^{1}/_{2}$ |
| Office TPM | $^{1}/_{9}$ | $^{1}/_{7}$ | $^{1}/_{9}$ | $^{1}/_{8}$ | $^{1}/_{8}$ | $^{1}/_{5}$ | 1 | $^{1}/_{9}$ |
| Safety Health Environment | 1 | 1 | 1 | 1 | 1 | 2 | 9 | 1 |
| Sum | 6 $^{3}/_{5}$ | 7 $^{1}/_{7}$ | 6 $^{3}/_{5}$ | 6 $^{5}/_{8}$ | 6 $^{5}/_{8}$ | 12 $^{1}/_{5}$ | 56 | 6 $^{3}/_{5}$ |
| Consistency Parameters | $\lambda_{max}$ = 7.9971 CI=0.041 RI= 1.141 CR = ..000293CR < 0.1 | | | | | | | |

**Table 12.7.** Pairwise degree comparison matrix of Critical factors of the component 'maintenance parameters'

| Critical factors of the component 'Maintenance parameters' | OEE | MTBF | MTTR | Performance efficiency | MDT | Availability |
|---|---|---|---|---|---|---|
| OEE | 1 | 7 | 4 | 1 | 1 | 1 |
| MTBF | $^1/_7$ | 1 | $^1/_2$ | $^1/_9$ | $^1/_6$ | $^1/_6$ |
| MTTR | $^1/_4$ | 2 | 1 | $^1/_5$ | $^1/_3$ | $^1/_3$ |
| Performance efficiency | 1 | 9 | 5 | 1 | 1 | 2 |
| MDT | 1 | 6 | 3 | 1 | 1 | 1 |
| Availability | 1 | 6 | 3 | $^1/_2$ | 1 | 1 |
| Sum | $4\,^2/_5$ | 31 | $16\,^1/_2$ | $3\,^4/_5$ | $4\,^1/_2$ | $5\,^1/_2$ |
| Consistency Parameters | $\lambda_{max}$ = 6.0520 CI=0.041 RI= 1.24 CR= 0.00838 CR < 0.1 | | | | | |

**Table 12.8.** Pairwise degree comparison matrix of Critical factors of the component 'quality prameters'

| Critical factors of the component 'quality parameters' | Improved maintenance | Increased profit | Upgraded core competence | Enhanced goodwill |
|---|---|---|---|---|
| Improved maintenance | 1 | 9 | 2 | 1 |
| Increased profit | $^1/_9$ | 1 | $^1/_5$ | $^1/_9$ |
| Upgraded Core Competence | $^1/_2$ | 5 | 1 | $^1/_2$ |
| Enhanced goodwill | 1 | 9 | 2 | 1 |
| Sum | $2\,^3/_5$ | 24 | $5\,^1/_5$ | $2\,^3/_5$ |
| Consistency Parameters | $\lambda_{max}$ = 4.0014 CI=0.00046 RI= 0.9 CR = 0.00518 CR < 0.1 | | | |

other. Local sensitivity refers to the average of normalized values of each critical factor. Normalization matrices of the MQFD components are shown in Tables 12.9-12.13.

**Table 12.9 Normalized values of critical factors of the component 'House of Quality'**

| Normalized values of the component 'House of Quality' | Customer | Technology | Competitor | Local sensitivity |
|---|---|---|---|---|
| Customer | 0.621. | 0.624 | 0.600 | 0.615 |
| Technology | 0.310 | 0.313 | 0.333 | 0.319 |
| Competitor | 0.069 | 0.063 | 0.067 | 0.066 |

**Table 12.10. Normalized values of critical factors of the component 'Decision making '**

| Normalized values of the component 'Decision making' | Personnel | Value of decisions | Reliability of decisions | Local sensitivity |
|---|---|---|---|---|
| Personnel | 0.609 | 0.583 | 0.615 | 0.602 |
| Value of decisions | 0.087 | 0.084 | 0.077 | 0.083 |
| Reliability of decisions | 0.304 | 0.333 | 0.308 | 0.315 |

**Table 12.11. Normalized values of critical factors of the component 'TPM Pillars'**

| Normalized values of the component 'TPM Pillars' | Autonomous maintenance | Individual improvement | Planned maintenance | Quality maintenance | Education and Training | Development management | office TPM | Safety Health and Environment | Local sensitivity |
|---|---|---|---|---|---|---|---|---|---|
| Autonomous maintenance | 0.151 | 0.140 | 0.151 | 0.151 | 0.151 | 0.164 | 0.161 | 0.151 | 0.153 |
| Individual improvement | 0.151 | 0.140 | 0.151 | 0.151 | 0.151 | 0.082 | 0.124 | 0.151 | 0.137 |
| Planned mainte nance | 0.151 | 0.140 | 0.151 | 0.151 | 0.151 | 0.164 | 0.161 | 0.151 | 0.153 |
| Quality maint enance | 0.151 | 0.140 | 0.151 | 0.151 | 0.151 | 0.164 | 0.143 | 0.151 | 0.15 |
| Education and Training | 0.151 | 0.140 | 0.151 | 0.151 | 0.151 | 0.164 | 0.143 | 0.151 | 0.15 |
| Development management | 0.077 | 0.140 | 0.076 | 0.075 | 0.075 | 0.082 | 0.089 | 0.077 | 0.086 |
| office TPM | 0.017 | 0.020 | 0.018 | 0.019 | 0.019 | 0.016 | 0.018 | 0.017 | 0.018 |
| Safety, Health and Environment | 0.151 | 0.140 | 0.151 | 0.151 | 0.151 | 0.164 | 0.161 | 0.151 | 0.153 |

**Table 12.12. Normalized values of critical factors of the component 'maintenance parameters'**

| Normalized values of the component 'Maintenance parameters' | OEE | MTBF | MTTR | Performance efficiency | MDT | Availability | Local sensitivity |
|---|---|---|---|---|---|---|---|
| OEE | 0.228 | 0.225 | 0.242 | 0.262 | 0.222 | 0.182 | 0.227 |
| MTBF | 0.032 | 0.032 | 0.030 | 0.030 | 0.038 | 0.030 | 0.032 |
| MTTR | 0.056 | 0.065 | 0.061 | 0.053 | 0.074 | 0.060 | 0.062 |
| Performance efficiency | 0.228 | 0.290 | 0.303 | 0.262 | 0.222 | 0.364 | 0.278 |
| MDT | 0.228 | 0.194 | 0.182 | 0.262 | 0.222 | 0.182 | 0.212 |
| Availability | 0.228 | 0.194 | 0.182 | 0.131 | 0.222 | 0.182 | 0.190 |

**Table 12.13. Normalized values of critical factors of the component 'quality parameters'**

| Normalized values of the component 'Quality parameters' | Improved maintenance | Increased profit | Upgraded core competence | Enhanced goodwill | Local sensitivity |
|---|---|---|---|---|---|
| Improved maintenance | 0.383 | 0.375 | 0.385 | 0.383 | 0.381 |
| Increased profit | 0.043 | 0.042 | 0.038 | 0.043 | 0.042 |
| Upgraded Core Competence | 0.191 | 0.208 | 0.192 | 0.191 | 0.196 |
| Enhanced goodwill | 0.383 | 0.375 | 0.385 | 0.383 | 0.381 |

The method of computing the normalized values given in the customer column of Table 12.9 is illustrated here. The sum of these values in Table 12.4 under the customer column is $1^3/_5$. Each value in this column is divided by this sum. That is, in the customer row and column in Table 12.4, the value 1 is divided by the sum $1^3/_5$. This value is 0.621, which is posted in Table 12.9. Similarly, in the 'Technology' row and 'customer' column, the value $^1/_2$ is divided by $1^3/_5$ The value 0.310 is posted in Table 12.9 In the competitors raw and the customer's in Table 12.4, the score $^1/_9$ is divided by $1^3/_5$. The resultant value 0.069 is posted in the representing cell in Table 12.9. In so me cases normalized values were slightly modified so that the sums under each column are equal to 1.

The term local sensitivity of critical factor or sub-factor refers to its influence over the system with respect to the immediate upper level entity, which may either be a component or critical factor. In the case of critical factors, the local sensitivities will directly influence only the associated components. However, in the case of sub factors, their sensitivities will affect their associated critical factors as well as components. Hence the sensitivities of critical factors will be globalized in the system under study. Therefore, in the case of sub-factors , their global sensitivities have to be computed. The global sensitivity of the sub-factor is the product of its local sensitivity and that of its parent critical sub-factor/factor. The global sensitivity of sub-factors computed during this simple application study is presented in Tables 12.38 to 12.49.

As a sample, the computation of the global sensitivity to the sub-factor 'frequency of vehicle breakdown' for the parent critical factor 'customer' is illustrated here. As shown in Table 12.25, its local sensitivity is 0.157. As shown in Table 12.9, the local sensitivity of its associated critical factor 'customer' is 0.615. These two values are multiplied together to obtain the global sensitivity of the sub-factor 'Frequency of vehicle breakdown'. This value 0.097 is posted in Table 12.38. This means that any changes in the functioning of this sub-factor will affect the working of MQFD to the extent of 9.7 % (0.097× 100). After the computation of global sensitivities, their true representation of reality had to be checked by computing the consistency index (CI).

## 12.3. 2. Computation of consistency ratio

The CI for each pair-wise comparison matrix was calculated by using the following formula

$$CI = \frac{\lambda_{max} - n}{n-1}$$

where the $\lambda_{max}$ stands for the principal eigen value of the matrix. $n$ is the size of the matrix. $\lambda_{max}$ was evaluated using the software 'MATLAB'. The parameter random index depends on the size of the matrix. It has to be found out from Saaty's Table given in Table 12.50 (Ramanathan et.al, 2001 ). The sample calculation of C.I is illustrated by choosing the Saaty's table.The $\lambda_{max}$ value for the Table 12.4 depicting the pairwise degree comparison matrix of critical factors of House of Quality, using 'MATLAB' programme, was found out as 3.0012. As it was a 3 X 3 matrix, the value 3 was used for n. Using these values, the CI was computed as 0.58. From Saaty's table, the value of Random Index (RI) for 3 X 3 matrix was taken. It was 0.58. The ratio of C.I to the average R.I for the same order matrix is called consistency ratio (*C.R*). Using the values of CI and RI obtained in Table. 12.4, CR value of 0.00103 was obtained.

As a thumb rule, this value is to be less than 0.1 or 10%, This is considered as the criterion of consistency of the results. Rarely CRs are greater than 0.1. In these cases, decision makers have to reconsider their judgments. However, if they are satisfied with the results, they can accept the results even if the CR values are more than 0.1 (Muller and Fairlie-Clarke, 2001). The CR values of the pairwise comparison matrices developed during this sample application study are shown in the last row of the Tables 12.4 to12.8. Only in the matrix of pairwise degree matrix of sub-factors of the component 'Development management', the CR value is 0.229, which is more than the conventionally accepted value of 0.1. The limitation value 0.1 is only a guideline. As mentioned above, if the investigator of the system is satisfied with the consistency, then the consistency level can be accepted. Hence in our case, since the investigation was conducted systematically, it was concluded that the results were consistent.

**Table 12.14.** Pairwise degree comparison matrix of Sub-factors of the critical factor 'customer'

| 'Customer' | Frequency of vehicle breakdown | Cultural background | Duration of maintenance | Emergency/ Necessity | Quality of spare parts | Cost of maintenance |
|---|---|---|---|---|---|---|
| Frequency of vehicle breakdown | 1 | 4 | 1 | 1 | $^1/_2$ | 1 |
| Cultural background | $^1/_4$ | 1 | $^1/_3$ | $^1/_5$ | $^1/_9$ | $^1/_4$ |
| Duration of maintenance | 1 | 3 | 1 | $^1/_2$ | $^1/_3$ | 1 |
| Emergency/ Necessity | 1 | 5 | 2 | 1 | $^1/_2$ | 1 |
| Quality of spare parts | 2 | 9 | 3 | 2 | 1 | 2 |
| Cost of maintenance | 1 | 4 | 1 | 1 | $^1/_2$ | 1 |
| Sum | 6.250 | 26 | 8.33 | 5.7 | 2.944 | 6.250 |
| Consistency Parameters | $\lambda_{max}$ = 6.0479 CI=0.00958 RI=1.24 CR = 0.00772 CR < 0.1 | | | | | |

**Table 12.15.** Pairwise degree comparison matrix of Sub-factors of the critical factor 'technology'

| 'Technology' | Infrastructure | Skill of the personnel | Employer employee relationship | Organizational climate | Maintenance methods |
|---|---|---|---|---|---|
| Infrastructure | 1 | 1 | 1 | 7 | 2 |
| Skill of the personnel | 1 | 1 | 2 | 9 | 3 |
| Employer employee relationship | 1 | $^1/_2$ | 1 | 5 | 5 |
| Organizational climate | $^1/_7$ | $^1/_9$ | $^1/_5$ | 1 | $^1/_3$ |
| Maintenance methods | $^1/_2$ | $^1/_3$ | $^1/_2$ | 3 | 1 |
| Sum | 3 2/3 | 3 | 4 5/7 | 25 | 11 $^1/_3$ |
| Consistency Parameters | $\lambda_{max}$ =5.3471 CI=0.868 RI=1.12 CR = 0.077 CR < 0.1 | | | | |

**Table 12.16. Pairwise degree comparison matrix of Sub-factors of the critical factor 'competitors'**

| Normalized values of the component 'Competitors' | Financial power | Performance of competitors | Customer relationship | Strategies of competitors | Management scheme | Quality policies | new technology |
|---|---|---|---|---|---|---|---|
| inancial ower | 1 | 1 | 1 | 1 | 9 | 1 | 1 |
| erformance f competitors | 1 | 1 | 1 | 1 | 8 | 1 | 1 |
| ustomer elationship | 1 | 1 | 1 | 1 | 8 | 1 | 1 |
| trategies of ompetitors | 1 | 1 | 1 | 1 | 5 | 1 | $^1/_2$ |
| Ianagement cheme | $^1/_9$ | $^1/_8$ | $^1/_8$ | $^1/_5$ | 1 | $^1/_8$ | $^1/_9$ |
| Quality olicies | 1 | 1 | 1 | 1 | 8 | 1 | 1 |
| Iew echnology | 1 | 1 | 1 | 2 | 9 | 1 | 1 |
| SUM | 6 $^1/_9$ | 6 $^1/_8$ | 6 $^1/_8$ | 7 $^1/_5$ | 48 | 6 $^1/_8$ | 5 $^3/_5$ |
| Consistency Parameters | $\lambda_{max}$ =7.0626 CI=0.014043 RI=1.32 CR = 0.0079 CR < 0.1 | | | | | | |

**Table 12.17. Pairwise degree comparison matrix of Sub-factors of the critical factor 'personnel'**

| Pairwise degree comparison matrix of Sub-factors of 'Personnel' | Authority | Responsibility | Initiatives | Motivation |
|---|---|---|---|---|
| Authority | 1 | $^1/_9$ | $^1/_3$ | $^1/_7$ |
| Responsibility | 9 | 1 | 3 | 1 |
| Initiatives | 3 | $^1/_3$ | 1 | $^1/_2$ |
| Motivation | 7 | 1 | 2 | 1 |
| Sum | 20 | 2 $^4/_9$ | 6 $^1/_3$ | 2 $^2/_3$ |
| Consistency Parameters | $\lambda_{max}$ =4.0157 CI=0.00523 RI=0.90 CR =0.0581 CR < 0.1 | | | |

**Table 12.18. Pairwise degree comparison matrix of Sub-factors of the critical factor 'autonomous maintenance'**

| Pairwise degree comparison matrix of Sub-factors of 'Autonomous maintenance' | Attitude of workers | Attitude of Management | Motivation Schemes | Incentive schemes | Financial benefits | Lubrication management | Daily maintenance of machinery data |
|---|---|---|---|---|---|---|---|
| Attitude of workers | 1 | 1 | 7 | 1 | 1 | 2 | 1 |
| Attitude of Management | 1 | 1 | 7 | 1 | 1 | 2 | 1 |
| Motivation Schemes | 1/7 | 1/7 | 1 | 1/9 | 1/7 | 1/4 | 1/6 |
| Incentive schemes | 1 | 1 | 9 | 1 | 1 | 2 | 2 |
| Financial benefits | 1 | 1 | 7 | 1 | 1 | 2 | 1 |
| Lubrication management | 1/2 | 1/2 | 4 | 1/2 | 1/2 | 1 | 1/2 |
| Daily maintenance of machinery data | 1 | 1 | 6 | 1 | 1 | 2 | 1 |
| Sum | 5 2/3 | 5 2/3 | 41 | 5 3/5 | 5 2/3 | 11 1/4 | 6 2/3 |
| Consistency Parameters | $\lambda_{max}$ = 7.1445 CI= 0.0240 RI= 1.32 CR = 0.0182 CR < 0.1 | | | | | | |

**Table 12.19. Pairwise degree comparison matrix of Sub-factors of the critical factor 'individual improvement'**

| Pairwise degree comparison matrix of Sub-factors of 'individual improvement' | Reputation | Kaizen | Suggestion box | Employee involvement scheme | Daily maintenance of machinery | Interpersonal relationship | Employee wish |
|---|---|---|---|---|---|---|---|
| Reputation | 1 | 1/2 | 2 | 1 | 4 | 1 | 1 |
| Kaizen | 2 | 1 | 5 | 3 | 9 | 2 | 3 |
| Suggestion box | 1/2 | 1/5 | 1 | 1/2 | 2 | 1/2 | 1/2 |
| Employee involvement scheme | 1 | 1/3 | 2 | 1 | 3 | 1 | 1 |
| Daily maintenance of machinery | 1/4 | 1/9 | 1/2 | 1/3 | 1 | 1/4 | 1/3 |
| Interpersonal relationship | 1 | 1/2 | 2 | 1 | 4 | 1 | 1 |
| Employee wish | 1 | 1/3 | 2 | 1 | 3 | 1 | 1 |
| Sum | 6 3/4 | 3 | 14 1/2 | 7 5/6 | 26 | 6 3/4 | 7 5/6 |
| Consistency Parameters | $\lambda_{max}$ =70.278 CI= 0.00463 RI=1.32 CR = 0.00351 CR < 0.1 | | | | | | |

**Table 12.20.** Pairwise degree comparison matrix of Sub-factors of the critical factor 'planned maintenance'.

| Pairwise degree comparison matrix of Sub-factors of 'Planned maintenance' | Schedule | Frequency | Idleness | Repetition |
|---|---|---|---|---|
| Schedule | 1 | 9 | 2 | 5 |
| Frequency | 1/9 | 1 | 5 | 2 |
| Idleness | 1/2 | 1/5 | 1 | 1/3 |
| Repetition | 1/5 | 1/2 | 3 | 1 |
| Sum | 1 4/5 | 10 2/3 | 11 | 8 1/3 |
| Consistency Parameters | $\lambda_{max}$ =5.1002 CI=0.3341 RI=0.90 CR = 0.371 CR < 0.1 | | | |

**Table 12.21.** Pairwise degree comparison matrix of Sub-factors of the critical factor 'quality maintenance'

| Pairwise degree comparison matrix of Sub-factors of 'Quality maintenance' | TQM tools | Sampling | Data management |
|---|---|---|---|
| TQM tools | 1 | 7 | 1 |
| Sampling | 1/7 | 1 | 1/9 |
| Data management | 1 | 9 | 1 |
| Sum | 2 1/7 | 17 | 2 1/9 |
| Consistency Parameters | $\lambda_{max}$ =3.007 CI=0.0035 RI=0.58 CR =0.006 CR < 0.1 | | |

**Table 12.22.** Pairwise degree comparison matrix of Sub-factors of the critical factor 'Office TPM"

| Pairwise degree comparison matrix of Sub-factors of 'Office TPM' | New technology | Training | Motivation | Proximity of customer | Proximity of Suppliers | Processing speed |
|---|---|---|---|---|---|---|
| New technology | 1 | 1 | 2 | 9 | 3 | 1 |
| Training | 1 | 1 | 1 | 7 | 2 | 1 |
| Motivation | 1/2 | 1 | 1 | 5 | 2 | |
| Proximity of customer | 1/9 | 1/7 | 1/5 | 1 | 1/3 | 1/8 |
| Proximity of Suppliers | 1/3 | 1/2 | 1/2 | 3 | 1 | 1/3 |
| Processing speed | 1 | 1 | 2 | 8 | 3 | 1 |
| Sum | 4 | 4 2/3 | 6 5/7 | 33 | 11 1/3 | 3 1/2 |
| Consistency Parameters | $\lambda_{max}$ =6.0503 CI=0.01006 RI=1.24 CR =0.00811 CR < 0.1 | | | | | |

**Table 12.23. Pairwise degree comparison matrix of Sub-factors of the critical factor 'Education and Training'**

| Pairwise degree comparison matrix of Sub-factors of 'Education and Training' | Feasibility for higher studies | Facility | Employee interest | Motivation | Rewards |
|---|---|---|---|---|---|
| Feasibility for higher studies | 1 | 7 | 7 | 5 | 9 |
| Facility | $^1/_7$ | 1 | 1 | 1 | 1 |
| Employee interest | $^1/_7$ | 1 | 1 | 1 | 1 |
| Motivation | $^1/_5$ | 1 | 1 | 1 | $^1/_2$ |
| Rewards | $^1/_9$ | 1 | 1 | 2 | 1 |
| Sum | $1\,^3/_5$ | 11 | 11 | 10 | $12\,^1/_2$ |
| Consistency Parameters | $\lambda_{max}$ =5.1220 CI=0.0305 RI=1.12 CR = 0.0272<br>CR < 0.1 | | | | |

**Table 12.24. Pairwise degree comparison matrix of Sub-factors of the critical factor 'Development Management'**

| Pairwise degree comparison matrix of Sub-factors of 'Development Management' | Target setting | Job scheduling | Production plan | Maintenance schedule |
|---|---|---|---|---|
| Target setting | 1 | 1 | 9 | 1 |
| Job scheduling | 1 | 1 | 8 | 1 |
| Production plan | $^1/_9$ | $^1/_8$ | 1 | 1 |
| Maintenance schedule | 1 | 1 | 1 | 1 |
| Sum | $3\,^1/_9$ | $3\,^1/_8$ | 19 | 4 |
| Consistency Parameters | $\lambda_{max}$ =4.6206 CI=0.206 RI=0.90<br>CR = 0.229 CR >0.1 | | | |

**Table 12.25. Pairwise degree comparison matrix of Sub-factors of the critical factor 'Safety, health and Environment'**

| Pairwise degree comparison matrix of Sub-factors of 'Safety, health and Environment' | Hospital | Gymnasium | Pollution | Safety rule | Green belt | Safety training | Safety display | Medical Checkup |
|---|---|---|---|---|---|---|---|---|
| Hospital | 1 | $^1/_2$ | 1/8 | $^1/_9$ | $^1/_6$ | $^1/_7$ | $^1/_7$ | $^1/_6$ |
| Gymnasium | 2 | 1 | $^1/_4$ | $^1/_5$ | $^1/_3$ | $^1/_4$ | $^1/_4$ | $^1/_3$ |
| Pollution | 8 | 4 | 1 | 1 | 1 | 1 | 1 | 1 |
| Safety rule | 9 | 5 | 1 | 1 | 2 | 1 | 1 | 2 |
| Green belt | 6 | 3 | 1 | $^1/_2$ | 1 | 1 | 1 | 1 |
| Safety training | 7 | 4 | 1 | 1 | 1 | 1 | 1 | 1 |
| Safety display | 7 | 4 | 1 | 1 | 1 | 1 | 1 | 1 |
| Medical checkup | 6 | 3 | 1 | $^1/_2$ | 1 | 1 | 1 | 1 |
| Sum | 46 | 24 $^1/_2$ | 6 $^3/_8$ | 5 $^1/_3$ | 7 $^1/_2$ | 6 $^2/_5$ | 6 $^2/_5$ | 7 $^1/_2$ |
| Consistency Parameters | $\lambda_{max}$ =8.070 CI=0.00957 RI=1.41 CR = 0.00678 CR < 0.1 | | | | | | | |

**Table 12.26. Normalized values of Sub-factors of the critical factor 'customer'**

| Normalized values of Sub-factors of 'Customer' | Frequency of vehicle breakdown | Cultural background | Duration of maintenance | Emergency/ necessity | Quality of spare parts | Cost of maintenance | Local sensitivity |
|---|---|---|---|---|---|---|---|
| Frequency of vehicle breakdown | 0.160 | 0.154 | 0.120 | 0.175 | 0.170 | 0.160 | 0.157 |
| Cultural background | 0.040 | 0.039 | 0.040 | 0.035 | 0.038 | 0.040 | 0.039 |
| Duration of maintenance | 0.160 | 0.115 | 0.120 | 0.089 | 0.112 | 0.160 | 0.126 |
| Emergency/ necessity | 0.160 | 0.192 | 0.240 | 0.175 | 0.170 | 0.160 | 0.183 |
| Quality of spare parts | 0.320 | 0.346 | 0.360 | 0.351 | 0.340 | 0.320 | 0.339 |
| Cost of maintenance | 0.160 | 0.154 | 0.120 | 0.175 | 0.170 | 0.160 | 0.157 |

**Table 12.27. Normalized values of Sub-factors of the critical factor 'technology'**

| Normalized values of Sub-factors of 'Technology | Infrastructure | Skill of the personnel | Employer employee relationship | Organizational climate | Maintenance methods | Local sensitivity |
|---|---|---|---|---|---|---|
| Infrastructure | 0.275 | 0.340 | 0.213 | 0.280 | 0.176 | 0.257 |
| Skill of the personnel | 0.275 | 0.340 | 0.425 | 0.360 | 0.265 | 0.333 |
| Employer employee relationship | 0.275 | 0.170 | 0.213 | 0.200 | 0.442 | 0.260 |
| Organizational climate | 0.039 | 0.037 | 0.043 | 0.040 | 0.029 | 0.038 |
| Maintenance methods | 0.136 | 0.113 | 0.106 | 0.120 | 0.088 | 0.113 |

**Table 12.28. Normalized values of Sub-factors of the critical factor 'competitors'**

| Normalized values of Sub-factors of 'Competitors' | Financial power of competitors | Performance of competitors | Customer relationship | Strategies of competitors | Management scheme | Quality policies | New technology | Local sensitivity |
|---|---|---|---|---|---|---|---|---|
| Financial power of competitors | 0.164 | 0.163 | 0.163 | 0.139 | 0.188 | 0.163 | 0.178 | 0.165 |
| Performance of competitors | 0.164 | 0.163 | 0.163 | 0.139 | 0.167 | 0.163 | 0.178 | 0.162 |
| Customer relationship | 0.164 | 0.163 | 0.163 | 0.139 | 0.167 | 0.163 | 0.178 | 0.162 |
| Strategies of competitors | 0.164 | 0.163 | 0.163 | 0.139 | 0.103 | 0.163 | 0.089 | 0.141 |
| Management scheme | 0.016 | 0.022 | 0.022 | 0.027 | 0.020 | 0.022 | 0.021 | 0.021 |
| Quality policies | 0.164 | 0.163 | 0.163 | 0.139 | 0.167 | 0.163 | 0.178 | 0.162 |
| New technology | 0.164 | 0.163 | 0.163 | 0.278 | 0.188 | 0.163 | 0.178 | 0.185 |

**Table 12.29. Normalized values of Sub-factors of the critical factor 'personnel'**

| Normalized values of Sub-factors of 'Personnel' | Authority | Responsibility | Initiatives | Motivation | Local sensitivity |
|---|---|---|---|---|---|
| Authority | 0.050 | 0.045 | 0.053 | 0.055 | 0.051 |
| Responsibility | 0.450 | 0.409 | 0.473 | 0.378 | 0.428 |
| Initiatives | 0.150 | 0.137 | 0.158 | 0.189 | 0.158 |
| Motivation | 0.350 | 0.409 | 0.316 | 0.378 | 0.363 |

**Table 12.30.** Normalized values of Sub-factors of the critical factor ' autonomous maintenance'

| Normalized values of Sub-factors of 'Autonomous maintenance' | Attitude of workers | Attitude of Management | Motivation schemes | Incentive schemes | Financial benefits | Lubrication management | Daily maintenance of Machinery data | Local sensitivity |
|---|---|---|---|---|---|---|---|---|
| Attitude of workers | 0.177 | 0.177 | 0.171 | 0.178 | 0.177 | 0.178 | 0.150 | 0.173 |
| Attitude of Management | 0.177 | 0.177 | 0.171 | 0.178 | 0.177 | 0.178 | 0.150 | 0.173 |
| Motivation schemes | 0.026 | 0.025 | 0.024 | 0.021 | 0.026 | 0.021 | 0.025 | 0.024 |
| Incentive schemes | 0.177 | 0.177 | 0.220 | 0.178 | 0.177 | 0.178 | 0.300 | 0.201 |
| Financial benefits | 0.177 | 0.177 | 0.170 | 0.178 | 0.177 | 0.178 | 0.150 | 0.173 |
| Lubrication management | 0.089 | 0.090 | 0.098 | 0.089 | 0.089 | 0.089 | 0.075 | 0.088 |
| Daily maintenance of Machinery data | 0.177 | 0.177 | 0.146 | 0.178 | 0.177 | 0.178 | 0.150 | 0.169 |

**Table 12.31.** Normalized values of Sub-factors of the critical factor 'individual improvement'

| Normalized values of Sub-factors of ' Individual improvement' | Reputation | Kaizen | Suggestion box | Employee involvement scheme | Daily maintenance of Machinery | Interpersonal relationship | Employee's wish | Local sensitivity |
|---|---|---|---|---|---|---|---|---|
| Reputation | 0.148 | 0.168 | 0.138 | 0.128 | 0.154 | 0.148 | 0.128 | 0.144 |
| Kaizen | 0.296 | 0.336 | 0.345 | 0.382 | 0.346 | 0.296 | 0.382 | 0.341 |
| Suggestion box | 0.075 | 0.067 | 0.069 | 0.063 | 0.078 | 0.074 | 0.063 | 0.070 |
| Employee involvement scheme | 0.148 | 0.112 | 0.138 | 0.128 | 0.115 | 0.148 | 0.128 | 0.131 |
| Daily maintenance of Machinery | 0.037 | 0.037 | 0.034 | 0.043 | 0.038 | 0.038 | 0.043 | 0.038 |
| Interpersonal relationship | 0.148 | 0.168 | 0.138 | 0.128 | 0.154 | 0.148 | 0.128 | 0.144 |
| Employee's wish | 0.148 | 0.112 | 0.138 | 0.128 | 0.115 | 0.148 | 0.128 | 0.131 |

**Table 12.32.** Normalized values of Sub-factors of the critical factor 'planned maintenance'

| Normalized values of Sub-factors of 'Planned maintenance' | Schedule | Frequency | Idleness | Reputation | Local sensitivity |
|---|---|---|---|---|---|
| Schedule | 0.553 | 0.841 | 0.181 | 0.600 | 0.544 |
| Frequency | 0.061 | 0.093 | 0.455 | 0.240 | 0.212 |
| Idleness | 0.276 | 0.019 | 0.091 | 0.040 | 0.106 |
| Reputation | 0.110 | 0.047 | 0.273 | 0.120 | 0.137 |

**Table 12.33.** Normalized values of Sub-factors of the critical factor 'quality maintenance'

| Normalized values of Sub-factors of 'Quality maintenance' | TQM tools | Sampling | Data management | Local sensitivity |
|---|---|---|---|---|
| TQM tools | 0.467 | 0.412 | 0.473 | 0.451 |
| Sampling | 0.066 | 0.059 | 0.053 | 0.059 |
| Data management | 0.467 | 0.529 | 0.474 | 0.490 |

**Table 12.34.** Normalized values of Sub-factors of the critical factor 'Education and Training'

| Normalized values of Sub-factors of 'Education and Training' | Feasibility for higher studies | Training facility | Employee's own interest | Motivation for Training | Rewards for better performance | Local sensitivity |
|---|---|---|---|---|---|---|
| Feasibility for higher studies | 0.627 | 0.636 | 0.636 | 0.500 | 0.720 | 0.624 |
| Training Facility | 0.089 | 0.091 | 0.091 | 0.100 | 0.080 | 0.090 |
| Employee's own interest | 0.089 | 0.091 | 0.091 | 0.100 | 0.080 | 0.090 |
| Motivation for Training | 0.125 | 0.091 | 0.091 | 0.100 | 0.040 | 0.089 |
| Rewards for better performance | 0.070 | 0.091 | 0.091 | 0.200 | 0.080 | 0.106 |

**Table 12.35.** Normalized values of Sub-factors of the critical factor 'Office TPM'

| Normalized values of Sub-factors of 'Office TPM' | New technology | Training | Motivation | Proximity of customer | Proximity of Suppliers | Processing speed | Local sensitivity |
|---|---|---|---|---|---|---|---|
| New technology | 0.254 | 0.215 | 0.299 | 0.273 | 0.265 | 0.289 | 0.266 |
| Training | 0.254 | 0.215 | 0.149 | 0.212 | 0.176 | 0.289 | 0.216 |
| Motivation | 0.126 | 0.215 | 0.149 | 0.152 | 0.176 | 0.000 | 0.137 |
| Proximity of customer | 0.027 | 0.032 | 0.030 | 0.030 | 0.029 | 0.037 | 0.031 |
| Proximity of Suppliers | 0.085 | 0.108 | 0.074 | 0.091 | 0.088 | 0.096 | 0.090 |
| Processing speed | 0.254 | 0.215 | 0.299 | 0.242 | 0.266 | 0.289 | 0.261 |

**Table 12.36.** Normalized values of Sub-factors of the critical factor 'Development Management'

| Normalized values of Sub-factors of 'Development Management' | Target | Job scheduling | Production plan | Maintenance schedule | Local sensitivity |
|---|---|---|---|---|---|
| Target | 0.321 | 0.320 | 0.474 | 0.250 | 0.341 |
| Job scheduling | 0.321 | 0.320 | 0.422 | 0.250 | 0.328 |
| Production plan | 0.037 | 0.040 | 0.053 | 0.250 | 0.095 |
| Maintenance schedule | 0.321 | 0.320 | 0.053 | 0.250 | 0.236 |

**Table 12.37.** Normalized values of Sub-factors of the critical factor 'Safety, health and environment'

| Safety, health and environment | Hospital | Gymnasium | Pollution | Safety rule | Green belt | Safety training | Safety display | Medical Checkup | Local sensitivity |
|---|---|---|---|---|---|---|---|---|---|
| Hospital | 0.023 | 0.022 | 0.019 | 0.021 | 0.022 | 0.022 | 0.022 | 0.022 | 0.021 |
| Gymnasium | 0.043 | 0.041 | 0.039 | 0.039 | 0.044 | 0.039 | 0.039 | 0.044 | 0.041 |
| Pollution | 0.174 | 0.163 | 0.157 | 0.188 | 0.135 | 0.156 | 0.157 | 0.134 | 0.158 |
| Safety rule | 0.196 | 0.204 | 0.157 | 0.188 | 0.267 | 0.156 | 0.157 | 0.268 | 0.199 |
| Green belt | 0.130 | 0.122 | 0.157 | 0.094 | 0.133 | 0.156 | 0.157 | 0.133 | 0.135 |
| Safety training | 0.152 | 0.163 | 0.157 | 0.188 | 0.133 | 0.157 | 0.156 | 0.133 | 0.155 |
| Safety display | 0.152 | 0.163 | 0.157 | 0.188 | 0.133 | 0.157 | 0.156 | 0.133 | 0.155 |
| Medical checkup | 0.130 | 0.122 | 0.157 | 0.094 | 0.133 | 0.157 | 0.156 | 0.133 | 0.135 |

**Table 12.38.** Global sensitivity of Sub-factors of the critical factor 'Customer'

| Sub-factors of Customer | Local sensitivity | Global sensitivity= 0.615× Local sensitivity |
|---|---|---|
| Frequency of vehicle breakdown | 0.157 | 0.097 |
| Cultural background | 0.039 | 0.024 |
| Duration of maintenance | 0.126 | 0.077 |
| Emergency/ necessity | 0.183 | 0.113 |
| Quality of spare parts | 0.339 | 0.208 |
| Cost of maintenance | 0.157 | 0.097 |

**Table 12.39.** Global sensitivity of Sub-factors of the critical factor 'Technology'

| Sub-factors of Technology | Local sensitivity | Global sensitivity= 0.319× Local sensitivity |
|---|---|---|
| Infrastructure | 0.257 | 0.082 |
| Skill of the personal | 0.333 | 0.106 |
| Employer employee relationship | 0.26 | 0.083 |
| Organizational climate | 0.038 | 0.012 |
| Maintenance methods | 0.113 | 0.036 |

**Table 12.40.** Global sensitivity of Sub-factors of the critical factor 'Competitors'

| Sub-factors of Competitors | Local sensitivity | Global sensitivity= 0.066× Local sensitivity |
|---|---|---|
| Financial power | 0.165 | 0.033 |
| Performance of competitors | 0.162 | 0.032 |
| Customer relationship | 0.162 | 0.032 |
| Strategies of competitors | 0.141 | 0.028 |
| Management scheme | 0.021 | 0.004 |
| Quality | 0.165 | 0.033 |
| New technology | 0.185 | 0.037 |

**Table 12.41.** Global sensitivity of Sub-factors of the critical factor 'Personnel'

| Sub-factors of Personnel | Local sensitivity | Global sensitivity= 0.602× Local sensitivity |
|---|---|---|
| Authority | 0.051 | 0.031 |
| Responsibility | 0.428 | 0.258 |
| Initiatives | 0.158 | 0.095 |
| Motivation | 0.363 | 0.219 |

**Table 12.42.** Global sensitivity of Sub-factors of the critical factor 'Autonomous maintenance'

| Sub-factors of Autonomous maintenance | Local sensitivity | Global sensitivity= 0.153× Local sensitivity |
|---|---|---|
| Attitude of workers | 0.173 | 0.026 |
| Attitude of Management | 0.173 | 0.026 |
| Motivation | 0.024 | 0.004 |
| Incentive schemes | 0.201 | 0.031 |
| Financial benefits | 0.173 | 0.026 |
| Lubrication management | 0.088 | 0.013 |
| Daily maintenance of Machinery data | 0.169 | 0.026 |

**Table 12.43.** Global sensitivity of Sub-factors of the critical factor 'Individual improvement'

| Sub-factors of Individual improvement | Local sensitivity | Global sensitivity= 0.137× Local sensitivity |
|---|---|---|
| Reputation | 0.144 | 0.002 |
| Kaizen | 0.341 | 0.047 |
| Suggestion box | 0.07 | 0.010 |
| Employee involvement scheme | 0.131 | 0.018 |
| Daily maintenance of Machinery | 0.038 | 0.005 |
| Interpersonal relationship | 0.144 | 0.019 |
| Employee wish | 0.131 | 0.018 |

**Table 12.44.** Global sensitivity of Sub-factors of the critical factor 'Planned maintenance'

| Sub-factors of Planned maintenance | Local sensitivity | Global sensitivity= 0.134× Local sensitivity |
|---|---|---|
| Schedule of maintenance | 0.544 | 0.085 |
| Frequency | 0.212 | 0.032 |
| Idleness of machine | 0.106 | 0.016 |
| Repetition of work | 0.137 | 0.02 |

**Table 12.45.** Global sensitivity of Sub-factors of the critical factor 'Quality maintenance'

| Sub-factors of Quality maintenance | Local sensitivity | Global sensitivity= 0.15 × Local sensitivity |
|---|---|---|
| TQM tools | 0.451 | 0.067 |
| Sampling | 0.059 | 0.009 |
| Data management | 0.49 | 0.074 |

**Table 12.46.** Global sensitivity of Sub-factors of critical factor 'Education and training'

| Sub-factors of Education and training | Local sensitivity | Global sensitivity= 0.15 × Local sensitivity |
|---|---|---|
| Feasibility for higher studies | 0.624 | 0.094 |
| Facility | 0.09 | 0.013 |
| Employee interest | 0.09 | 0.013 |
| Motivation | 0.089 | 0.013 |
| Rewards | 0.106 | 0.016 |

**Table 12.47.** Global sensitivity of Sub-factors of the critical factor 'Development management'

| Sub-factors of Development management | Local sensitivity | Global sensitivity= 0.086 × Local sensitivity |
|---|---|---|
| Target | 0.341 | 0.029 |
| Job scheduling | 0.328 | 0.028 |
| Production plan | 0.095 | 0.009 |
| Maintenance schedule | 0.236 | 0.02 |

**Table 12.48.** Global sensitivity of Sub-factors of the critical factor 'Office TPM'

| Sub-factors of Office TPM | Local sensitivity | Global sensitivity= 0.018× Local sensitivity |
|---|---|---|
| New technology | 0.266 | 0.005 |
| Training | 0.216 | 0.004 |
| Motivation | 0.137 | 0.002 |
| Proximity of customer | 0.031 | 0.001 |
| Proximity of Suppliers | 0.09 | 0.002 |
| Processing speed | 0.261 | 0.004 |

**Table 12.49.** Global sensitivity of Sub-factors of the critical factor 'Safety, Health and Environment'

| Sub-factors of Safety, Health and Environment | Local sensitivity | Global sensitivity= 0.153 × Local sensitivity |
|---|---|---|
| Hospital | 0.021 | 0.003 |
| Gymnasium | 0.041 | 0.006 |
| Pollution | 0.158 | 0.024 |
| Safety rule | 0.199 | 0.03 |
| Green belt | 0.135 | 0.021 |
| Safety training | 0.155 | 0.024 |
| Safety Display | 0.155 | 0.024 |
| Medical checkup | 0.135 | 0.021 |

**Table 12.50.** Saaty's Table for Random Index vs. Size of the Matrix

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |
| n = size of the matrix | | | | R.I – Average Random Index | | | | | | |

**Table 12.51. Global sensitivity and local sensitivities of critical factors and Sub-factors of MQFD**

| Critical Factors | Local sensitivities | Sub-factors | Global sensitivities |
|---|---|---|---|
| Customer | 0.615 | Frequency of vehicle breakdown | 0.097 |
| | | Cultural background | 0.024 |
| | | Duration of maintenance | 0.077 |
| | | Emergency/necessity | 0.113 |
| | | Quality of spare parts | 0.208 |
| | | Cost of maintenance | 0.097 |
| Technology | 0.319 | Infrastructure | 0.082 |
| | | Skill of the personal | 0.106 |
| | | Employer employee relationship | 0.083 |
| | | Organizational climate | 0.012 |
| | | Maintenance methods | 0.036 |
| Competitors | 0.066 | Financial power | 0.033 |
| | | Performance of competitors | 0.032 |
| | | Customer relationship | 0.032 |
| | | Strategies of competitors | 0.028 |
| | | Management scheme | 0.004 |
| | | Quality policies | 0.033 |
| | | New technology | 0.037 |
| Personnel | 0.602 | Authority | 0.031 |
| | | Responsibility | 0.258 |
| | | Initiatives | 0.095 |
| | | Motivation | 0.219 |
| Value of decision | 0.083 | | |
| Reliability of decision | 0.315 | | |
| Autonomous maintenance | 0.153 | Attitude of workers | 0.026 |
| | | Attitude of Management | 0.026 |
| | | Motivation schemes | 0.004 |
| | | Incentive schemes | 0.031 |
| | | Financial benefits | 0.026 |
| | | Lubrication management | 0.013 |
| | | Daily maintenance | 0.026 |
| Individual improvement | 0.137 | Reputation | 0.02 |
| | | Kaizen | 0.047 |
| | | Suggestion box | 0.01 |
| | | Employee involvement scheme | 0.018 |
| | | Daily maintenance | 0.005 |
| | | Interpersonal relationship | 0.019 |
| | | Employee wish | 0.018 |
| Planned maintenance | 0.153 | Schedule of maintenance | 0.085 |
| | | Frequency | 0.032 |
| | | Idleness of machine | 0.016 |
| | | Repetition of work | 0.02 |

Table Contd............

| | | | |
|---|---|---|---|
| Quality maintenance | 0.15 | TQM tools | 0.067 |
| | | Sampling | 0.009 |
| | | Data management | 0.074 |
| Education and training | 0.15 | Feasibility for higher studies | 0.094 |
| | | Facility | 0.013 |
| | | Employee interest | 0.013 |
| | | Motivation for training | 0.013 |
| | | Rewards | 0.016 |
| Development management | 0.086 | Target | 0.029 |
| | | Job scheduling | 0.029 |
| | | Production plan | 0.007 |
| | | Maintenance schedule | 0.02 |
| Office TPM | 0.018 | New technology | 0.005 |
| | | Training | 0.004 |
| | | Motivation | 0.002 |
| | | Proximity of customer | 0.001 |
| | | Proximity of Suppliers | 0.002 |
| | | Processing speed | 0.004 |
| Safety, Health and Environment | 0.153 | Hospital | 0.003 |
| | | Gymnasium | 0.006 |
| | | Pollution | 0.024 |
| | | Safety rule | 0.03 |
| | | Green belt | 0.021 |
| | | Safety training | 0.024 |
| | | Display | 0.024 |
| | | Medical checkup | 0.021 |
| OEE | 0.227 | | |
| MTBF | 0.032 | | |
| MTTR | 0.062 | | |
| PE | 0.278 | | |
| MDT | 0.212 | | |
| Availability | 0.190 | | |
| Improved maintenance | 0.381 | | |
| Increased profit | 0.042 | | |
| Upgraded Core competence | 0.196 | | |
| Enhanced goodwill | 0.381 | | |

**Table 12.52.** Global sensitivity and Sub-factors in the descending order

| Sub-factors | Global sensitivities |
|---|---|
| Responsibility | 0.258 |
| Motivation | 0.219 |
| Quality of spare | 0.208 |
| Emergency/necessity | 0.113 |
| Skill of the personal | 0.106 |
| Frequency of vehicle breakdown | 0.097 |
| Cost of maintenance | 0.097 |
| Initiatives | 0.095 |
| Feasibility for higher studies | 0.094 |
| Schedule of maintenance | 0.085 |
| Employer employee relationship | 0.083 |
| Infrastructure | 0.082 |
| Duration of maintenance | 0.077 |
| Data management | 0.074 |
| TQM tools | 0.067 |
| Kaizen | 0.047 |
| New technology | 0.037 |
| Maintenance methods | 0.036 |
| Financial power | 0.033 |
| Quality parameters | 0.033 |
| Performance of competitors | 0.032 |
| Customer relationship | 0.032 |
| Frequency | 0.032 |
| Authority | 0.031 |
| Incentive schemes | 0.031 |
| Safety rule | 0.03 |
| Target | 0.029 |
| Strategies of competitors | 0.028 |
| Job scheduling | 0.028 |
| Attitude of workers | 0.026 |
| Attitude of Management | 0.026 |
| Financial benefits | 0.026 |
| Daily maintenance of machinery data | 0.026 |
| Cultural background | 0.024 |
| Pollution | 0.024 |
| Safety training | 0.024 |
| Safety display | 0.024 |
| Green belt | 0.021 |
| Medical checkup | 0.021 |
| Repetition of work | 0.02 |
| Maintenance schedule | 0.02 |
| Reputation | 0.02 |
| Interpersonal relationship | 0.019 |
| Employee involvement scheme | 0.018 |

Table Contd………

| | |
|---|---|
| Employee wish | 0.018 |
| Idleness of machine | 0.016 |
| Rewards | 0.016 |
| Lubrication management | 0.013 |
| Facility | 0.013 |
| Employee interest | 0.013 |
| Motivation for training | 0.013 |
| Organizational climate | 0.012 |
| Suggestion box | 0.01 |
| Sampling | 0.009 |
| Production plan | 0.009 |
| Gymnasium | 0.006 |
| Daily maintenance | 0.005 |
| New technology | 0.005 |
| Processing speed | 0.005 |
| Management scheme | 0.004 |
| Training | 0.004 |
| Motivation Schemes | 0.003 |
| Hospital | 0.003 |
| Motivation | 0.002 |
| Proximity of Suppliers | 0.002 |
| Proximity of customer | 0.001 |

**Table 12.53.** Local sensitivity and critical factors in the descending order

| Critical Factors | Local sensitivities |
|---|---|
| Customer | 0.615 |
| Personnel | 0.602 |
| Improved maintenance | 0.381 |
| Enhanced goodwill | 0.381 |
| Technology | 0.319 |
| Performance efficiency | 0.278 |
| OEE | 0.227 |
| MDT | 0.212 |
| Upgraded Core competence | 0.196 |
| Availability | 0.190 |
| Autonomous maintenance | 0.153 |
| Planned maintenance | 0.153 |
| Safety, Health and Environment | 0.153 |
| Quality maintenance | 0.15 |
| Individual improvement | 0.137 |
| Education and training | 0.131 |
| Development management | 0.086 |
| Competitors | 0.066 |
| MTTR | 0.062 |
| Increased profit | 0.042 |
| MTBF | 0.032 |
| Office TPM | 0.018 |

## 12.4. Results and discussions

The final outcomes of AHP in MQFD in the company under study were the enumeration of local sensitivities of critical factors and global sensitivities of sub factors. The values of these sensitivities were useful in determining the priorities among the critical factors and sub factors. The company may show different levels of interest and care regarding these factors while implementing MQFD. In order to determine these priorities, the sensitivities computed during AHP studies were subjected to analysis. This process began by preparing the table containing the sensitivities. This is shown as Table 12.52. Further, the table showing the local sensitivities of critical factors in the descending order was prepared and shown in Table 12.53. Likewise the global sensitivities of all sub-factors have also been shown in Table 12.52 in the descending order. The bar chart depicting the local sensitivities of critical factors are shown in Figure 12.3. These tables and Figure 12.3 reveal the following observations which demarcate the environment prevailing in the company under study for implementing MQFD.

- As shown in Table 12.53 and Figure 12. 3, 'customer' possesses the highest value of local sensitivity. This indicates that the company has to make maximum investment in this critical factor for the succesful application of MQFD.

- As shown in Table 12.53 and Figure 12.3, the local sensitivity of the critical factor 'Office TPM' is the least among all. Hence the company has to spend minimum time and money on office TPM while implementing MQFD.

- As shown in Table 12.52, the sub-factor 'responsibility' has the highest global sensitivity. Hence the company has to show maximum interest and commitment towards this sub-factor while implementing MQFD.

- As shown in Table 12.52, the sub-factor 'proximity to customer' possesses the least global sensitivity. Hence, the company needs to spend very little resource and care on it.

- An analysis indicates that no critical factors and sub-factors have more than 75% local and global sensitivities. This indicates that these factors are inherently in progress in the company and do not require urgent care and abudent resource allocation for their deployment. In other wards, this finding indicates the existence of culture conducive to MQFD implementation in the company.

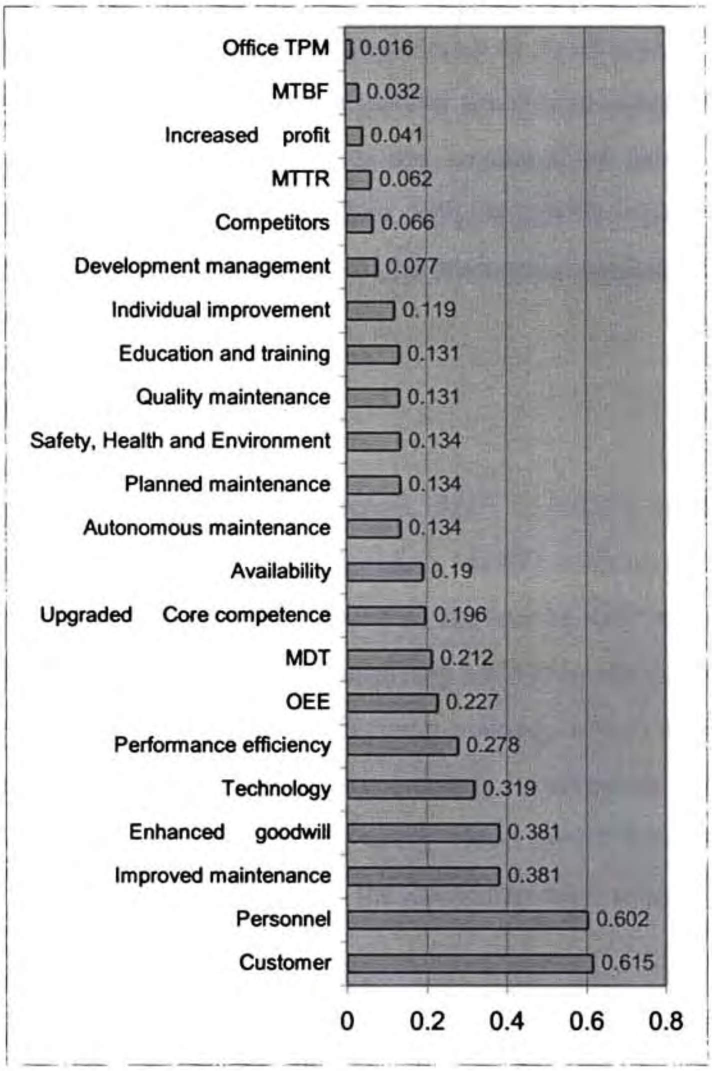


**Figure 12.3. Hierarchy of sensitivity of critical factors**

- The critical factors, whose global sensitivities fall between 50% and 75%, are customer and personnel. This indicates that extreme care has to be taken by the company towards customer related strategies and personal selection while implementing MQFD.

- 20 number of critical factors and 66 sub-factors have sensitivity less than 50%. This indicates that the company has to care to the minimum extent about these activities. This finding indicates that, MQFD implementation requires much less investment and care on the part of the company.

On the whole, the company may not face any difficulty in implementing MQFD, because the local and global sensitivities of its critical factors and sub factors are less than 50%. Since it is a general practice to accept favorably the implementation of any system, which is not sensitized by any critical factors and sub-factors to any extent more than 50%, it can be concluded that the company under study is vulnerable to the succesful application of MQFD technique.

## 12.5. Application

As mentioned in the previous section, AHP on MQFD conducted in the company revealed that feasibility of applying MQFD without any hurdles and extraordinary care and investment. However, the use of AHP on MQFD is not limited just to assess the feasibility of applying MQFD in the company. Rather, its real use lies in the multi criteria decision-making, which is a hallmark of strategic decision of MQFD model. Accordingly, a company has to adopt a strategic maintenance quality policy by using which the MQFD cycle has to be propelled. In our case, we think that the company may adopt the following strategic maintenance quality policy.

i) Critical factors having sensitivities more than 20% may be processed through eight pillars of TPM. Others may be subjected to direct implementation.

ii) The sub-factors with global sensitivities more than 10% may be diverted towards the eight pillars of TPM. Other sub-factors may be subjected to direct implementation.

According to the first policy, the critical factors MDT, OEE, Performance quality, Technology, enhanced goodwill, improved maintenance, personnel and customers have to be given maximum orientation while implementing eight pillars. Other critical factors may be subjected to implementation by spending minimum resources. For example, the supervisors may just orally educate the subordinates about those critical factors. In these cases, the formal conduct of training programmes spending considerable resources is not required.

According to the second policy, the company has to forward the sub-factors, namely responsibility, motivation, initiatives, quality of spare parts and emergencies/ necessity towards eight pillars of TPM. Other sub-factors may be subjected to implementation by spending minimum resources on them.

Thus the AHP on MQFD is useful in recognizing the critical factors and sub-factors which will sensitize the MQFD programme. Subsequently it tilts MQFD implementation towards these critical factors and sub-factors by taking high care by investing significant resources in them.

## 12.6. Conclusion

The world has been experiencing global competition from the latter part of twentieth centaury. Right from this period, the intensity of this competition has been increasing exponentially (Chong and. Rundus, 2004). In order to cope with this unabated global competition, the human race has been witnessing the contribution of a number of models and techniques by researchers and practitioners. Some of them include TQM, BPR, TPM, QFD, Quality circle, and kaizen. An overall view of the literature would indicate that despite their contributions to face competitions, these revolutionary principles have time and again resulted in failures in certain organizations.(Al-Najjar and Alsyouf, 2003, Hansson and Klefsjo., 2003, Nwabueze, 2001). Researchers have been exploring the reasons and bringing out new methodologies to overcome these failures. The world has been witnessing this kind of detection-based approach for a little long time. This is not a desirable situation because implementing of all these principles in organizations requires a major investment and structural changes. Hence a sustainable tool is necessary to ensure that any revolutionary technique or model that is developed is able to withstand the changes in the organizational scenario. In this context, the module of the research work reported in this chapter was carried out with the primary objective of fitting MQFD in organizations with varied levels of managerial and technological developments.

In the module of the research work reported in this chapter, AHP on MQFD was subjected to a sample implementation study in an Indian State-Government-run maintenance intensive unit. The final outcome of this study was the determination of the global and local sensitivities of critical factors and sub-factors. This process facilitates the identification of the critical factors influencing MQFD implementation and the quantification of the sensitivities. Using these quantified values, a company may tilt its decisions to concentrate on the most sensitive critical and sub-factors. This prevents the company from wasting the resources on considering the critical factors, which are least sensitive to the successful implementation of MQFD in the company. Accordingly, a company can tailor-make the MQFD implementation programme which would concentrate more on the sensitivities of critical factors and sub-factors. This action prevents the failure of MQFD in the company.

The results of undertaking the module of research work portrayed in this chapter the author indicated the existence of favorable situation for successful implementation of MQFD in the company. Further the factors and sub-factors with higher global and local sensitivities were enumerated. These findings coincided with the environment prevailing in the company, which is conducive to the implementation of MQFD implementation. Hence it is concluded that the application of AHP in MQFD is a good proposition to achieve the successful results of MQFD implementation. Though the sample implementation study proceeded without any hitches, it was found that the mathematical calculations dominate the application of AHP to MQFD. Thus there exists every possibility of an executive who is busy with routine activities adopting the AHP application study on MQFD. In this connection the utility of the executive support system (ESS) reported in the literatures requires recognition (Turban and Walls, 1995, Nord and Nord, 1995, Huang and Windsor, 1998, Watson and

Rainer, Jr, 1991, Rainer and Watson, 1995). At this juncture, this chapter is concluded by stating that an ESS would be adding strength to the successful adoption of AHP studies while implementing MQFD programme and the making of tailor-made implementation programme for its successful implementation in the concerned company.

Chapter - 13

# CONCLUSION

*Content*

# CONCLUSION

## 13.1. Introduction

This research work was started at the time when TPM concept has been established as a world-class manufacturing strategy. In India, where the author resides, during the past two decades, both theoreticians and practitioners had been nourishing the merits of TPM programmes. Many Indian companies have been actively implementing TPM concepts. In few cases, training programmes in TPM are being conducted by the experts drawn from Japan. Now, TPM concepts have spread across the world. However, it is reported that a considerable number of companies have failed to yield the expected results through TPM implementation. It is also observed that many of the TPM implementing companies are unable to implement it in full swing. The survey results conducted during the beginning phase of this research work corroborate this observation. One of the reasons for this situation is the absence of customer focus in TPM. In this contemporary business scenario, customer has become the center tenant of business. Hence, it is concerning that TPM is devoid of customer appraisal principles.

On studying, the author understood that the proponents of TPM have integrated TQM philosophy with maintenance engineering principles. In this context, the author realized that TPM programmes are not exhaustive for they have not been integrated with all the features of TQM. If the same techniques used in TQM are also used in TPM project, then it will not only result in savings but will also ensure higher success rate. In this context, the author believed that TPM concepts are imperative but should be subjected to improvement and modification to ensure focused application. Particularly, TQM researchers have enunciated the technique QFD as an ideal one to take care of the voice of customers. Thus the author proceeded this research work with the proposition that if QFD principles are integrated in TPM by suitable means, it can overcome the lacunas of TPM. Subsequently, the author designed MQFD model, which formed the foundation of this work.

## 13.2. Receptivity of the Research work

In order the test the receptivity and practical validity of MQFD model, investigations were conducted. Although practical implementation could not achieved on full scales, the results of these investigations revealed that the elements of MQFD model could be successfully implemented in companies. Meanwhile, the author submitted the details of the research work to various podiums. Particularly, three peer-reviewed papers were published in three UK based international journals namely International journal of process management and benchmarking, International journal of management practice and 'journal of quality in maintenance engineering'. Some more papers have been communicated to the in International Journals, which are under review. These developments indicate the favorable receptivity of MQFD and its elements among academicians, researchers and practitioners.

In order to test the validity of MQFD model in total, an explorative study was conducted. The results of this study also indicated the possibility of successfully applying MQFD model in companies. Much more thrust is needed to effect the percolation of MQFD model in real time environment. The author has recommended the future researchers to work in this direction under the next section. In this background, the author believes that this research work has resulted in the evolution of practically compatible and useful MQFD model, which would be useful to both theoreticians and practitioners.

## 13.3. Future scope of research

This research work has created an avenue for carrying out further work in the some direction. In order to make the MQFD model a dent in practical arena, the author advises the future researchers to contact the professional bodies like Japanese Institute of Plant Maintenance and appraise the details of MQFD. These researchers may develop strong relationships with practitioners and implement MQFD in their working environments. Though the implementation studies proceeded without any hitches, it was found that the mathematical calculations dominate the application of MQFD. Thus there exists every possibility that an executive who is busy with routine activities will stay from involving the AHP application study on MQFD. In this direction the utility of executive support system (ESS) being reported in literature requires recognition (Turban and Walls, 1995, Nord and Nord, 1995, Huang and Windsor, 1998, Watson and Rainer, Jr, 1991, Rainer and Watson, 1995). At this juncture, the author appraises that an ESS would be adding strength to the successful adoption of AHP MQFD programme in companies. In literature, the author requests that the future researchers can develop ESS on MQFD by incorporating the latest IT devises. This will ensure that MQFD is implemented with the support of the chief executive officers and executives in companies in sustained manner to yield continuous maintenance quality improvement.

## 13.4. Concluding Remarks

The main contribution of this research work is the MQFD model. The receptivity of this model has been so good that the scholarly anonymous reviewers recommended the publication of five papers containing the features of MQFD model in four international

UK based Journals. Further, despite the week link existing between the engineering education and the industry, the author strived to test implement the MQFD model in typical companies. The author also employed the way of applying MQFD model in engineering educational scenario to enhance the quality of engineering education. Further the author has been seeing the failure reports of revolutionary principles and models like TQM, BPR and quality circles. In order to prevent the failure of MQFD model, the author has contributed the strategic receptivity scorecard approach. In order to fit MQFD in varied organizational cultures, the author has shown the way of applying AHP technique so as to ensure the succesful implementation of MQFD. Thus the contributions of this research work are not only validated for their application feasibility, the derailment of their succesful implementation is also prevented by using the two tools namely strategic receptivity scorecard and AHP. The fruitfulness of the contributions of these research work would be realized when MQFD is popularized among both researchers and practitioners and implemented in practical fields.

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# ANNEXURE

## *ANNEXURE A*

**Questionnaire for assessing the level of implementation of TPM and QFD**

A I. Has TPM been implemented in your company? Yes/No

If the answer is Yes, please answer A II to X. Other wise please proceed to section B

A II. What is the level of implementation of the first pillar (titled as JISHU – HOZEN meaning AUTONOMOUS MAINTENANCE) in your company?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

A III. What is the level of implementation of the second pillar (titled as KOBETSU KAIZEN meaning INDIVIDUAL IMPROVEMENTS) in your company?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

A IV. What is the level of implementation of the third pillar (titled as PLANNED MAINTENANCE) in your company?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

A V. What is the level of implementation of the fourth pillar (titled as QUALITY MAINTENANCE) in your company?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

A VI. What is the level of implementation of the fifth pillar (titled as OFFICE TPM meaning TPM IN NON- SHOP FLOOR AREAS) in your company?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

A VII. What is the level of implementation of the sixth pillar (titled as EDUCATION & TRAINING) in your company?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

A VIII. What is the level of implementation of the seventh pillar (titled as SAFETY / HEALTH & ENVIRONMENT) in your company?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

A IX. What is the level of implementation of the eighth pillar (titled as INITIAL CONTROL meaning DEVELOPMENT MANAGEMENT) in your company?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

A X. Have your company ever used internal and external customers concept while implementing TPM?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

B I. Has your company ever implemented quality function deployment (QFD)? Yes/No

If your answer is Yes, please proceed to respond to the following questions.

B II To which extent QFD has been implemented in your company?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

B III. Who are the personnel involved while implementing QFD? Please tick

| Top Management Personnel | Middle Level Management Personnel | Bottom Level Management Personnel | Transaction Processors Operators | Others please specify |
|---|---|---|---|---|
| Managing Director | General Manager | Supervisors | Clerical Personnel | |
| President | Works Manager | Office Superintendents | Data entry operators | |
| Vice- President | | | Typists | |

B IV. What are the benefits that your company has derived by implementing QFD?

Please tick the appropriate boxes ☐

Reduced design changes ☐

Shorter Product development cycles ☐

Lowered costs and enhanced productivity ☐

Improved product quality and reliability ☐

Increased market share ☐

Increased attention to customer's perspectives ☐

Any other, please specify

# ANNEXURE B

## Survey for Better Maintenance
Government Vehicle workshop, Coimbatore

**Instructions**

Kindly Answer the following

Please do not reveal your name or identity

You are supported to discuss with your colleagues.

Answer should be done individually.

Please mark (√) to the respective grade against each question

E - Excellent A - Average G - Good B - Bad
Z - Excellent bad

| Q No | Description | E | G | A | B | Z |
|---|---|---|---|---|---|---|
| 1 | Condition of Drivers seat | | | | | |
| 2 | Condition of raer view mirrors | | | | | |
| 3 | Condition of front light | | | | | |
| 4 | Engine condition | | | | | |
| 5 | Condition of Gear box | | | | | |
| 6 | Condition of Transmission | | | | | |
| 7 | Condition of suspension/Springs | | | | | |
| 8 | Condition of Tyres | | | | | |
| 9 | Condition of Steering | | | | | |
| 10 | Condition of Breaks | | | | | |
| 11 | Condition of Clutches | | | | | |
| 12 | Ride Comfort | | | | | |
| 13 | Handling characteristics | | | | | |
| 14 | Oil leak if any | | | | | |
| 15 | Mileage | | | | | |
| 16 | Periodical maintenance | | | | | |
| 17 | Response from maintenance department against problems | | | | | |
| 18 | Control of repeated breakdowns | | | | | |
| 19 | Consideration of drivers suggestion by maintenance people | | | | | |
| 20 | Skill of maintenance people | | | | | |

**The following questions may be answered in 3 or 4 sentences**

21. According to you what are the major complaints of the vehicle

22. What are the wrong maintenance practices exists in your knowledge

23. List your five strong points as a driver

24. List your five weaknesses as a driver

25. List any five strong points of the maintenance stream

26. List any five week points of maintenance stream

# *ANNEXURE C*

## Survey for Better Maintenance.

### Instructions

Kindly answer the following
Please do not reveal your name or identity.
You are supported to discuss with your colleagues.
Answer should be done individually.
Please mark (√) to the respective grade against each question

E - Excellent. G - Good A - Average
B - Bad Z - Extremely bad

| | | E | G | A | B | Z | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | Condition of operators' Cabin | | | | | | |
| 2 | Condition of operators' seat | | | | | | |
| 3 | Condition of lighting & ventilation | | | | | | |
| 4 | Condition of wind shield | | | | | | |
| 5 | Condition of control panel | | | | | | |
| 6 | Engine condition | | | | | | |
| 7 | Condition of transmission/ hydraulic pump | | | | | | |
| 8 | Cleanliness of equipment | | | | | | |
| 9 | Condition of Final Drive / under carriage | | | | | | |
| 10 | Load taking characteristics | | | | | | |
| 11 | Handling characteristics | | | | | | |
| 12 | Maintenance of lubrication system of equipment | | | | | | |
| 13 | Periodical Maintenance | | | | | | |
| 14 | Face / Bench/ Road Condition | | | | | | |
| 15 | Availability of loose material (Lime stone/Black rock) | | | | | | |
| 16 | Response from maintenance department against problem | | | | | | |
| 17 | Control of repeated break down | | | | | | |
| 18 | Condition of operators suggestion | | | | | | |
| 19 | Skill of the operators | | | | | | |
| 20 | Skill of maintenance people | | | | | | |

**The following question may be answered in 3 or 4 sentences**

21. According to you where are all the majors complaints of the equipment.

    a. Operators' comfort

    b. Condition of equipment

    c. Working condition

22. What are all the wrong operating practices exists in your knowledge?

23. List your five strings point as an operator.

24. List your five weaknesses as an operator.

25. List any 5 strong point of maintenance stream.

26. List any 5 weak points of maintenance stream

# *ANNEXURE D*

## Questionnaire

**A Questionnaire for Implementation of MQFD in RUBCO, Kottayam**

Kindly answer the following questions on the product **HEAVEN**

( **0** = Not at all satisfied, **5** = Somewhat satisfied, **9** = Fully satisfied )

---

**Essential Product Features:**

1. How much are you satisfied with

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

i) Cushioning effect of mattress

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

ii) Colour of clothes

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

iii) Corner cutting

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

iv) Finish

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

a. Smoothness

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

b. Appearance

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

v) Thickness

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

vi) Stitching

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

vii) Durability

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

**Design Parameters**

i) Handling feasibility

a) Weight

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

b) Folding feasibility

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

ii) Structural Features

a) Shape of Quilting Patterns

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

b) Stitching of Pattern

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

c) Pattern Size

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

**Dealer Relationship**

i) Complaint residual system

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

ii) Credit facility

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

iii) Emergency order fulfillment

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

iv) Effectiveness of sales promotion

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

**Cost**

Price of the product

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|

**Packaging**

i) Attractiveness

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

ii) Durability

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

ii) User friendliness

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

**Supply Chain**

i) Responsiveness

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

ii) Transportation

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

iii) Ability to meet the order

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

**General**

1. Any other suggestions regarding the product .............

2. How will you rate the product ``**HEAVEN**`` with the competitors product on:

a. Quality

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

b. Cost

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

c. Customer preference

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

3. Can you specify the nature of recurring complaint, if any

Your Name:

Official Address: Period of Dealership

Signature

**............................................Thank you for your co-operation.**

# *ANNEXURE E*

Dear Sir,

Please find enclosed here with the following questionnaire, your valuable responses will be very helpful for my research work. I request you to be kind enough to fill up the questionnaire and send back.

Thanking you

Yours sincerely

Pramod.V.R
Lecturer
Department of Mechanical Engineering
N.S.S.College of Engineering
Palakkad
Kerala 678008

# QUESTIONNAIRE ON MQFD IMPLEMENTATION IN ENGINEERING EDUCATIONAL INSITUTION

**Name:**

**Designation:**

**Official Address:**

**Your brief bio data showing previous positions held**

**Note: Tick Your Choice**

**Yes- Surely ( If the step is definitely possible to execute)**

**Yes- Partially (If the step is possible to execute to the extent between 50 and 80%)**

**Yes-Feebly (If the step is possible to execute to the extent below 50 %)**

**Not Possible (If the step is not possible to execute)**

---

**Step 1**

MQFD experts have to convince the top management and the principal/ director of the engineering educational institution about the benefits that can be reaped by the implementation of MQFD. This exercise has to be carried out by organizing seminars and brainstorming sessions. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
| --- | --- | --- | --- |

**Please write your comment**

**Step 2**

Management and the principal have to announce the implementation of MQFD as a policy. They have to state the objectives such that it will reach all personnel in the institution. Different types of educational campaigns have to be conducted for personnel at different levels in order to make them fit to attain MQFD objectives. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 3**

Form an MQFD team consisting of 7-8 members of different departments. They meet once in a week and draw out plans for the implementation. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 4**

Identify the customer languages of education. For this purpose the feedback of parents, alumnis and the employers who have employed aluminis has to be rigorously and regularly gathered. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 5**

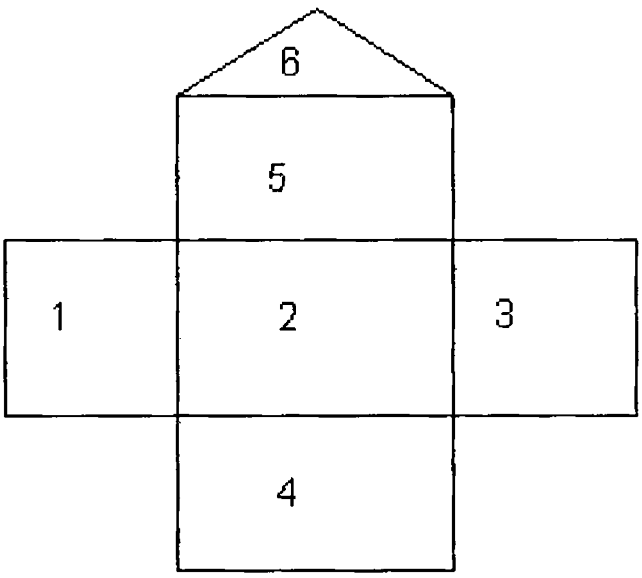
Customer languages shall have to be ranked based upon their importance. This can be done either by using previous experience and the views of management and personnel. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| | | | |
|---|---|---|---|
| **Yes- Surely** | **Yes- Partially** | **Yes-Feebly** | **Not Possible** |

**Please write your comment**

**Step 6**

The format of HoQ is given below.




1. Voice of Customers
2. Relationship Matrix
3. Ranking of Customer Language
4. Ranking of Technical Remedies
5. Technical Remedies
6. Technical correlation

To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

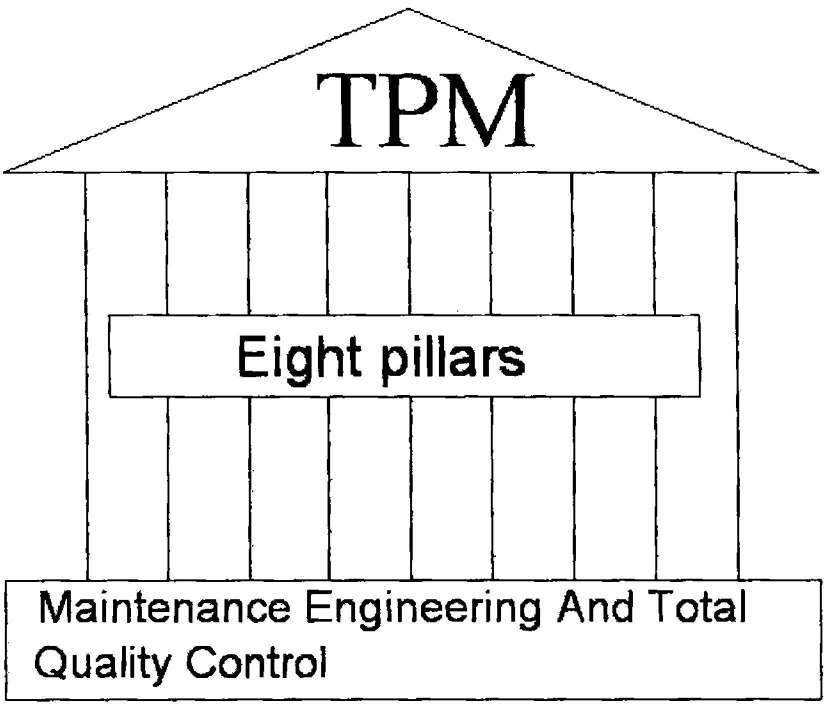
**Please write your comment**

**Step 7**

Management and principal have to take strategic decision to choose the outputs of HoQ which have to be passed through eight TPM pillars.

The eight TPM pillars are

1.Autonomous maintenance 2.Individual improvement 3.Planned maintenance
4.Quality maintenance 5.Development Management 6.Education and Training
7. Office TPM 8.Safety,Health and environment




To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 8**

Send the chosen outputs of HoQ through eight pillars of TPM. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 9**

Direct the results to the curriculum. To which extent do you believe that this exercise can be carried out given the prevailing engineering scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 10**

Evaluate the results based on the parameters namely

(Number of students placed, Percentage of students passed, Number of companies visited for campus interview, Overall performance quality of students, Number of students dropping the course and Availability of competent faculty and supporting staff). To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 11**

Compare the results with the set targets. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 12**

Identify the deviation of the results, if any. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 13**

The tactical suggestions have to be exposed to the management and principal, who will take strategic decisions to implement them. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 14**

Implement the recommended actions evolved after MQFD proceedings. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

**Please write your comment**

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Step 15**

After achieving the target, revise the target and HoQ matrix. If there is change in customers' languages, that also has to be considered while revising the matrix. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

**Step 16**

Review the working of MQFD Program as a whole and incorporate the top management's and principal's views while experimenting the MQFD for enhancing continuously the maintenance quality of engineering education. To which extent do you believe that this exercise can be carried out given the prevailing engineering educational scenario?

| Yes- Surely | Yes- Partially | Yes-Feebly | Not Possible |
|---|---|---|---|

**Please write your comment**

# ANNEXURE F
## Questionnaire

Name and address of the company :

Your name and designation

Your experience in the company

1. When was the company started?

2. What are the main products manufactured?

3. What is the turnover of the company?

4.Name the countries to which the products are exported?

5. Please list the TQM related activities that are being conducted?
Please also indicate the year of starting of the activity in brackets
eg.Quality circle (year)

6. Please list the TPM related activities that are being conducted?
Please also indicate the year of starting of the activity in brackets

7. Any othjer majour significant activities that are being carried out

# ANNEXURE G

## Questionnaire for constructing MQFD

**Phase I**

**Name your customers**

**1**

**2**

**3**

Are you able to get feedback from external customers? Yes/No

If yes,

a. What are the methods used to collect feedback from customers?

b. Are the external customers feedback ranked? Yes/No

If yes, What are the factors considered while ranking?

| Factors | Rank |
|---|---|
| | 1 |
| | 2 |
| | 3 |
| | 4 |

What are the technical remedies that you are generally suggesting against customer feedback?

a. Are these technical remedies ranked? Yes/No

If Yes,

b. What are the factors considered while ranking]

| Technical remedies | Rank |
|---|---|
| | 1 |
| | 2 |
| | 3 |
| | 4 |

Are you taking efforts to correlate technical matters among them? Yes/No

If Yes, how is it carried out in practice?

Phase II

Please refer to the "HOUSE OF QUALITY" part of MQFD model.

If used in your company, what will be the outputs of the above "HOUSE OF QUALITY"

1
2
3
4
5

Complete the following table to identify TPM pillars through which strategic decisions are to be passed.

| utputs of the "House Of Quality" | ategic decisions that may be taken | ersonnel responsible for Strategic decisions |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

**Phase III**

After implementing MQFD model, indicate the expected results by quantifying the following parameters using Likert's scale

OEE - Will improve/ Will retard

| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

MTTR - Will decrease/ Will increase

| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

MTBF - Will improve/ Will retard

| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

Performance quality of the organization Will improve/ Will retard

| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

MDT - Will decrease/ Will increase

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |

Availability - Will decrease/ Will increase

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |

Maintenance Quality -Will improve/ Will retard

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |

Core competence - Will upgrade/ Will degrade

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |

Profit - Will decrease/ Will increase

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |

Good will of the company- Will enhance/ Will retard

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 10 |

Do you find it necessary to again go to HoQ with Customer feedback? Yes/No

Spell out the reasons

To which extent you think that the targets are achievable through MQFD implementation?

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

0=Not at all possible, 10=Full Extent

What are your technical suggestions for improving the targets to achieve the output by MQFD?

What are the strategic decisions that may be made in this regard?

1

2

3

4

What are the favorable and unfavorable conditions that you expect while implementing strategic decisions?

favorable conditions

1

2

3

4

unfavorable conditions

1

2

3

4

Do you think that MQFD can be successfully imnplemented in real time situation? Yes/No

If your response is No, please suggest modification and refinements to the MQFD model so that it is made practically compatible.

# *ANNEXURE* H

## Questionnaire on MQFD

The following steps are essential in implementing MQFD in your esteemed company. Please rate the extent to which steps can be practically implemented in your esteemed organization.

Step 1

MQFD experts have to convince the top management about the benefits that can be reaped by the implementation of MQFD. This has to be done through seminars and brainstorming sessions.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 2

Top management has to announce the implementation of MQFD as a decision. They have to state the objectives either in company news letter or through similar media such that it will reach all in the company. Different types of educational campaigns have to be conducted for personnel at different levels in order to make them fit people fit to attaining objectives.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 3

Form an MQFD team consisting of 7-8 members of different departments . They meet once in a week and plans for the implementation.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 4

Identify the customer language

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 5

Rank customer language. This can be done either by using Analytical Hierarchy Process (AHP) or other similar techniques.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 6

Develop HoQ to convert customer languages in technical languages.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 7

Top Management has to take strategic decision to choose the outputs of HoQ which have to be passed through eight pillars

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 8

Send the chosen output of HOQ through eight pillars of TPM.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 9

Direct the results to the production system.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 10

Evaluate the results based on six parameters (OEE, MTBF, MTTR, Performance quality, MDT and Availability).

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 11

Compare the results with the set targets.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 12

The deviation of the results

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 13

The tactical suggestions have to exposed to the top management, who will take strategic decisions to implement them.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 14

Implement the results of the recommended MQFD proceedings.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 15

After achieving the target, revise the target and revise the matrix. If there is change in customers languages, that also has to be considered while revising the matrix.

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

0 = Not at all possible 10 = Completely possible

Please write your comments in this regard

Step 16

Review the working of MQFD Programme as a whole and incorporate the top management's view while experimenting the scope of MQFD in different directions of copmpany's performance

Please use the following in Likert's scale of range 0-10 to rate the implementation feasibility.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

0 = Not at all possible 10 = Completely possible

Please write your comments in these regard,

# *ANNEXURE I*
# QUESTIONNAIRE

**KINDLY ANSWER THE FOLLOWING QUESTIONS.**

1. As per your judgment how much **CUSTOMER'S** (Driver's) voice influences the organizational prospects

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (a).To which extent the **frequency of vehicle breakdown** influences customer behavior I

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (b).To which extent **cultural background influences** customer behavior

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (c).To which extent the **duration of maintenance** influences customer behavior

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (d).To which extent **necessities/emergencies** influence customer behavior

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (e).To which extent the **quality of spare parts** influences customer behavior

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (f).To which extent **cost of maintenance** influences customer behavior

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

2. As per your judgment how much **Technology** influences organizational prospects

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (a).To which extent **infrastructure** influences maintenance efficiencies

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (b).To which extent **skill of the personnel** influences maintenance Efficiencies

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (c).To which extent **employer employee relationship influences** maintenance efficiencies

   1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

   (d).To which extent **organizational climate** influences maintenance efficiencies

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(e).To which extent **maintenance methods** influence maintenance efficiencies

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

3. As per your judgment how much **COMPETITORS** influences organizational prospects

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(a).To which extent **financial power** of competitors influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(b).To which extent **performance of competitors** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(c).To which extent **customer relationship** influences future prospects of the organization.

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(d).To which extent **strategies of competitors** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(e).To which extent **change management scheme** influences future prospects of the organizations

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(f).To which extent **quality parameters** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(g).To which extent **new technology** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

I. As per your judgment how much **Personnel factor** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(a) To which extent **authority** of personnel influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(b) To which extent **responsibility** of personnel influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(c) To which extent **initiatives** of personnel influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(d) To which extent **motivation** of personnel influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

II. As per your judgment how much **value of decisions** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

III. As per your judgment how much **reliability of decisions** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

A. As per your judgment how much **AUTONOMOUS MAINTENANCE** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(a) To which extent **attitude** of worker influences autonomous maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(b) To which extent **attitude** of management influences autonomous maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(c) To which extent **motivation** schemes influences autonomous maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(d) To which extent **incentive** of salary influences autonomous maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(e) To which extent **financial benefits** influences autonomous maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(f) To which extent **lubrication** management influences autonomous maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(g) To which extent **daily maintenance** influences autonomous maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

B. As per your judgment how much **INDIVIDUAL improvement** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(a) To which extent **reputation of individual** influences future prospects of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(b) To which extent **kaizen's principles** influences future prospects of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(c) To which extent **employee suggestion scheme** influences future prospects of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(d) To which extent **employee involvement scheme** influences future prospects of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(e) To which extent **daily maintenance** influences future prospects of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(f) To which extent **interpersonal relationship** influences future prospects of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(g) To which extent **employee's wish** influences future prospects of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

C. As per your judgment how much **PLANNED MAINTENANCE** influences organizational prospects?

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(a) To which extent **schedule of maintenance** influences planned maintenance of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(b) To which extent **frequency of breakdown** influences planned maintenance of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(c) To which extent **idleness of machine** influences planned maintenance of organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(d) To which extent **schedule of maintenance** influences planned maintenance of the organization

1□ 2□ 3□ 4□ 5□ 6□ 7□ 8□ 9□

(e) To which extent **repetition of same problem** influences planned maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

D. As per your judgment how much **QUALITY MAINTENANCE** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(a) To which extent **TQM tools** influences quality maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(b) To which extent **sampling** influences quality maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(c) To which extent **data management** influences quality maintenance of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

E. As per your judgment how much **EDUCATION and TRAINING** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(a) To which extent **feasibility for higher studies** influences education and training

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(b) To which extent **training facility** influences education and training

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(c) To which extent **employee's own interest** influences education and training

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(d) To which extent **motivation for training** influences education and training

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(e) To which extent **rewards for better performance** motivates people for education and training

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

F. As per your judgment how much **DEVELOPMENT MANAGEMENT** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(a) To which extent **target setting** influences development management

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(b) To which extent **job scheduling** influences development management

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(c) To which extent **production planning** influences development management

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(d) To which extent **maintenance schedule** influences development management

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

G. As per your judgment how much **OFFICE TPM** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(a) To which extent **new technology influences** office TPM

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(b) To which extent **training** influences office TPM

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(c) To which extent **motivation influences** office TPM

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(d) To which extent **proximity of customer** influences office TPM

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(e) To which extent **proximity of suppliers** influences office TPM

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(f) To which extent **data processing speed** influences office TPM

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

H. As per your judgment how much **SAFETY, HEALTH and ENVIRONMENT** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(a) To which extent **hospital** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(b) To which extent **gymnasium influences** future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(c) To which extent **pollution** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(d) To which extent **safety rules** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(e) To which extent **green belt concepts** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(f) To which extent **safety training** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(g) To which extent **displays for safety** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(h) To which extent **periodic medical check up** influences future prospects of the organization

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

1. As per your judgment how much **OVERALL EQUIPMENT EFFICIENCY** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

2. As per your judgment how much **MEAN TIME BETWEEN FAILURE** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

3. As per your judgment how much **MEAN TIME TO REPAIR** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

4. As per your judgment how much **PERFORMANCE EFFICIENCIES** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

5. As per your judgment how much **MEAN DOWN TIME** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

6. As per your judgment how much **AVAILABILITY** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(i).As per your judgment how much **IMPROVED MAINTENANCE** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(ii).As per your judgment how much **INCREASED PROFIT** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(iii).As per your judgment how much **UPGRADED CORE COMPETENCE** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

(iv).As per your judgment how much **ENHANCED GOODWILL** influences organizational prospects?

1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ 8☐ 9☐

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## PAPERS PUBLISHED BASED ON THIS RESEARCH WORK

### I. International Journals

**Published**


1. Pramod, V.R. Devadasan, S.R. and Jagathy Raj, V.P.(2006) "Customer voice adoption for maintenance quality improvement through MQFD and its receptivity analysis".*Int. J. Management Practice,* Vol. 2, No. 2, pp.83-108.

2. Pramod, V.R. Devadasan, S.R., Muthu, S. and Jagathy Raj, V.P.(2006),"MQFD: a model for synergising TPM and QFD", *Int. J. Process Management and Benchmarking, Vol. 1, No. 2,* pp.176-200.

3. Pramod V.R, Sampath, K. Devadasan , S.R. Jagathy Raj , V.P. and Dakshinamurthy, G., .(2006), "Integrating TPM and QFD for improving quality in maintenance engineering, Journal of quality in Maintenance Engineering". Vol. 12, No. 2, pp. 150-171.

4. Pramod V.R, Devadasan, S.R. Jagathyraj. V.P, and Murugesh, R. .(2006) "MQFD and its receptivity analysis in an Indian electronic switches manufacturing company", International Journal of Management Practice.

5. Pramod V.R, Sampath, K. Devadasan , S.R. Jagathy Raj , V.P. and Dakshinamurthy, G., .(2007) "Multi Criteria Decision Making in Maintenance Quality Function deployment through analytical hierarchy Process", International Journal of Industrial and system Engineering. Vol. 2, No. 4, pp. 454-478.


**Under review**


1. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P, "Quality Improvement in Engineering Education through the synergy of TPM and QFD", International Journal of Continuing Engineering Education and Life-Long Learning.

2. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P, "Strategic receptivity of Maintenance Quality Function Deployment across heterogeneous organizational cultures", International Journal of strategic change Management.

3. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P, "Implementation of MQFD in Tyre Manufacturing", International Journal of Process management and Bench marking.

4. Pramod V.R, Devadasan, S.R. and Jagathy Raj.V.P, "MQFD: A means to implement quality assurance in maintenance engineering",International Journal of Quality and Operations Management.

6. Pramod V.R, Devadasan, S.R. and Jagathy Raj.V.P, "Evaluation of Maintenance Quality parameters: A case study in a mine", International Journal of manufacturing research.

7. Pramod V.R, Devadasan, S.R. and Jagathy Raj.V .P, "Failure analysis of critical equipments in the Mines of a Cement Plant" ,International Journal of Technology, Policy and management

8. Pramod V.R, Devadasan, S.R. and Jagathy Raj.V .P, "Implementation of MQFD in mattress Manufacturing" International Journal of strategies and Operations management

## II. National Journals

**Published**

1. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P "Receptivity Analysis Of MQFD",Organizational management, Journal of Management education foundation of Palakkad management association.

2. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P "MQFD a new episode in maintenance engineering", Manufacturing technology and management, Quarterly Journal of Institution of Production Engineers. Vol.2, No1, pp. 14-23.

3. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P Leveraging of TPM through MQFD: A receptivity analysis, Manufacturing technology and management, Quarterly Journal of Institution of Production Engineers. Vol.2, No1, pp.24-30.

## III. International Conferences

1. Pramod V.R, Devadasan, S.R. and Muthu, S. "Implementation of QFD in six TPM implementing companies: A survey report", International Conference on Responsive supply chain and organizational competitiveness, organized by Coimbatore Institute of Technology and University of Masschusetts, Coimbatore Institute of Technology, Coimbatore, Tamilnadu state, India., Jan 5-7,2004.

2. Pramod V.R, Devadasan, S.R. and Muthu, S. "Trends of TPM and QFD: past, present and future", International Conference on Responsive supply chain and organizational competitiveness,organized by Coimbatore Institute

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4. Pramod V.R, Devadasan, S.R. and Muthu, S. "A coceptual model for MQFD", 9th International symposium on Logistics, Indian Institute of Management, Bangalore.,pp 215-219, July 11-14, 2004

5. Pramod V.R, Devadasan, S.R. Muthu, S. and Jagathy Raj. V.P, "The need of MQFD in the era of globalization", Emerging Technologies in Intelligent System and Control, (EISSCO-2005), Organized by Kumaraguru College of Technology in Collberation with Centre for intelligent Product and manufacturing system(CIPMAS), National University of Singapore, Singapore,Product development and manufacturing Centre, Okland University, USA, Kumaraguru College of Technology, Coimbatore, Tamilnadu state, India.pp-765-770, Jan 5-7, 2005.

6. Pramod V.R, Sampath, K. Devadasan , S.R. and Jagathy Raj , V.P. "Implementation of MQFD through AHP", Team Tech, 2006,Indian Institute of Science , Bangalore, India.

## IV. National Conferences

1. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P "Integrating TPM and QFD in Indian Industry: A Case Study" National Conference on Advances in manufacturing Technology, NSS Collge of Engineering, Palakkad, Kerala state, India.

2. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P "Innovation in engineering education through MQFD", National Conference on Innovated TQM, PSG College of Technology, Coimbatore, Tamilnadu state, India. February 25-26,2005

3. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P "Receptivity Analysis Of the innovated TPM model", National Conference on Innovated TQM, PSG College of Technology, Coimbatore, Tamilnadu state, India. February 25-26,2005

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5. Pramod V.R, Devadasan, S.R. and Jagathy Raj. V.P, "Innovations in maintenance: A survey report", National Conference on Innovated TQM, PSG College of Technology, Coimbatore, Tamilnadu state, India. February 25-26,2005

6. Pramod V.R, Vinoth,S., Devadasan, S.R. and Jagathy Raj. V.P "Maintenance quality Function Deployment (MQFD): A Way for Excellence in Engineering Education", National Conference on Integrating Humanisic values and social concerns with technical education,Department of Humanities, PSG College of Technology, Coimbatore, Tamilnadu state, India. 24-25 February, 2006.

7. Pramod V.R, Devadasan, S.R. Jagathy Raj. V.P and Murugesh R "MQFD in Engineering Education" , ISTE convention 2006, held at Bennari Amman institute of technology, Sathyamangalam , Tamilnadu state, India. December 14-16,2006.

**Lectures delivered by the author in Professional bodies based on this doctoral work**

1. The author delivered a lecture titled "TPM", in the Monthly meeting of Institution of Engineers, Plakkad Chapter, on 19th February 2004.

2. The author delivered a lecture titled "TPM in Manufacturing" in ISTE winter school held at NSS College of Engineering, Palakkad on 19th November 2004.

3. The author delivered a lecture titled "MQFD, A Solution for Managerial problems", in the Monthly Meeting of Palakkad Management association on 10th August, 2005.

4. The author delivered a lecture titled "MQFD", Institution of Engineers, Palakkad Chapter, on 23rd March, 2006.

5. The author delivered a lecture titled "QFD" in ISTE, Palakkad chapter, on 20th February, 2004.

6. The author delivered a lecture titled "TPM" in ISTE winter school held at NSS College of Engineering, Palakkad on 21st December 2006.