ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

Overall Equipment Effectiveness Enhancement through Total Productive Maintenance: A Case of Mugher Cement Factory

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DECLARATION

I hereby declare that the work which is being presented in this thesis entitled "**Overall Equipment Effectiveness Enhancement through Total Productive Maintenance: A Case of Mugher Cement Factory**" is original work of my own, has not been presented for a degree of any other university and all the resource of materials used for this thesis have been accordingly acknowledged.

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Abstract

Total Productive Maintenance program is an excellent maintenance technique with aim of increasing overall effectiveness of an industry by maximizing resource utilization. It attempts to involve all employees in maintenance system of a company. The purpose of this study is to enhance overall equipment effectiveness through total productive maintenance in the case company Mugher Cement Factory. In Mugher Cement Factory, the average overall equipment effectiveness for the period 2014-2018 was found to be 22.2% which is below the world class target of 85%, this decrement was due to machine frequent failures, lack of integration of maintenance staff and other departments, lack of inspection and lack of quality spare parts. In order to undertake this study, both primary and secondary sources of data were used. The primary data were collected by using questionnaire, interview, observation and discussion with target groups. A survey questionnaire was prepared and distributed to 25 respondents and the responses are analyzed using statistical techniques using SPSS. A correlation was also performed in order to indicate the interrelationship between TPM pillars and manufacturing performance of the company. Besides, secondary data was gathered from the company reports (yearly and monthly reports, strategic plan and log sheet). Based on the results from the analysis and evaluating the existing maintenance practices of the company, a TPM implementation framework and guideline was developed. In addition to the TPM framework, autonomous maintenance guideline that can be used as a foundation to introduce Total Productive Maintenance in Mugher Cement Factory on the improvement of availability and OEE is proposed. Even though TPM is not a new concept, to the best knowledge of the researcher, the introduction of the concept into Ethiopian Cement Industries especially In Mugher Cement Factory is not covered well. Therefore, this paper will fill this gap.

Key words:

Total Productive Maintenance, Overall Equipment Effectiveness, Availability, Autonomous Maintenance

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Acronyms

MCF: Mugher Cement Factory

TPM: Total Productive Maintenance

OEE: Overall Equipment Effectiveness

MCT: Measuring Control Technician

CBM: Condition Based Maintenance

RCM: Reliability Centered Maintenance

PM: Preventive Maintenance

AM: Autonomous Maintenance

C_3S: Tricalcium Sulfate

C_2S: Dicalcium Sulfate

C_3A: Tricalcium Aluminate

C_4AF: Tetra calcium Alumino Ferrite

CHAPTER ONE

INTRODUCTION

1.1 Introduction

A production process or a manufacturing process is the transformation of raw material or components into finished products. The production line in industries can be categorized into three types, i.e. automated production line, semi-automated production line and manual production line. The nature of production line depends on the complexity of the manufacturing parts, the production volume, the sensitivity of the product and cost. Industries have installed machineries to assist workers this is known as semi-automated process line. Automated process line is designed to operate with fewer workers. This can cut cost in the long run. A fully automated process line is designed to full fill mass production output and is ideally suited to serve large production line affected by improper maintenance of machineries (Subramaniam et al. 2009). This will result in low standards of produce parts and increase the maintenance of machineries. Machine can be less productive due to improper maintenance.

Tsang et Al., 1999 defines maintenance as the routine and continual operation of keeping a particular asset or machine in its normal operating condition so that it can deliver its expected performance or services. As a result of the global market forces demanding more emphasis on customization, quick delivery and excellent quality, manufacturers worldwide are opting for using high-tech equipment as well as adopting non-traditional maintenance management techniques such as Total Productive Maintenance, Reliability Centered Maintenance and Condition Based Maintenance.

According to Bamber et Al., 1997, Ahmed et. Al., 2005, effective maintenance strategy significantly adds value to the production activities and subsequent business. One of the well-known innovative maintenance programs adopted by manufacturers is the Total Productive Maintenance (TPM). It was proven as one of the innovative approach for maintenance since it helps to optimize equipment effectiveness, eliminates breakdown and promotes autonomous maintenance via day today activities involving the firm’s total workforce. Since it was introduced a few decades ago, it has attracted many companies in multi- industries to implement it.

To measure effectiveness of production plants, TPM uses Overall Equipment Effectiveness (OEE) index that is the core metric to measure the success of TPM implementation program; it is the combination of three parameters as availability, performance and quality. As it arises as a very relevant parameter that influence OEE in automated flow line manufacturing systems. In fact, in accord with TPM framework, with an effective maintenance action plan, most of downtimes related to failures can be controlled and reduced; also quality loss remain a relevant cause of inefficiency, that needs a focused analysis. They are not related to failures, or to particular problems that requires maintenance staff intervention; they could be managed and solved by production operators. But they lead to the big error in achieving OEE improvement.

1.2 Back Ground and Justification

Global competition and the demand to increase the productivity of manufacturing and production lines have attracted many industrial organizations from a wide spectrum to introduce Total Productive Maintenance (TPM), as a tool for improving productivity and overall equipment effectiveness (OEE) of a machine (Irungu, 2015).

Looking at the history of Japanese maintenance activities, the time before 1950 is referred to as the "breakdown maintenance" period. Preventive maintenance was introduced in the 1950s from the United States of America and total productive maintenance became well known during the 1960 (Nakajima, 1989).

According to Meng, 2011 the development of TPM began in the 1970s with the recognition of a single and true fact by management, it is basically a company wide effort to maximize the efficiency and effectiveness of any industry by performing preventive maintenance activities continuously to minimize the different failure and maximize availability of the machine.

Graisia, 2014 stated that TPM in cement industry has introduce to improve the productivity of the machine, to improve OEE of machine, improve working culture, cost reduction and increase the profit of their product.

MCF is established with a purpose of producing and supplying cement and carrying out such related activities that are deemed important for the attainment of its objectives, and it is one of the biggest cement plants in the country in terms of productions, profit and market share.

Mugher Cement Factory, the mother plant of the enterprise, is a factory with three production lines which started operation in 1984, 1990 and 2011 respectively. After the military regime was thrown away and the command economy is liberalized the country's fast socio economic development was being assisted by MCF at a significant level. Infrastructural development among others is growing from time to time for which cement is a major input. Currently because the demand from government projects, investors, building contractors, private housing builders, and producers that utilize cement as an input such as hollow block manufactures is so high, MCF with a couple of other cement producers in the country could not even meet the supply demand gap. Currently, the factory has three clinker production lines with a capacity of 1.5million ton/year and three cement mill sites located at Addis Ababa, Tatek and Mugher with a capacity of 2.2million ton/year (MCF technological design manual).

According to Ahmed et. Al., 2005, towards competitiveness in the globalization economy, the manufacturing industry must be supported by effective and efficient quality control and maintenance system. An excellent quality system must be supported by well maintained and reliable manufacturing equipment. The process of maintaining the equipment and processes for its efficiency and reliability becomes the main priority for the organization since it directly affects quality, cost and delivery of the services or product produced. Reliable equipment and process is part of the key business success in any organization.

MCF annual reports for previous years show that overall equipment effectiveness is highly affected by poor machine availability. Several factors contribute to the poor availability of the machineries. The major contributing factor is the absence of an effective maintenance management system.

As it is indicated in Table 1.1, the annual equipment availability for the period September to August 2017/2018 is 36% against a world class target of 97% and the OEE is 21% against the world class target of 85%. Therefore, the need for the implementation of TPM is highly crucial for the company to improve its productivity.

Table 1.1 Annual availability, performance, quality and OEE (Author's computation from the company's annual report, 2017/2018)

Factors	MCF (%)
Availability	36
Performance	60
Quality	98
OEE	21

1.3 Statement of the Problem

According to Karanjkar, 2008 and Fore & Luze, 2010, maintenance is the function of manufacturing management that is concerned with the day today problem of keeping the physical plant in a good operating condition. The presence of a well-organized maintenance system helps an organization to achieve increased machine availability, reduced production downtime, reduced production losses and overtime costs. It also lowers labor requirements for maintenance personnel by giving them more time on ordinary repairs and adjustments than on breakdown repairs. Good maintenance practice also leads to less large-scale repairs and repetitive repairs, fewer product rejects and better quality control of the products and an effective maintenance system benefits in Plant reliability.

The cement industry is characterized by intensive energy and raw materials, large Work-In-Progress inventories, high breakdown levels, and the need to increase the productivity in order to meet high demands (Bahatty et al, 2004).

Al-Muhaisen et al., 2002 have reported that costs of the maintenance activities in the cement industry are about 20-25 percent of the total production costs; furthermore they stressed the vital role the maintenance system to prevent failures, and enhance the overall. Numerous researchers have attempted to enhance maintenance system within the cement industry. For example Eti et al, 2006 have emphasised the needs for an appropriate maintenance system which maintains high performance by the reduction of unplanned down-time and inventory, and reduces the maintenance time instead of relying on reactive maintenance procedures.

Tourki (2010) also describes the challenges the cement industry face such as the significant global increases of fuel and energy costs that have heavily impacted the cement industry, market pressure to keep prices lower than the competitors and the high market demands that have put the cement industry under pressure to simultaneously reduce cycle time and downtimes, and increase utilization and throughput of the equipment.

Mugher cement factory has annual downtime plan for maintenance but it is not followed and the machineries operate until failure occurs. According to the company's reports for the year 2014-2018, the company experiences frequent machine breakdowns that are causing excessive downtime resulting in low machine availability, which in turn results in low productivity of the plant and poor overall equipment effectiveness. A contributing factor to this problem is the absence of an effective maintenance management system problem of following continuous improvement strategy, limited skill and poor knowledge, less attention is given to maintenance problem and there is lack of integration between production and maintenance departments where the production department tends to overlook the maintenance functions in an effort to meet the production targets. This results in critical and prolonged equipment failures.

The situation of not achieving the expectation of high machine utilization and production rates, low breakdown rates, and trouble free operation processes within the cement production line has motivated the undertaken research to investigate the factors resulting in poor overall equipment effectiveness of the plant. The study also carried out root cause analysis for major problems contributing to frequent downtime. It also proposes mitigating ways of the problems so that the plant performs within the required target.

1.4 Research question

1. What is the need for implementation of TPM in MCF?
2. What is the status of implementation of TPM pillars in MCF?
3. What are the major challenging factors and causes for lower OEE of MCF?
4. How can the challenges and the problem of OEE improved?
5. What is the relation between TPM pillars and manufacturing performance in MCF?

1.5 Objectives

1.5.1 General objective

The general objective of this study is to investigate the ways of improving the overall equipment effectiveness (OEE) by implementing total productive maintenance (TPM). This objective is accomplished by answering the research questions and developing a framework for the implementation of TPM.

1.5.2 Specific objectives

- To investigate the need for TPM implementation in MCF
- To evaluate the company by using TPM pillars
- To investigate major problems leading to lower OEE
- To identify the interrelationship between TPM pillars and manufacturing performance
- To develop a framework for TPM implementation

5.1 Scope of the research

This paper focuses on the ways to improve effectiveness of Mugher Cement Factory and on the ways of minimizing factors that affect the production capacity and main factors contributing to down time. This can be achieved through analyzing and giving solution for the factors that affect overall equipment effectiveness, identification and justification of problems and proposing solutions and recommending to the concerned body for implementation. The study is conducted from July 2014 until December 2018. Even though the plant has three production lines, this study focuses on line three because line two is not in operation since 2016 and line 1 has a production capacity of 1000tpd compared to line three which produces 3000tpd and significant result can be achieved by implementing TPM on line 3.

5.2 Significance of the study

The outcome of this study is expected to provide important suggestion to Mugher cement factory to improve efficiency and utilization and maintenance system so that the performance of the factory is improved. The findings from the research can also be used as a bench mark in order to implement the concept of TPM in other cement factories in Ethiopia.

5.3 Organization of the Research

The first chapter gives a brief introduction to the concept of total productive maintenance and it specifies overview of the research questions and objectives along with the problems and issues addressed in the research. The second chapter contains a literature review of the research work performed in the areas of maintenance practices, types of maintenance, history of TPM, followed by pillars of TPM. The third chapter deals with the methodology the study followed. The fourth chapter presents general overview of the cement production process along with the data presentation, analysis and discussion. The fifth chapter provides the conclusions and recommendation along with a summary for future works.

CHAPTER TWO

LITERATURE REVIEW

2. Introduction

The purpose of this chapter is to investigate the literature available for TPM and the concept of TPM approach is reviewed initially. Then, mostly the literature review on TPM definition and history, goals, maintenance types, manufacturing losses, OEE calculation, maintenance in cement industry, success history of TPM in Ethiopia and others are cited by the researcher.

2.1 Definition of terms

Total productive maintenance is a manufacturing improvement program that involves all levels of the workforce in the organization working towards increasing productivity and reducing losses in operations. TPM strives towards improving the productive capacity and developing an effective and efficient workforce.

Overall equipment effectiveness is a metric to monitor and assess the effectiveness of equipment, an operation or manufacturing process. It is gauged on equipment or operation that measures the productive and non-productive time. This technique works to eliminate the six big losses; downtime (caused by equipment failure), set-up and adjustment (conversion, alignment and fine tuning), equipment stoppage, speed losses (not operating at ideal speed), startup rejects (initial check-out and reworks) and production rejects (caused by process defects and low yield) (Nakajima, 1989).

Manufacturing performance measures how well companies use their assets to maximize the volume of production output. It is also a general measure of the company's output performance to its designed capacity

2.2 Introduction to maintenance

According to the UK's Department of Trade and Industry DTI, 1991, maintenance can be defined as "the management, organization, execution and quality of those activities which will make sure that optimum levels of availability and overall performance of plant are attained". Imai, 1997 developed a definition that is more in line with the strategic aim of maintenance: "Maintenance refers to activities directed toward maintaining current technological, managerial and operating standards and upholding such standards through training and discipline".

Maintenance is seen as an important part of any plant or system that is necessary to operate effectively. The way in which maintenance is carried out has a strategic effect on the real life of the equipment or component. In practice, there are many approaches to maintenance management, where managers formulate a perception of how the above definitions should be applied within their company. In the majority of companies, it is usual to find that maintenance activities are carried out as a Quick fix solution, it is also reasonable to suspect that maintenance activities are not aligned to the commercial strategy because the impact of maintenance on system or business performance has not been recognized (Murthy and Atrens, 2002), (Alan and Brit, 2009). In this condition, maintenance management teams usually will not have a mechanism to formulate a maintenance strategy that can be aligned to their business strategy. As a replacement, maintenance managers will usually base their maintenance policies on cost or available resources without examining the prevailing conditions within the production environment.

Maintenance managers should be considering the necessary levels of maintenance for their particular production situation, allowing the development of a maintenance objective that is in accordance with their manufacture strategies. The cost of not developing an appropriate maintenance strategy can result in a costly non-competitive situation. According to the Department of Trade and Industry (DTI; 1988) "most companies do not know the cost of downtime and what the overall financial effect of unusable machinery is on their business". The report concluded by stating that management attitudes towards maintenance must change, and that maintenance must be integrated into the manufacturing strategy.

2.3 Maintenance Practices

The stoppage of equipment can be mitigated by variety of maintenance policies whose rationale depends, mainly, on the failure characteristics of the equipment. Over the years, there have been many different approaches to improving maintenance efficiency; these have been called Modern Maintenance Practices (MMP) (Sherwin, 2000; Waeyenbergh and Pintelon, 2002.

Maintenance is a very important function in an organization that operates in conjunction with production to ensure the production flow. To receive a continuous production from machinery and equipment, manufacturers should consider maintenance as a heart function that needs to be planned in a strategic way.

Ollila and Malmipuro, 1999; Yamashina, 1995 stated that the increasing competitive power of the company depends on the making of advanced manufacture engineering to establish an appropriate production process , that demands brilliant maintenance practice in such a way that machines, and processes are available whenever wanted, and produce required products with a needs quality level. The role of maintenance in the long-term should be seen as an important function in an organization's strategy. Maintenance should be planned with awareness and realistically according to the organization's ability and resources.

The clear development of maintenance and application will help to get better equipment's reliability and availability by reducing unplanned breakdowns and defects, and this will help in providing the marketplace with products that have high quality and lower cost.

According to Katkamwar et al., 2013 study performed on Total Productive Maintenance approach undertaken in spinning industry suggested ways in implementing TPM to improve effectiveness of the equipment. The study primarily implemented TPM practices on a model machine where the author developed direct and indirect benefits of TPM by applying quality tools. The results obtained from this study showed ways to improve effectiveness of machines based on availability and performance.

Ahmed et al., 2010 contributed their research work by implementing total productive maintenance (TPM) in pharmaceutical sector. The study focused by identifying major losses and their factors which contributed to productivity losses. The study suggested planned maintenance program to be implemented which helps pharmaceutical sectors to have smooth and increased efficiency on manufacturing load time, cycle time, and reduction in defects while producing units.

Goyal and Jindal, 2015 identified overall equipment effectiveness (OEE) has important parameter for success in implementing TPM within a firm. The study evaluated areas like reduction of manufacturing cycle time, customer complaints, handling autonomous groups on their skills and confidence levels and derived recommendations and conclusions to improve equipment efficiency and effectiveness.

Wudhikarn, 2013 proposed a new framework Analytic Network Process (ANP) along with OEE for improving the existing OEE measures and adapted measurement. ANP allows accurate judgment on decision maker even though OEE is still a balanced tool to rectify unconformities to undertake appropriate decisions in handling and managing equipment.

Singh and Bhatia, 2013 discussed current TPM solutions and methodological practices avail world class manufacturing by overall effectiveness of equipment through team of people not by technology and standalone systems. Successful implementation of TPM depends on the aspects like human interaction, effective organizational structures and the availability of continuous TPM programs.

Singh et al., 2013 implemented TPM practices on Computer Numerical Control (CNC) machines by incorporating pillars of TPM through staged approach methods to eliminate losses for proper utilization of the CNC machines. The author studied TPM practices on CNC machines with different capacities by analyzing their overall equipment losses in order to identify effectiveness and efficiency.

Ahuja and Kumar, 2009) carried out a study on an Indian manufacturing facility and revealed that TPM initiatives are far more influential in affecting manufacturing performance improvements as compared to traditional maintenance practices. Another study was carried out by Bartz, Siluk and Barth, 2014) to evaluate the improvement in industrial performance of a company in Brazil based on indicators of industrial performance. According to the specifications of TPM, the scrap, rework and efficiency rates showed significant improvement and positive trends. They found out that the production line studied benefited from TPM, becoming more competitive in relation to those of competitors and providing better performance.

Several studies have been conducted in Asia (Ahuja and Khamba, 2008) and in Europe where Bamber, Sharp and Hides, 1999) conducted a study to develop a critical understanding of factors affecting successful implementation of TPM in a UK small to medium size enterprise. In the cement industry a study has been conducted on the Libyan and Kenyan cement industry by Graisa and Al-Habaibeh, 2011 and Irungu, 2015.

The study conducted by Wakjira and Singh, 2012 identified the correlations between numerous features of TPM to enhance manufacturing efficiency by applying overall equipment effectiveness (OEE) in a boiler plant in Ethiopia. Major success factors of TPM identified in this study was to improve performance enhancements.

Mamo, 2019 evaluated selected TPM pillars' contribution towards manufacturing performance on Nile Sole Factory. The study was conducted by collecting Production, Downtime, reasons of downtime, scrap level, and rework data from the company and analyzed to see the current performance of the company. The study revealed that among the eight pillars of TPM, five of them: focused improvement, planned maintenance, autonomous maintenance and Training and education showed significant contribution towards the identified manufacturing performance indicators such as cost, availability, delivery and flexibility.

2.4 Types of Maintenance

There are mainly three types of maintenance as defined by Al-Najjar, 199), Albert, 200), Graisa and Al-Habaibeh, 2007 unplanned breakdown maintenance, planned scheduled maintenance and Condition monitoring Based Maintenance (CBM). The efficiency of the production system is highly affected by unplanned maintenance and unpredictable failure of machines which results in increased downtime and unnecessary and unexpected costs. However, planned scheduled maintenance is normally based on the statistical analysis of the machine failure history and maintenance recommendation of machines. The condition monitoring based maintenance strategy is a planned maintenance based upon measuring the conditions of the critical elements of the machine during operation. The analysis of the condition monitoring data can be done to predict the failure time which will further allow maintenance to be planned (Qin and Tang, 2005, Juan, 2009 and Rosqvist et al., 2009.

Condition monitoring can minimize breakdown costs by improving preventive maintenance scheduling and effectiveness of maintenance operations.

Table 2.1 Development of Maintenance Philosophies (Sherwin 2000; Waeyenbergh and Pintelon 2002).

Period Between 1900 – Present	**Characteristics of equipment**	**Maintenance Philosophy**
First generation maintenance (1900-1939)	Equipment is simple and easy to repair	• Basic and routine maintenance • Reactive maintenance, Only repair when broken
Second generation maintenance (1945 - 1979)	• Equipment is more complex, greater dependence of industry on equipment • Maintenance costs are higher in relation to other operating costs	• Planned preventive maintenance • Time based approach • Total Productive maintenance (TPM) Total employee participation. • Team based approach to maintenance, examines Culture and people, not systems.
Third generation maintenance (1980s – Present)	• Equipment complexity increasing • Accelerated use of automation • Downtime very expensive • Increasing use of Just-In-Time • Customers now demanding higher quality goods • Tightening legislation on safety	• Condition monitoring (CM), hazard studies, failure modes and effect analysis • Reliability Centered Maintenance (RCM) • Examines machine or system • Computer aided maintenance management • Multi-skilled workforce • Emphasis on equipment reliability and availability • Maintenance is now proactive and strategic.

2.5 The Importance of Maintenance in Production Systems

Large and small factories of today's global companies are characterised by their high emphasis on productivity, delivery and quality, which represent competitive business strategy for many companies to be the best in the market in their fields. To respond to these requirements, manufactures are using high-tech equipment. They are also adopting new material control methods such as the just-in-time (JIT) philosophy, which calls for non-stop production systems working without inventory-set-up and adjustment times are also reduced to a lowest. These factors are forcing companies to shift their focus to maintenance, since unplanned unavailability of machines results in severe problems (Hayes and Pisano, 1996; Christian et al., 2009).

As Blanchard, 1997 described, actual trends indicate that in general, systems' complexity is rising with the introduction of new technologies. However, they are not meeting customers' expectations in terms of performance and effectiveness. Further, systems are becoming more costly relative to their process and support. As a result, it is not only the cost of the maintenance that makes it more essential than before, even though the cost can be high, but it is also the requirement of controlling the equipment to serve the need of the production line to be competitive in the market. According to (Cecille and Gunaskeran, 1998) equipment maintenance and reliability management are essential in the effective running of business enterprises at present. By means of the growing dependence on technologies for the majority business operations, it is an aim to develop appropriate maintainability and reliability strategies to ensure that these organisations are able to transport high quality and dependable services to their customers. Maintenance of machines is a necessary piece of the operation's function and an effective and efficient maintenance strategy can significantly contribute in adding value to the production activities. Maintenance should be considered and measured as a world class principal for manufacturers. Manufacturing organisations determined for world-class performance have shown that the contribution of an effective maintenance strategy can be important in providing a competitive improvement (Bamber et al., 1999; Al-Najar, 1996). The most important output of production is the desired product. However, the need for maintenance is secondary output, which is in turn an input for the maintenance function. Maintenance produces secondary input to product in the form of production capacity. While production manufactures the product, maintenance produces the capacity for manufacture. Therefore, the effect of maintenance on production can be realized by the increase in production capacity and controlling the quality and quantity of output.

Maintenance is a very important function in an organisation that operates in conjunction with production to ensure the production flow. To receive a continuous production from machinery and equipment, manufacturers should consider maintenance as a heart function that needs to be planned in a strategic way.

Ollila and Malmipuro, 1999; Yamashina, 1995 stated that the increasing competitive power of the company depends on the making of advanced manufacture engineering to establish an appropriate production process , that demands brilliant maintenance practice in such a way that machines, and processes are available whenever wanted, and produce required products with a needs quality level. The role of maintenance in the long-term should be seen as an important function in an organisation's strategy. Maintenance should be planned with awareness and realistically according to the organisation's ability and resources.

The clear development of maintenance and application will help to get better equipment's reliability and availability by reducing unplanned breakdowns and defects, and this will help in providing the marketplace with products that have high quality and lower cost.

2.6 Total Productive Maintenance

Some of the great challenges faced in the industrial environment regard the correct and efficient use of the resource available both operational and man power for the production. In continuous production systems high productivity through appropriate distribution of these resources and adequate operational procedures becomes a priority. However productivity in such production system depends directly on the efficiency of their critical operations or "bottlenecks" (Moellmann et al., 2006; Moraes and Santoro, 2006).

TPM is aimed at continuous improvement that embraces all aspects of an organisation. A complete definition of TPM includes the following five TPM objectives according to the above references:

1. TPM aims to maximise Overall Equipment Effectiveness (OEE);
2. TPM establishes a thorough system of preventive maintenance for the equipment's entire life span;
3. TPM is implemented by various departments (engineering, operation and maintenance);
4. TPM involves every single employee, from top management to workers; and
5. TPM is based on the promotion of preventive maintenance through motivation management.

The objective of TPM programme is to significantly increase production while, at the same time, increasing employee morale and job satisfaction, this is done by focusing on the employee as part of the maintenance and production strategy.

Total productive maintenance (TPM) according to Maggard, 1992 is predominantly used because it integrates production and maintenance functions but more importantly redefines the roles of the operators and maintainers, hence empowering the workforce, something that should be at the heart of any change in maintenance actives. Pintelon, 1999 claimed that TPM implementation is impractical within a short time because it wants through planning and sufficient management support including the approval of funds.

Figure 1 presents a general definition of Total Productive Maintenance. TPM includes employees and eliminates all machine problems and encompasses all departments. Maintenance is integrated within production and problems are eliminated or minimised. Machines are kept at excellent working conditions and preventive maintenance and Condition-Based Maintenance (CBM) are used.

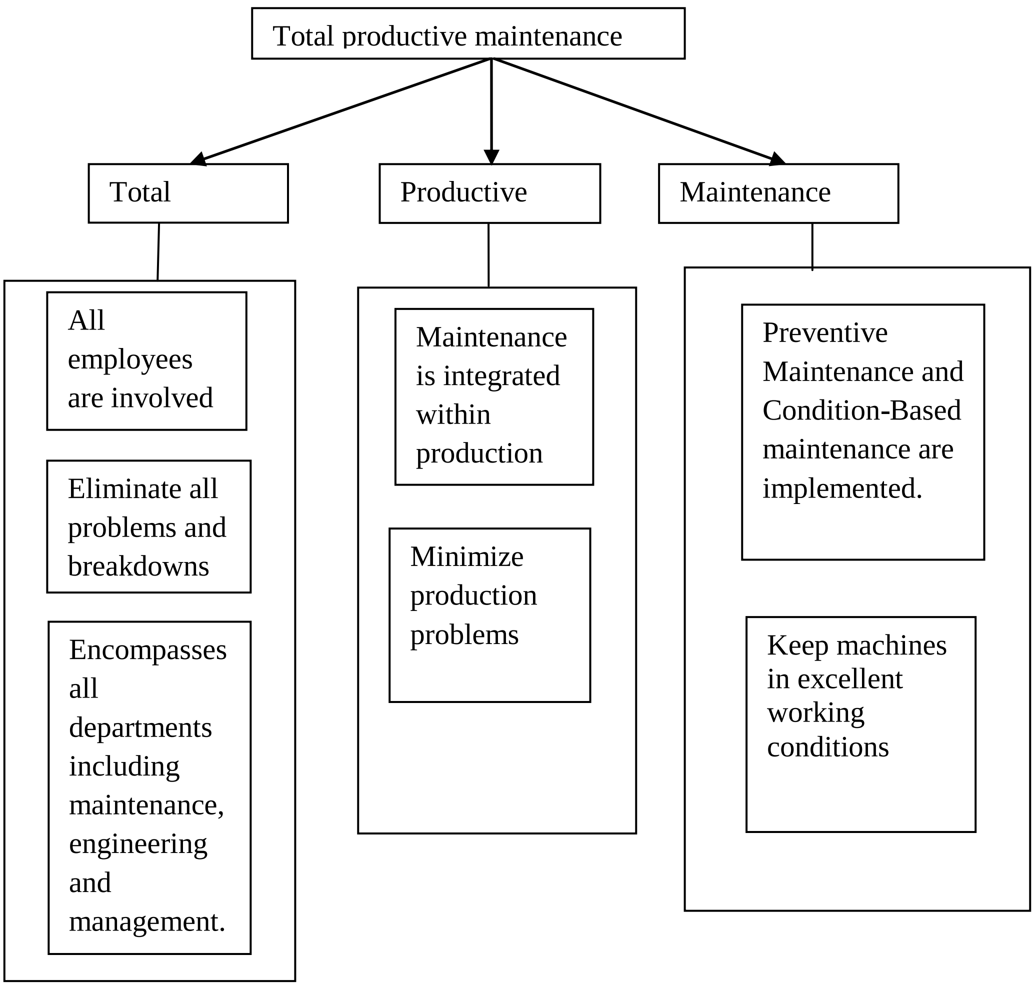

Figure 2.1 Definition of Total Productive Maintenance (Graisa, 2011)

Maggard and Rhyne (1992, cited by Lawrence 1999) claimed that TPM is essentially an integration of production and maintenance function with the goal of optimising equipment reliability and reducing downtime and waste. Example of TPM effectiveness have claimed to reduce downtime by up to 80%, reduce the waste and rework by 75% and increase labour efficiency by 100% (Labib 2000; Tsang 1998; Cooke 2005 and Shad 2008).

According to Chan et al, 2005, the Total Productive Maintenance TPM is a well established method which aims to improve equipment reliability and efficiency rates, eliminate defect wastes, minimize process variations, and reduce production costs. These objectives can be achieved through identifying the root causes of failures and downtimes, maximizing the length of the time period between failures (Mean Time to Failure), and involving and empowering people of all levels within the organization (Ireland et al 2001 and Blanchard 1997). McKone et al., 2001 have emphasized the contribution of the TPM into manufacturing performance improvement through enhancing the firm capability to identify and resolve problems; furthermore TPM aids in improving organizational culture and eliminating traditional departmental barriers between maintenance and production people. According to Bamber et al., 2000 and Ahmed et al., 2005 the TPM system comprises the following elements:

1- People development:

Training and developing people have become the main objective of TPM. According to Prouty, 2006, and Mouss et al., 2004 well organized and planned training programs must be available to ensure required levels of knowledge and skills are provided to improve workers performance. People should to be trained well in order to avoid unnecessary machinery downtime and improve productivity (Binninger, 2004).

2- Documentation:

Documentation records of monitoring, control, and maintenance activities should be kept well.

3- Regular maintenance:

Scheduled and planned regular equipment maintenance aiming to reduce breakdown rates and enhance the equipment utilization. TPM stresses that the implementation of systematic maintenance scheme is a necessary component which has vitally important role within the organizations. Bris et al., 2003 have emphasized the role of routine maintenance activities such as inspection, tightening, oiling, and cleaning within the preventive process of failures and defects which may be caused by malfunction equipments.

4- Housekeeping keys:

Implementation of housekeeping keys (5S) in order to improve the interior environment. According to Eti et al, 2004 the housekeeping functions (5S) can be listed as:

a) Sort (Seiri)- identifying the necessary materials and tools in the working area,

b) Straighten (Seiton)- unnecessary materials and tools should be removed from the working area,

c) Sweep (Seiso)- routine maintenance and cleaning-up activities have to be performed to the working area,

d) Standardise (Seiketsu)- work and process should flow documented standard rules and regulation, and

e) Self discipline (Shitsuke) - discipline standardization through implementation of the above steps and make them as a part of everyday task.

2.7 History of Total Productive Maintenance (TPM)

According to (Roberts, 1995) in the 1970s with the growing complexity of equipment and high degree of automation, expectations from maintenance were growing. TPM was introduced as an organization-wide initiative. This new approach to maintenance was termed Total Productive Maintenance (TPM).

The history of Total Productive Maintenance (TPM) can be traced to Nippondenso Company, a supplier of electrical parts to the Toyota motors car company. Nippondenso soon realized Toyota has already improved their working practices by incorporating and developing the Toyota Production System (TPS). A system, according to (Ohno, 1978) was developing for "the absolute elimination of waste". Production increased at Toyota as did their requirement for spare parts, soon demand exceeded supply. The senior management at Nippon decided to measure a mixture of factors such as output per hour, lost time due to machine breakdowns and defect rates (Yamashina 1995; Anish et al., 2008).

TPM achieves this by placing a high value on group work, consensus building and continuous enhancement (Moore and Rath, 2000). Companies in Japan started adopting this approach as a basic maintenance philosophy and between the 1970s and 1980s, TPM gradually developed as an organization–wide initiative, as its remarkable advantages and benefits became recognized with the concepts of tools upkeep underwent a paradigm shift from 'I operate you fix it' to 'it is my machine, I operate and maintain it' (Hokoma et al., 2008).

According to Cooke, 2000, TPM is intended to carry out both functions: production and maintenance together by a combining good working practices, group working and continuous improvement.

Labib, 2000 stated that the idea of TPM is to transport maintenance and production together, during small groups, to exchanges skills and take specific actions. This action helps to identify maintenance problems and suggest methods to overcome them. TPM is derived from Total Quality Management (TQM) concept of zero defects. Applying it to equipment will help to decrease the number of breakdowns and minimal production loss (Goto, 1991; Ahuja and Pankaj, 2009).

The premise of TPM was to maintain equipment in optimal working condition, extend its practical life, eliminate breakdown and reduce, if not eliminate, unplanned stoppages. On the other hand, this can only be achieved if the commitment from senior management is visible to all workers.

TPM is not a quick fix it must be seen as an ongoing process allowing maintenance activity to be brought into focus as a required and important operation within a business. Organizations can plan downtime for maintenance, which will become part of the manufacturing day. TPM has now been recognized as a maintenance program that involves a recently defined concept, the introduction of operation to perform maintenance on equipment. Nakajima, 1988 often regarded as the father of TPM, defines the target of TPM as to improve equipment effectiveness and maximize equipment output. It achieves this by the determination to attain and maintain optimal equipment conditions in order to prevent unexpected shutdowns, speed losses and quality defects in process.

During the implementation of TPM, it should also be possible to increase employee morale and job satisfaction by allowing the employees to be involved with every aspect of TPM.

Nakajima, 1988 developed five pillars, namely life cycle of equipment, training, improving maintenance, involving production and improving equipment that originally guided TPM. According to Kennedy, 1998, in the 1980s "opportunities were being lost because of poor production scheduling, hence the development of the second generation of TPM which focused on the production process".

Recently TPM's issues relating to quality and safety have been identified as 'necessary pillars' of TPM. Consequently, according to Kennedy, 1998 this now adds two extra pillars to TPM and creates a third generation.

Most of the universally established definitions of TPM by authors such as Bamber et al., 1999, Rich, 1999, Cooke, 2000, Blanchard, 1997, Davis, 1995 and Willmott, 1997 build upon the basic five pillars outlined by Nakajima, 1988. They state that in order for TPM to be doing well all of the five original pillars must be used to eliminate equipment losses in a sustainable manner.

2.8 Measurement of Total Productive Maintenance Effectiveness

There are different ways of measuring manufacturing performance and the most common approach, as reported in published literature, is to use cost, overall equipment effectiveness, quality, delivery and customer satisfaction as the basic dimensions (Hon, 2005). McKone, Roger and Kristy, 1999, have observed that TPM has a strong and positive association with low cost, high levels of quality and strong delivery performance. TPM provides quantitative metric called overall equipment effectiveness (OEE) for measuring the productivity of manufacturing equipment (Nakajima, 1988).

2.8.1 Overall Equipment Effectiveness

The Overall Equipment Effectiveness is the traditional evaluation index of Total Productive Maintenance that has to be maximized; it compares the operating level with the ideal potential of the plant performance (Lanza et al., 2013).

The analysis of the production systems efficiency is a relevant topic to industrial companies. By calculating and monitoring resource productive efficiency it is possible to know their actual efficiencies, having as an objective to elaborate action plans and solution for the main reasons of production efficiency. Since the information for correct calculation of the resource efficiency is not available in the company's corporate systems, it is necessary to collect and analyze data from the productive resources (Passos et al., 2004).

The adoption of a correct measurement system and the management of key parameters are able to contribute for the increase of productivity of both multifunctional areas and the plant (Hansen, 2006).

One of the most important tools in the TPM philosophy is the Overall Equipment Effectiveness (OEE). The OEE indicator is a result of the multiplication of three parameters which have a relevant role in the TPM philosophy (Fuentes, 2006; Muchiri and Pintelon, 2008).

The target of TPM is to improve OEE percentage, to maximize plant productivity, to secure the equipment failure zero, defects and rework zero and industrial accident zero (Shirose et al., 1989).

Studies carried out worldwide have revealed that the average OEE in producing companies is at about 60% (Ryll et al., 2010); in this context, to reach at least an index of 85% could be a proper objective, in addition to economic and productivity benefits that OEE make risen.

OEE is a method to understand the performance of the manufacturing area, but also to identify possible limitations (Hansen, 2002). OEE calculates the percentage effectiveness of the manufacturing process. OEE is further a function consisting of the three factors, availability, performance efficiency and quality.

OEE= availability*performance*quality

Availability: It is the amount of time in which some equipment has been available to work in comparison with the amount of time in which it was programmed to work.

Availability= operating time/planned production time

Performance: It is how much the equipment works near the ideal time cycle to produce a piece. Ideal Cycle Time is defined as the minimum cycle time that a process can be expected to achieve in optimal circumstances (Ryll et al., 2010). It can also be stated as Design Cycle Time, Theoretical Cycle Time or Nameplate Capacity. Performance is capped at 100% or above, to ensure that if an error is made in specifying the Ideal Cycle Time or Ideal Run Rate the effect on OEE will be limited.

Performance = ideal cycle time/operating time

Quality: It is the total number of good pieces produced in comparison with the total number of Product.

Quality = total product-rejected product/total product

World Class OEE

OEE is the ratio of Fully Productive Time to Planned Production Time (Ryll et al., 2010). In practice, however, OEE is calculated as the product of its three contributing factors, availability, performance and quality.

OEE= Availability*performance*quality

The generally accepted World Class target for each factors are as shown in the table 2.2.

Table 2.2 OEE Factor World Class

Availability	90.0%
Performance	95.0%
Quality	99.9%
OEE	85.0%

Of course, every manufacturing plant is different. For example, if a plant has an active Six Sigma quality program, it may not be satisfied with a first-run quality rate of 99.9%. Studies carried out worldwide indicate that the average OEE rate in manufacturing plants is 60%. As it can be seen from the above table, a World Class OEE is considered to be 85% or better. In the first instance OEE should be applied to bottlenecks or other critical equipment. When driven correctly, as a fact of monitoring and improving the OEE, these areas will make significant improvements to the overall performance of the manufacturing line (Hansen, 2002).When OEE figures for the assets in the process has been established and all personnel are aware of its significance and meaning, OEE rates, according to Blanchard, 1997, Robert C. Hansen, 2002, is as follows:

- ✓ <65%, Unacceptable, assets are poorly being used.
- ✓ 65-75%, moderately acceptable only if the trend is improving.
- ✓ 75-85%, acceptable, however, adoption is likely to improve and should therefore be sought to do so.
- ✓ 85-90% world-class level.
- ✓ Continuous on stream process industries should have OEE values of 95% or better.

2.9 Six big losses

According to Venkatesh, 2007, one of the major goals of TPM and OEE programs is to reduce and/or eliminate what are called the Six Big Losses – the most common causes of efficiency loss in manufacturing.

The 6 Big Losses are the major causes of shortfall in manufacturing and as such are central to Overall Equipment Effectiveness OEE. They are related to the 7 Wastes. Being aware of the 6 big losses enables employees to spot them and either eliminate or minimize them (Chadli, 2014).

2.9.1 Breakdowns losses

Typically they occur when an unplanned activity stops production, such as something breaking, equipment failing or emergency maintenance (Induswe, (2013).

2.9.2 Setup and Adjustments

This too is categorized as a downtime loss. What happens here is productivity slows or stops as alterations take place in preparation for a change in production. Examples include tooling, die or equipment changes, as well as waiting for materials, parts or people (Induswe, (2013).

2.9.3 Small Stops

This is a speed loss that occurs for a short duration. Examples include blockages, jams, cleaning and inspection (Induswe, (2013).

2.9.4 Slow Running

This is classified as a speed loss. The issue here is equipment not running as fast as it can for some reason. Causes include poor maintenance, wear and tear and poor settings (Induswe, (2013).

2.9.5 Start-up Defects

This is categorized as a quality loss. At the start of a production run, typically there is waste as parts may be defective in some (Induswe, (2013).

Table 2.3 six big losses summary

Six Big Loss Category	OEE Loss Category	Event Example	Comment
Breakdowns	Downtime Loss	• tooling failures • unplanned maintenance • general breakdowns • equipment failure	There is flexibility on where to Set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss)
Setup and Adjustments		• setup/changeover • material shortages • operator shortages • major adjustments • warm-up time	This loss is often addressed through setup time reduction programs
Small Stops	Speed Loss	• obstructed product flow • component jams • sensor blocked • delivery blocked	Typically only includes stops that are under five minutes and that do not require maintenance personnel.

		• cleaning/checking	
Reduced Speed		• rough running • under nameplate • capacity • under design capacity • equipment wear • operator inefficiency	Anything that keeps the process from running at its theoretical maximum speed (Ideal Run Rate or Name plate Capacity).
Startup Rejects	Quality Loss	• scrap • rework • in-process damage in-process expiration • incorrect assembly	Rejects during warm-up, Startup or other early production. May be due to improper setup, warm-up period, etc.
Production Rejects		• scrap • rework • in-process damage • in-process expiration • incorrect assembly	Rejects during steady-state production.

2.10 Pillars of TPM

The Japan Institute of Plant Maintenance proposed that the introduction of TPM program is based on the implementation of a series 8 pillars of TPM in a systematic way to optimize plant and equipment efficiency by creating perfect relationship between man and equipment (JIPM). The common structure of TPM is shown in figure 2.

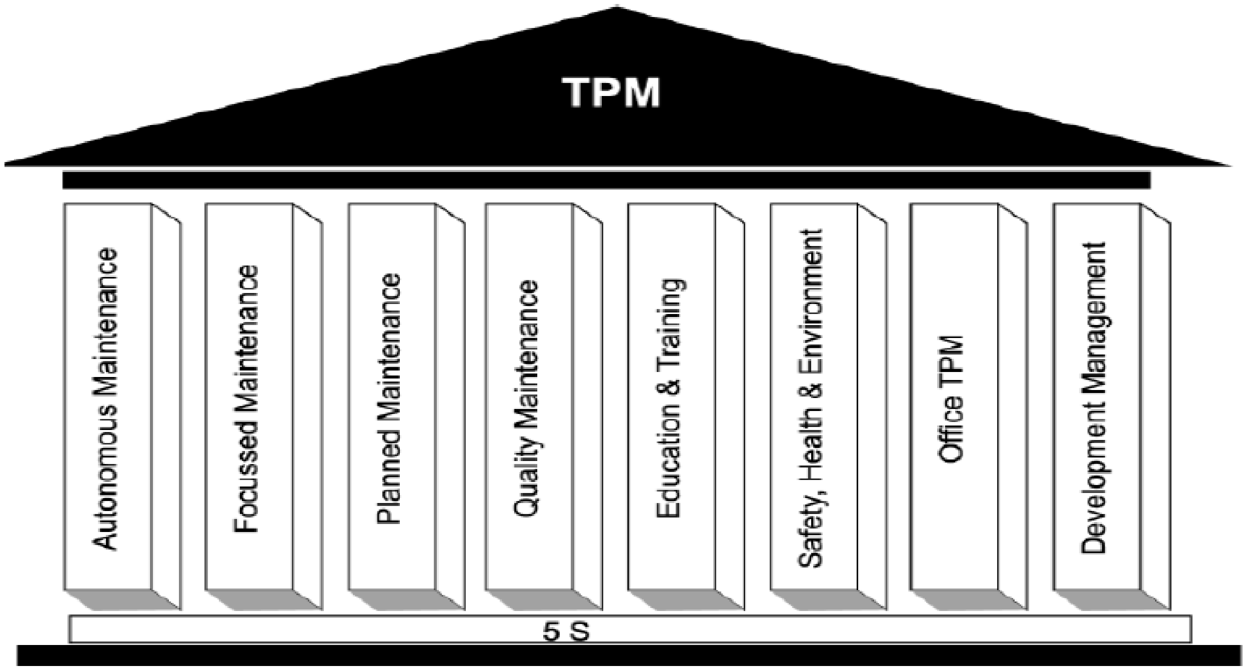

Figure 2.2 Eight pillars approach for TPM implementation (suggested by JIPM)

2.10.1 Autonomous Maintenance

Robinson and Ginder, 1995 describe autonomous maintenance as the process where equipment operators accept and share responsibility with maintenance personnel for the improved performance and health of their equipment. The basic concept behind autonomous maintenance is the creation of 'expert equipment operators' for the purpose of 'protecting their own equipment' (Shirose, 1996) Autonomous maintenance is the cornerstone of TPM activities (Komatsu, 1999). Autonomous Maintenance aims to foster the development and knowledge of the equipment operators and to establish an orderly shop floor, where the operator may easily detect departure from optimal conditions (Tajiri and Gotoh, 1992). If autonomous maintenance activities are not applied effectively, the expected results will not become visible even if the other pillars of TPM are sustained (Komatsu, 1999). This makes it the most basic among the TPM pillars. Autonomous maintenance empowers (and requires) equipment operators to become knowledgeable managers of their production activities and able to: detect signs of productivity losses, discover indications of abnormalities and act on those discoveries.

2.10.2 Focused Improvement

Focused improvement involves all activities that improve the overall effectiveness of plants, processes and equipment by eliminating losses and therefore improve performance (Suzuki, 1994). The objective of focused improvement is for equipment to perform very well each and every day. The better the machines run, the more productive the shop floor and the more successful the business becomes (Leflar, 2001). The main concept behind focused improvement is zero losses. According to (Nakajima, 1988), maximizing equipment effectiveness requires the complete elimination of failures, defects, and other negative phenomena which in general can be considered as the wastes and losses incurred in equipment operation.

2.10.3 Planned Maintenance

The main objective of planned maintenance is to establish and maintain optimal equipment and process conditions (Suzuki 1994). The development of a planned maintenance system means maximizing output and improving the quality of maintenance technicians by raising machine availability. Implementing these activities efficiently can reduce input to maintenance activities and build a fluid integrated system, which includes: regular preventive maintenance to stop failures, corrective maintenance and daily maintenance prevention to lower the risk of failure, breakdown maintenance to restore machines to working order as soon as possible after failure and guidance and assistance in autonomous maintenance (Japan Institute of Plant Maintenance, 1996). Planned maintenance activities put a priority on the realization of zero failures (Shirose, 1996).

2.10.4 Quality Maintenance

Quality maintenance is the establishment of conditions that will preclude the occurrence of defects and control of such conditions to reduce defects to zero, which can be achieved by establishing conditions for ‘zero defects’, maintaining conditions within specified standards, inspecting and monitoring conditions to eliminate variation, and executing preventive actions in advance of defects or equipment/process failure. The key concept of quality maintenance is that it focuses on preventive actions that are taken before it happens rather than reactive measures taken after it happens (Japan Institute of Plant Maintenance, 1996). Quality maintenance supports a key objective of TPM which is ensuring that equipment and processes are so reliable that they always function properly (Schonberger, 1986). Pre-conditions for successful quality maintenance implementation include reduction of accelerated equipment deterioration, elimination of process problems, and the development of skilled and competent users (Shirose 1996).

2.10.5 Education and Training

Training and education pillar ensures that employees are trained in the skills identified as essential both for their personal development and for the successful deployment of TPM in line with the organization's goals and objectives (Marofi, 2014). Improved skills and performance of all employees throughout the organization is vital for successful implementation of TPM. The aim of training and education pillar is to have multi-skilled revitalized employees whose morale is high and are eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skills with the aim of creating a factory full of experts. The basic idea behind training employees is to achieve the four phases of skills which are: Phase 1- Do not know, Phase 2 - Know the theory but cannot do, Phase 3 - Can do but cannot teach and Phase 4 - Can do and also teach (Venkatesh, 2007).

2.10.6 Early Management

According to Suzuki 1994, Early Management also known as Maintenance Prevention refers to design activities carried out during the planning and construction of new equipment, that impart the equipment high degrees of reliability, maintainability, economy, operability, safety, and flexibility, while considering maintenance information and new technologies, and thereby reduce maintenance expenses and deterioration losses (Shirose, 1996). The classic objective of early management is to minimize the Life Cycle Cost (LCC) of equipment. In TPM, the concept of early management design is expanded to include design that aims at achieving not only no breakdowns (reliability) and easy maintenance (maintainability) but also prevention of all possible losses that may obstruct production system effectiveness and pursuit of ultimate system improvement. The early management design process improves equipment and process reliability by investigating weaknesses in existing equipment and processes and feeding the information back to the designers (Suzuki, 1994).

2.10.7 Office TPM

Office TPM is carried out in order to improve productivity, increase efficiency in administrative and technical functions, and to identify and eliminate losses. This includes analyzing processes and procedures with the aim of increasing office automation (Patra, Tripathy and Choudhary, 2005). Productivity of these departments can be increased by documenting administrative systems and reducing waste and loss. They can also help raise production-system effectiveness by improving every type of organized activity that supports production (Suzuki, 1994).

2.10.8 Safety, Health and Environment

Safety, Health and Environment (SHE) is one of the TPM pillars and its implementation focuses towards the achievement of zero accidents. TPM program is only meaningful with strict focus on safety, health and environmental concerns. TPM is built on the building blocks of ensuring equipment reliability, preventing human error, and eliminating accidents and pollution (Suzuki, 1994). Implementing the TPM safety, health and environmental pillar focuses on identifying and eliminating safety, health and environmental incidents. The concept of environmental safety goes beyond simply eliminating accidents it also includes reduction of energy consumption, elimination of toxic waste, and reduction of raw material consumption (Pomorski, 2004**).**

2.11 Maintenance in cement industry

The high productivity at the modern cement plant is highly dependent on regular scheduled maintenance. This requires planning ahead, in order to ensure that company staff always have the knowledge, manpower and spare parts available on hand to give equipment the attention it needs when the time for scheduled maintenance arrive(Graisia, 2014). The primary maintenance approach is to do what is necessary to keep the equipment running with maximum production. “Maintenance in the cement industry includes machine elements such as motor and bearing lubrication, motor and belt replacement, fan blade cleaning, fan wheel balancing, and compressed air system maintenance, sealing material maintenance, belt conveyer maintenance, machine devise cleaning” (Shafeek 2012).

(Graisia, 2014) stated that TPM in cement industry were introduced to improve productivity of the machine, to improve OEE of machine, improve working culture, cost reduction and increase the profit of their product. Venkatesh (2007) from his side stated that introduction of TPM in any industry helps to achieve the following objectives:

- ❖ Avoid wastage in a quickly changing economic environment.
- ❖ Producing goods without reducing product quality.
- ❖ Reduce cost.
- ❖ Produce a low batch quantity at the earliest possible time.
- ❖ Products sent to the customers must be with no defect.

2.12 Summary and Literature Gap

The need to implement Total Productive Maintenance (TPM) as a tool for improving productivity and systems output comes from the international competition and the demand to increase productivity of manufacturing and production lines. Total Productive Maintenance (TPM) is a maintenance philosophy that requires the total commitment of upper level management to the TPM program, empowers employees to take initiatives and corrective actions, and continuity and long term strategy since TPM is a continuous process. The implementation of the available technology and working culture change of employees and management are also crucial to achieve the objectives of the process.

With the successful implementation of TPM, maintenance is no longer the “necessary evil”, but it is a vitally significant part of the business. The general vision of TPM eliminates any 'conflict of interest' between the production and maintenance departments. If the objective is to optimise the performance of the production line, it is important to integrate both the production and maintenance activities in a comprehensive strategy.

Down time for maintenance should be planned as a fundamental part of the manufacturing process. Total Productive Maintenance is often defined as “Productive Maintenance that involves total participation”. The objective of TPM is the continuous improvement that involves all aspects of an organisation. This research work will utilise the concepts of TPM discussed in this chapter to investigate a suitable strategy for the implementation of TPM in Mugher cement factory.

In the above literature papers for TPM implementation, the authors clearly stated the importance of TPM methodologies to be followed in the organization. The authors focused on implementation of TPM and on ways to improve performance efficiency and effectiveness. They have also addressed the issues faced during the implementation of TPM in the specific organizations. And they have calculated the various losses which directly affected the productivity of an organization.

Due to the lack of comprehensive studies on TPM strategies Ethiopia, this study aims to find a suitable operational strategy or TPM pillars emphasis for the Ethiopian cement industry specifically Mugher cement factory. Besides that, analysis will be done to see the effect of these TPM initiatives towards the core manufacturing performance indicators. Especially, studies conducted worldwide considered the four basic manufacturing performance indicators such as cost, quality, delivery and flexibility. However most of them failed to consider Overall Equipment Effectiveness as a significant manufacturing performance indicator while implementing TPM. Therefore, this study will consider the impact of TPM implementation on this basic performance indicator. There is also limited information available regarding the contributions of TPM strategies in Ethiopia. Therefore, this study will fill this gap in knowledge and contribute towards the improvement of productivity of MCF.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1.Introduction

Detailed explanations of the procedures to be followed by the researcher have been included in this chapter. This section mainly covers the approach/design used by the researcher to answer the research questions and explains why the approach was chosen. The main steps of the research includes: the research design and strategies, methodology approach, method of data collection, data collection instrument, sampling techniques, and method of data processing and analysis.

3.2.Research Design

The research design that is applied in this paper is the case study method. Case study research method is chosen because it helps in gaining in-depth knowledge into the subject of overall equipment effectiveness through the implementation of Total Productive Maintenance. Yin (2012) describes a case study as a research method that facilitates a deep investigation of a real-life contemporary phenomenon in its natural context. The case study approach has been widely used in the studies of organizations and has generated a huge amount of high quality information which has contributed significantly in deepening the understanding of organizational life in reality. Case studies provide an important means for checking the effectiveness of the TPM philosophy in different fields of application, especially in manufacturing industries (Aspinwall and Elgharib, 2013). Both quantitative and qualitative research methods are used for this study.

3.3. Data collection

Methods such as semi structured interviews to the top management group, focus group discussion with middle level managers, structured interviews and a direct observation of the workplace are applied. A questionnaire is also utilized. Last but not least, a secondary data source is accessed from company reports and additional literatures are reviewed.

The background necessary for the development and implementation of TPM was studied, and work place assessment was carried out to identify the area where the TPM program could be most successfully carried out. MCF owns different major types of machineries for production. These machineries includes: quarrying, milling (raw mill and cement mill), kiln and packing machines. Among those kiln is critical equipment for the company. It is used for clinker production, which is the major raw material for cement production. If clinker is not produced there will be no cement. The kiln plays crucial role in the production of cement. However, the kiln faces different problems related to the Mechanical and electrical problem, Bricks lining problem, heating up, Technological problem and others. Therefore the researcher believes that implementation of TPM on this machine will benefit the overall company since the major reason behind shortage of cement is the frequent stoppage of the kiln.

A cross functional team consisting employees from the operation and maintenance departments is put in place in order to do the root cause analysis for the machinery downtime.

Collection of equipment history which includes production target, actual production, capacity, down time, product quality rate was performed in order to develop the overall equipment effectiveness for a period of four and half years (2014-2018), which is followed by setting up of a realistic and practical target for the OEE. It is believed that the target to be set should be neither too high nor too low. An unrealistically high benchmark would cause enthusiasm to decline with passage of time while a comparatively low benchmark would not be challenging at all. Finally, the causes of variations in the OEE will be analyzed and an action plan incorporating reinforcement is worked out and implemented.

3.4. Sampling Techniques

Census study is found to be the most appropriate because the population is small for the managers, supervisors, operators and technicians which consists 25 respondents. The managers and supervisors are the key informants in this study because they are mostly involved in the formulation and implementation of business strategies at the plant. Therefore, they will have better appreciation of the success factors, challenges and the benefits that can be achieved from these strategies. The operators and technicians can also respond with respect to their daily activity.

3.5. Techniques of Data Analysis

The qualitative data that the researcher get from semi structured and structured interviews as well as from the relevant documents are edited and analyzed by using content analysis methods and organized around the subtopics derived from the research questions. On the other hand the quantitative data that are obtained via questionnaire and document analysis are used in the descriptive statistics such as mean and percentages to indicate the extent of response or frequency per each item. The key success factors, results, and challenges that the case company, MCF, faced are compared, discussed and interpreted in relation to the relevant literature. Root cause and down time analysis for the major problems are done by using statistical quality control tools such as fish bone and Pareto diagram by using the QI macros and Visio 2016 software. The descriptive statistics and correlations were developed by using SPSS 20. Figure 3 indicates the methodological framework followed to conduct this research.

3.6 Reliability and Validity of Survey Questionnaire

Alan and Nadeen(2005) mentioned four tests for assessing the quality of a case research design; construct validity, internal validity, external validity and reliability. Construct validity focuses on correct operational measures. Internal validity is related to establishing causal links while external validity focuses on definition of the domain where the results can be generalized. Reliability deals with repeatability of the study. With these four tests as a base, one can judge the quality of almost any research method

According to Litwin (1995), reliability measures the reproducibility of the survey instrument's data. The various categories of TPM pillars and manufacturing performance dimensions are evaluated to ascertain the reliability of the input and output data collected through the questionnaires using reliability test known as Cronbach's coefficient alpha. Cronbach's alpha coefficient measures the internal consistent reliability among a group of items combined to form a single scale. It ranges from 0 to 1, where higher values indicate higher level of internal consistency. A Cronbach's alpha value of 0.7 is considered acceptable (Nunnally, 1978) and a value of 0.60 is considered satisfying for a relatively new measurement instrument (Sakakibara *et al*., 1997).

Validity is a scale on which a survey is able to measure the essential concepts it is designed to research on. The validity of the factors for each TPM elements will be tested using confirmatory factor analysis approach (Bagozzi, 1980). Besides that, principal component analysis will also be performed and items that do not load into a single factor will be eliminated and analysis is re-performed. The Eigen value of each factor is considered satisfactory if they are greater than 1.0 and acceptable if they are greater than 0.5 (Nunnally, 1978).

Reliability Test

According to Kothari 2014, measuring instrument is reliable if it provides consistent results. Reliable measuring instrument does contribute to validity, but a reliable instrument need not be a valid instrument. A valid instrument is always reliable. Accordingly reliability is not as valuable as validity, but it is easier to assess reliability in comparison to validity. If the quality of reliability is satisfied by an instrument, then while using it we can be confident that the transient and situational factors are not interfering.

The reliability test refers to a measurement that supplies consistent results with equal values (Blumberg et al., 2005). It measures consistency, precision, repeatability, and trustworthiness of a research (Chakrabartty, 2013). It indicates the extent to which it is without bias, and hence insures consistent measurement across time and across the various items in the instruments (the observed scores). The Cronbach's Alpha (α) is commonly used for this purpose and it typically varies between 0 and 1, where 0 indicates no relationship among the items on a given scale, and 1 indicates total internal consistency (Tavakol & Dennick 2011) Alpha values above 0.7 are generally considered acceptable and satisfactory, above 0.8 are usually considered quite good, and above 0.9 are considered to reflect exceptional internal consistency (Cronbach, 1951). Therefore Cronbach's Alpha values for the various categories of TPM pillars and manufacturing performance dimension were calculated to ascertain the reliability of the data collected from the survey questionnaire.

The alpha values range from 0.741 to 0.965 as shown in Table 3.1, which indicates an internal consistency with the alpha value of more than 0.70, so no items were dropped from each variable. These also indicate the significantly high reliability of data for various inputs and output categories and are a reliable measure of construct.

Table 3.1 Internal consistency test result

Factors	TPM pillars and manufacturing performance dimensions	No. of items	Cronbach's α value
Pillar1	Autonomous maintenance	5	0.963
Pillar2	Focused improvement	5	0.951
Pillar3	Planned maintenance	5	0.936
Pillar4	Quality maintenance	6	0.925
Pillar5	Early equipment management	4	0.943
Pillar6	Education, training and knowledge management	4	0.965
Pillar7	Office TPM	4	0.741
Pllar8	Safety, health and environment	5	0.955
MP1	Cost	3	0.934
MP2	Quality	4	0931
MP3	Delivery	3	0.911
MP4	OEE	4	0.953

Validity Test

Validity is the most critical criterion and indicates the degree to which an instrument measures what it is supposed to measure. Validity can also be thought of as utility. In other words, validity is the extent to which differences found with a measuring instrument reflect true differences among those being tested. But the question arises: how can one determine validity without direct confirming knowledge? The answer may be that we seek other relevant evidence that confirms the answers we have found with our measuring tool. What is relevant, evidence often depends upon the nature of the Research Methodology, research problem and the judgement of the researcher. Kothari, 2004

Validity of a research instrument assesses the extent to which the instrument measures what it is designed to measure (Robson, 2011). It is the degree to which the results are truthful. Therefore, it requires research instrument to correctly measure the concepts under the specific study [Pallant, 2011].

For this study, the validity of the factors for each TPM pillars are tested using confirmatory factor analysis approach. Factor analysis is used for structure detection which purpose is to examine the latent relationship between the variables (Bagozzi, 1980). The factor analysis test used is the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) which indicates the proportion of variance in the variables that might be caused by underlying factors and for construct validity. For KMO test, higher values (close to 1.0) generally indicate that a factor analysis may be useful with the data. If the KMO value is less than 0.50, the results of the factor analysis will not be that much useful. For such cases, as it is recommended by Kaiser (1974) it is necessary to collect more data or to exclude certain variables if the value is below 0.5. For this study, the KMO values for each factors range from 0.642 to 0.797 as seen in Table 3.2 which were considered satisfactory.

Table 3.2 Validity test with principal component analysis and KMO test

Factors	TPM pillars and manufacturing performance dimensions	Item deleted	Factor loading	KMO value
Pillar1	Autonomous maintenance	None	0.651 – 0.854	0.651
Pillar2	Focused improvement	None	0.632 – 0.841	0.657
Pillar3	Planned maintenance	None	0.652 – 0.835	0.643
Pillar4	Quality maintenance	None	0.542 – 0.674	0.686
Pillar5	Early equipment management	None	0.521– 0.724	0.642
Pillar6	Education, training and knowledge management	None	0.657 – 0.864	0.678
Pillar7	Office TPM	None	0.522 – 0.869	0.658
Pillar8	Safety, health and environment	None	0.642 – 0.851	0.652
MP1	Cost	None	0.830 – 0.968	0.762
MP2	Quality	None	0.729 - 0.838	0.736
MP3	Delivery	None	0.905 - 0.973	0.768
MP4	OEE	None	0.946 - 0.972	0.797

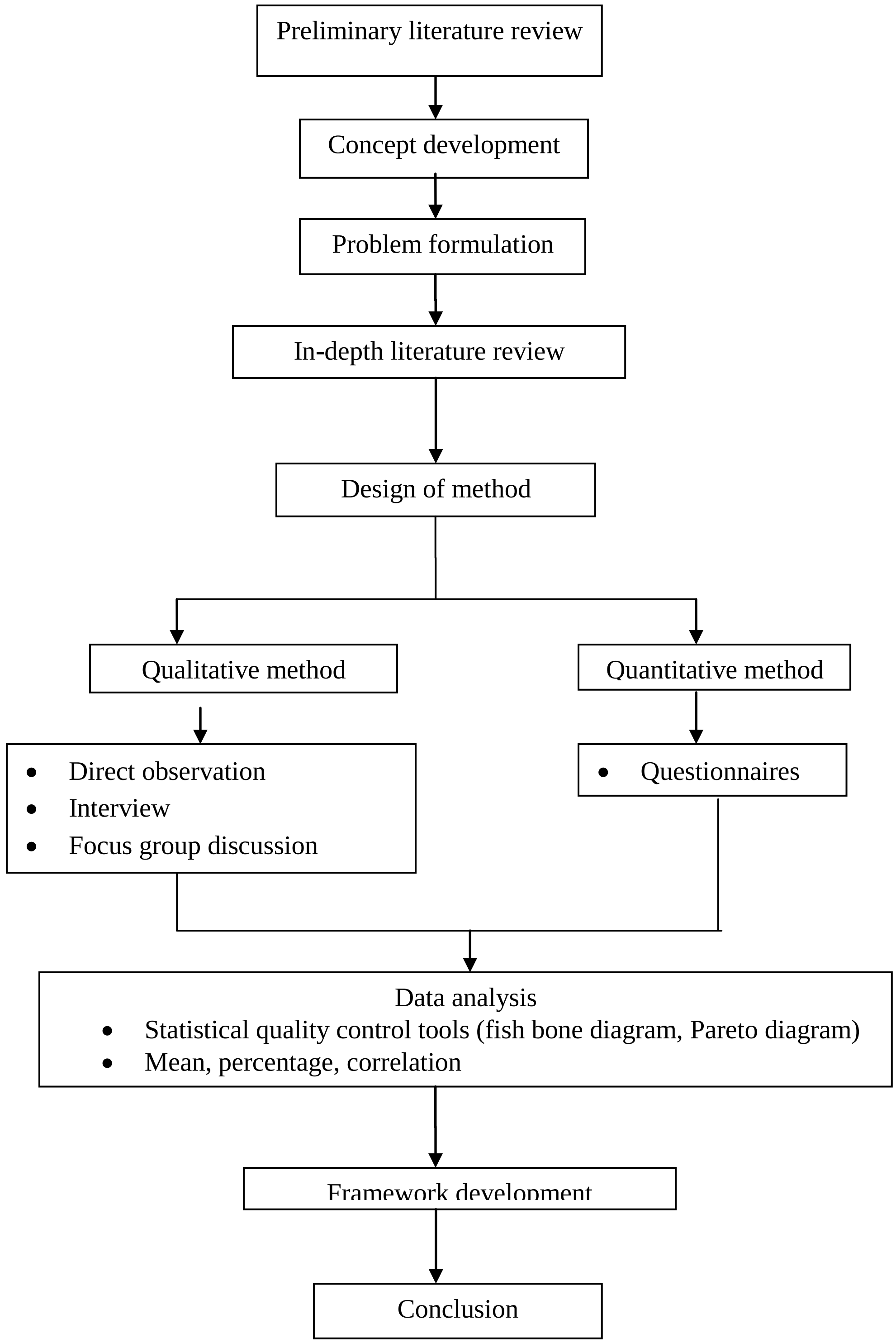

Figure 3.1 Methodological framework

CHAPTER FOUR

DATA ANALYSIS, RESULTS AND DISCUSSION

Introduction

This chapter presents overview of the cement production process and statistical analysis of the production data and downtime of MCF. The chapter attempts to fully understand the production situation and identify the problems in order to address them appropriately.

4.1 Description of the Cement Production Process

Cement

Cement is used to make concrete and mortar, which is a type of glue holding blocks and other building materials together. The first building glue in history was wet clay which sets hard as it dries and holds the stone in place. The Egyptians and Romans discovered how to make stronger building glue than clay by using limestone, which they burnt and mixed with gypsum. The pyramids are some of the oldest examples of blocks held together by cement like material (Lafarge cement 2007).

There are four fundamental stages in the cement manufacturing process:

- Quarrying
- Raw mix preparation
- Clinker formation
- Finish grinding

Quarrying

Typically limestone, clay and sand containing the required proportions of calcium, silicon, aluminum and iron oxides are extracted using drilling and blasting techniques. At this stage, conveyance of raw materials from the quarry using trucks and loading/unloading facilities are considered.

Raw Mix Preparation

The chemical components of the raw materials is expressed in terms of oxides and the most essential of these are CaO, SiO_2, Fe_2O_3, and, Al_2O_3. Theoretically, any material that can contribute to these oxides may constitute the raw mixture. The major raw mineral used in cement production that provides CaO is limestone (CaCO3) which is usually quarried from a calcareous rock. The rest of the oxides are obtained by the addition of clay, which are complementary with limestone in meeting the stoichiometric needs for developing Portland cement. Sand (SiO_2) is added to make adjustments to the chemistry of the clinker. After the raw materials have been quarried and brought to the plant, the individual raw mix ingredients are proportioned and crushed in order to produce the desired cement.

Clinker Formation

The formation of clinker requires very high temperatures. Preheater towers are used to pre-process the kiln feed and thus save energy. The hot exit gases from the kiln heat the raw materials as they swirl down through the cyclones of the preheater tower, so the kiln has less subsequent processing to do. In addition, as in the case of line 3, the preheater is equipped with a precalciner – an extra heat generating unit, which drives off carbon dioxide (CO_2) from the limestone ($CaCO_3$) in the raw mix isolating calcium oxide (CaO) for further chemical reactions in the kiln. Up to 90% of the required calcination may be achieved in the precalciner. The proportioned and milled raw materials then enter a large rotating furnace called the kiln. It is a sloped cylinder, lined with firebricks, which turns at about one to three revolutions per minute. From the preheater tower, the kiln feed enters the kiln at the upper end and moves down through progressively hotter zones toward the flame. Mugher cement factory uses coal to produce that flame. Here in the hottest part of the kiln, the raw materials reach the sintering temperature of about 1400-1450°C and become partially molten. A complex series of chemical reactions take place as the temperature rises, converting the calcium and silicon oxides into calcium silicates, cement's primary constituent. At the lower end of the kiln, the raw materials emerge as a new nodular substance called clinker.

After exiting the kiln, clinker falls onto a grate cooler where it is cooled by large air fans. To save energy, the heat recovered from the cooling process is re-circulated back to the kiln or preheater tower. Once the clinker is cooled, it is ready for the final stage of the cement manufacturing process, proportioning and milling in the finish mill.

Finish Grinding

Clinker is transported to the finish mill by a conveyor belt to be ground into a fine powder, cement. Gypsum is added during grinding to control the setting properties of the produced cement. Mugher cement factory uses ball mill, the most common equipment for cement grinding. Ball mill is a horizontal steel tube filled with steel balls and lined with liner plates. Material fed to the mill is crushed by impact forces and ground by attrition between the grinding steel balls. For increased efficiency, the closed-circuit systems are widely used in cement grinding, where the material exiting the ball mill is directed to the separator and divided into coarse and fine particles. The coarse part is sent to the mill's inlet for regrind, whereas the fine fraction becomes the cement. The rate of initial reaction of cement and water is directly proportional to the specific surface of cement therefore the grinding process is closely controlled to obtain a product with the desired fineness characteristics. The ground cement is conveyed by air slide and bucket elevator into a silo for storage. At this stage, it is ready for bagging and/or shipping in bulk.

4.2 Productive and Non-Productive Time

In order to clearly understand the actual problems facing the company, detailed statistical data was collected, which was then compiled and analyzed. The data represents production between 2014 and 2018. Table 6 presents the downtime of the factory and the reasons for the period from 2014 up to 2018.

Table 4.1 Statistical data of downtime 2014 - 2018 (annual report of the company, 2014-2018)

Year	Reasons for downtime (hour)										Actual working hour	Target Working hour	Total down time/ Target Working hour (%)
	Mechanical	Electrical	Power Interruption	Bricks Relining	Heating Up	MCT	Raw Material Shortage	Technological	Others	Total down time			
2014	256	3220	61	724	379	169	12	529	109	5459	3325	8784	62
2015	2231	311	150	914	422	42	412	275	160	4916	3868	8784	56
2016	1004	969	121	790	226	158	338	675	130	4411	4373	8784	50
2017	1728	502	394	1248	303	6	11	267	163	4622	4162	8784	53
2018	1716	525	194	86	151	1	146	216	140	3175	5609	4392	72

The majority of nonproductive time, as indicated in Figures 4.1 to 4.5, is mainly caused by mechanical, electrical and bricks relining problems and the ratio of total down time to target working hour ranges from 50 to 72%. This could be a result of unavailability of proper maintenance strategy. These results are clearly indicated by using Pareto analysis in the following figures 4.1 to 4.6.

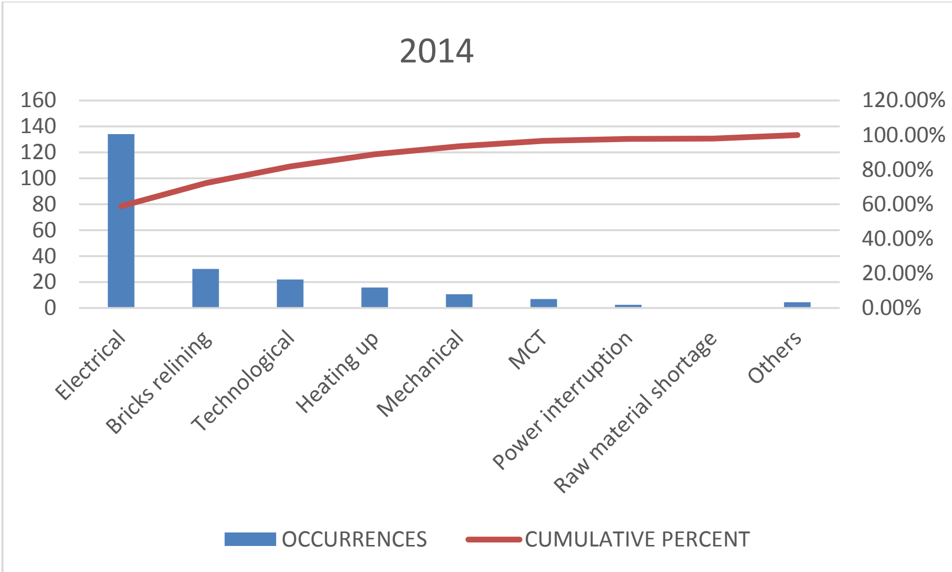

Figure 4.1 Pareto chart of down time reason for 2014

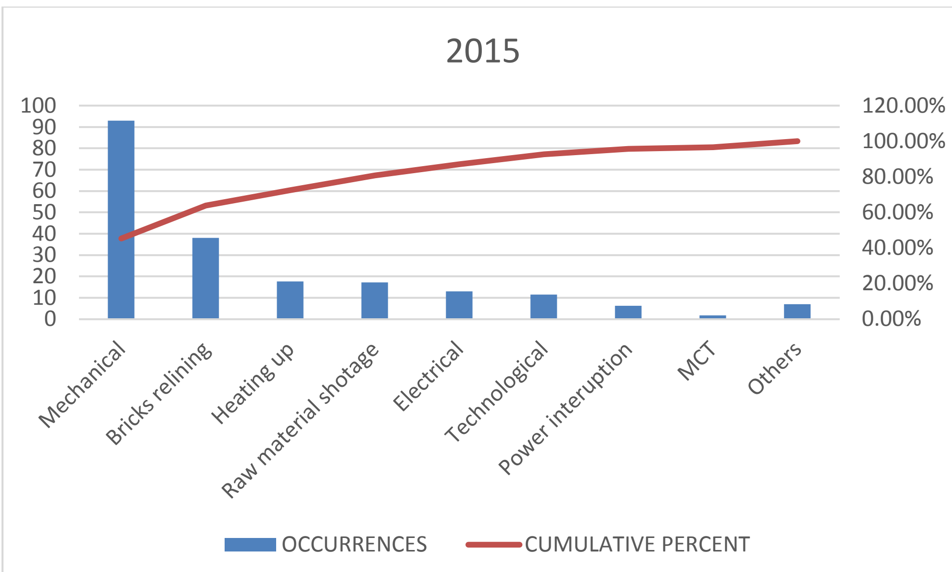

Figure 1.2 Pareto chart of down time reason for 2015

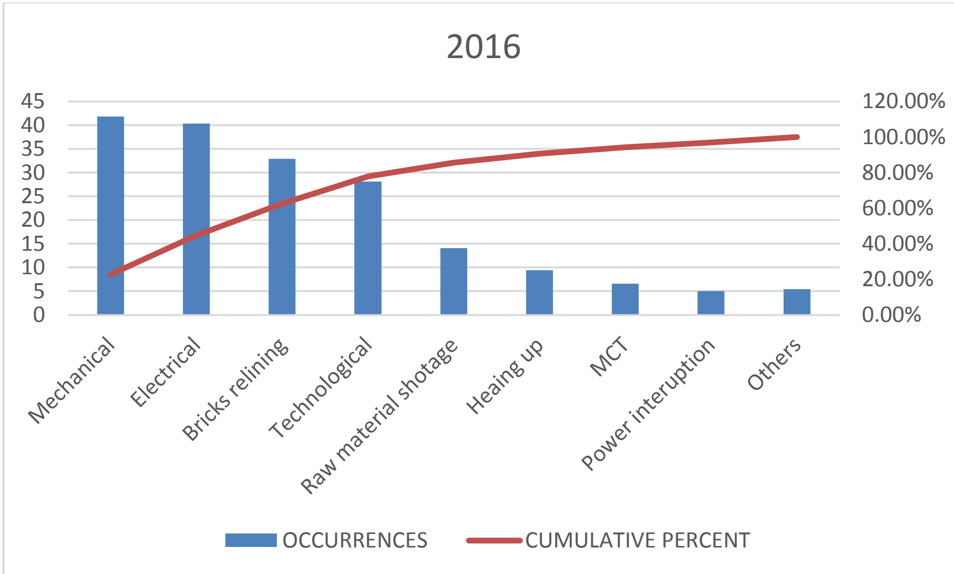

Figure 4.3 Pareto chart of down time reason for 2016

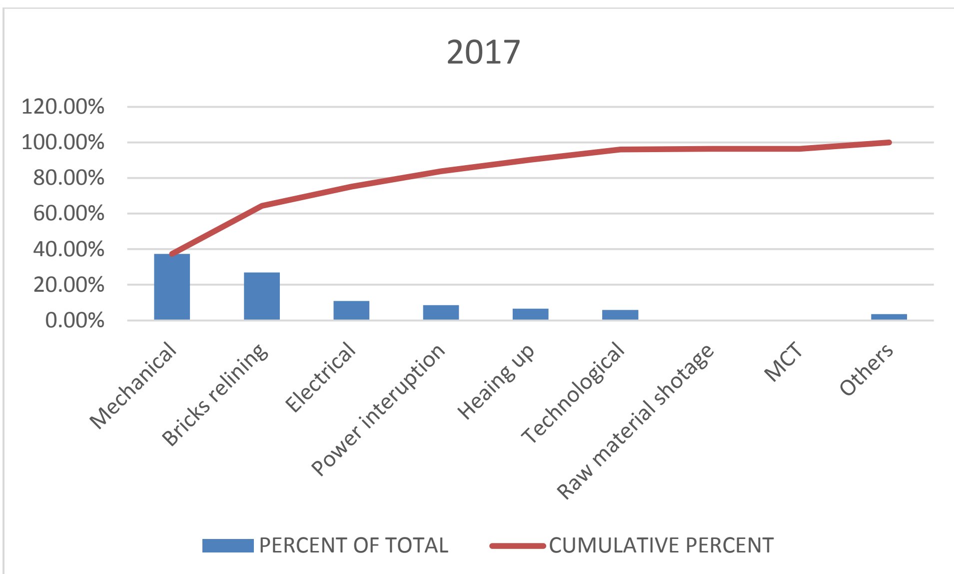

Figure 4.4 Pareto chart of down time reason for 2017

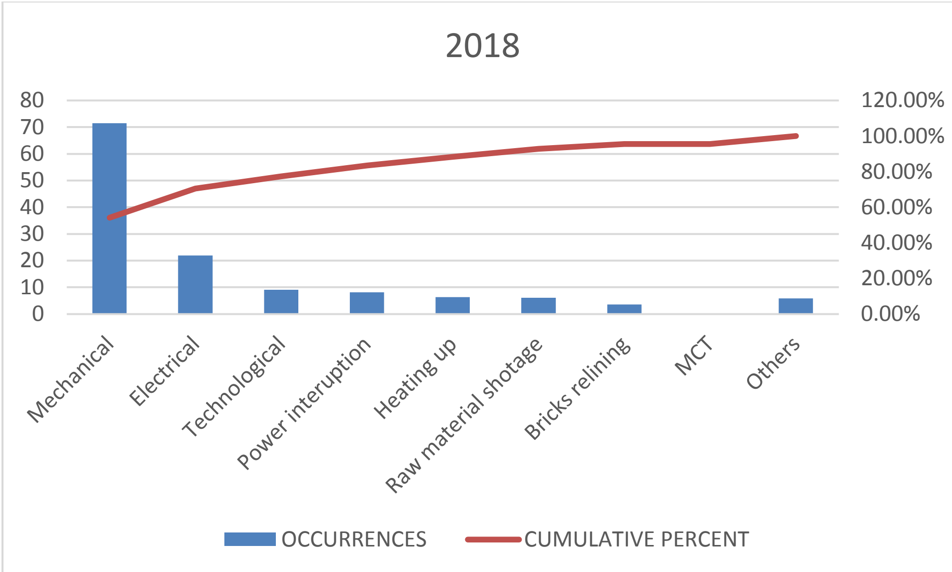

Figure 4.5 Pareto chart of down time reason for 2018

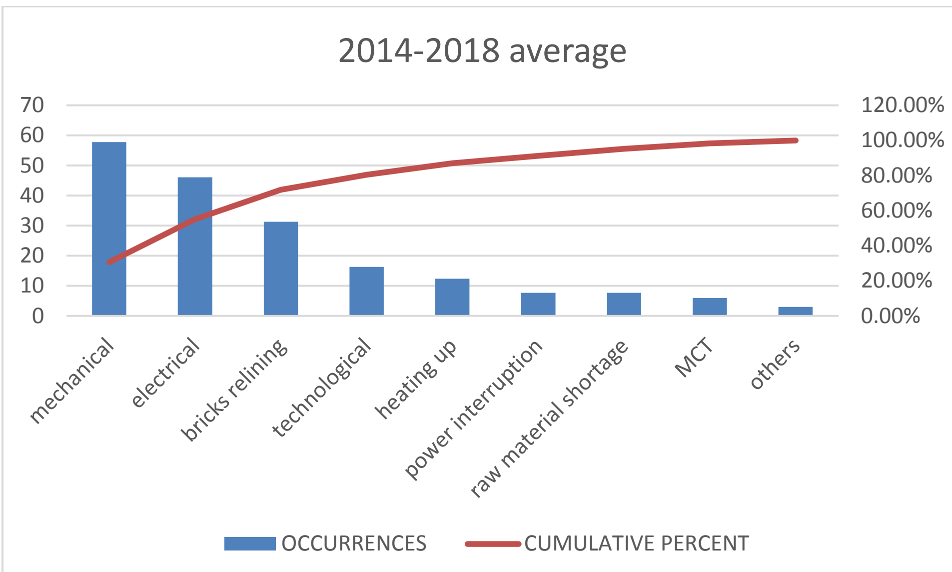

Figure 4.6 Pareto chart of average down time reason for 2014 - 2018

The problems categorized under others include shortage of service water, interruption of pulverized coal and shortage of raw coal. The Pareto charts illustrated in figures 4.1 to 4.6 indicate that the major problems contributing to down time are mechanical, electrical, bricks relining, technological and heating up problems constituting 80% of the problems. Down time due to heating up occur as a result of other downtimes since the kiln has to be heated up in order to reach the required temperature for clinkerization process.

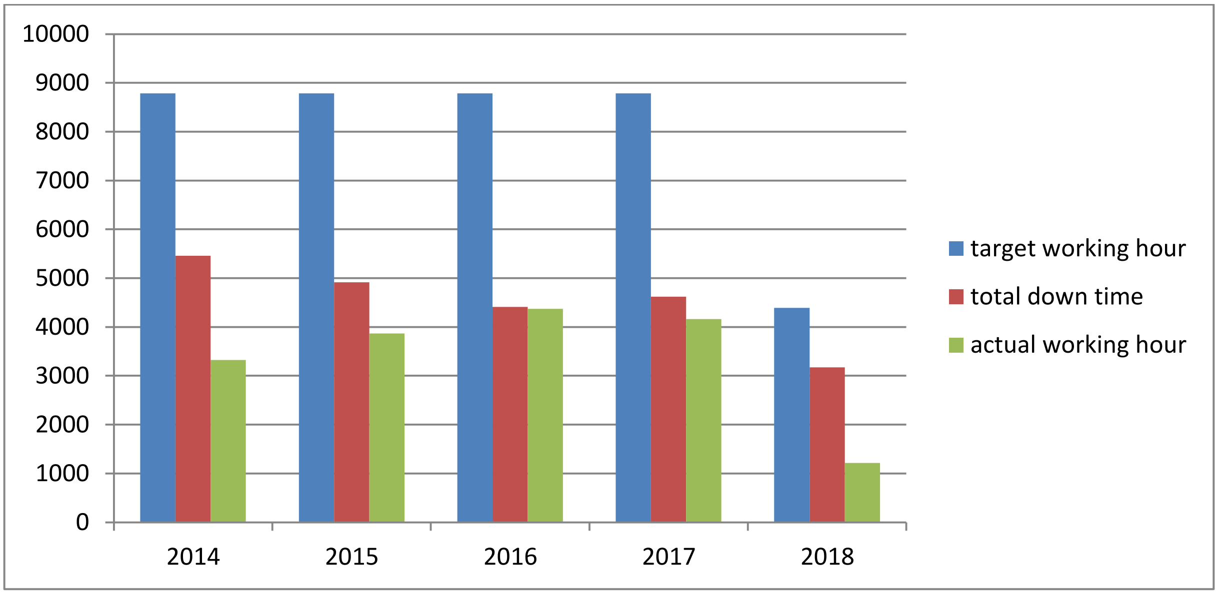

Figure 4.7 The relationship between target working hours, actual hours and downtime

As it is indicated in figure 4.7, for the observed production period, the operating times are much below the target operating hours, even though there is slight improvement in the actual operating hours throughout the observed time.

4.3 Capacity and Production Data

Table 4.2 illustrates actual and effective production levels for the period between 2014 and 2018. The Design capacity and actual production of the plant illustrates that the plant was not able to achieve neither the target nor the design capacity for the specific observation time..

Table 3.2 Actual and effective production levels

year	Design(ton)	Production(ton)		Ratio (%)	
		Effective	Actual	Design	Effective
2014	900,000	775,000	402,746	45	52
2015	900,000	709,000	505,063	56	71
2016	900,000	800,000	540,543	60	67
2017	900,000	810,000	596,989	66	74
2018	450,000	287,000	156,661	35	55

4.4 Overall Equipment Effectiveness

As it is summarized in table 4.3 and figure 4.8 & 4.9, the availability and OEE of the company is lower than the world class.

Table 4.3 Computation of OEE

	Year				
	2014	**2015**	**2016**	**2017**	**2018**
Total available time	8760	8760	8760	8760	4380
Planned down time	1872	2112	2352	2280	1248
Total out put	402746	505063	540543	596989	156661
Actual cycle time	0.39	0.33	0.28	0.24	0.40
Number of defect per year	4,797	6,504	7,768	9,767	2,114
Down time (failure)	4300	3900	3873	4126.32	2100
Loading time	6888	6648	6408	6480	3132
Actual operating time	2588	2748	2535	2353.68	1032
Availability	37.57	41.34	39.56	36.32	32.95
Performance rate	60.0	60.0	60.0	60.0	60.0
Quality rate	98.81	98.71	98.56	98.36	98.65
OEE	22.28	24.48	23.39	21.44	19.50

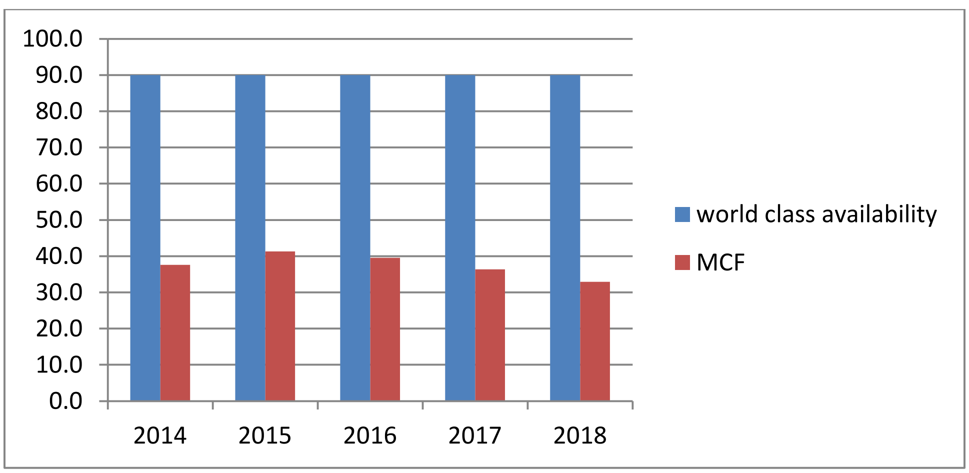

Figure 4.7 comparison of availability of MCF kiln with world class target

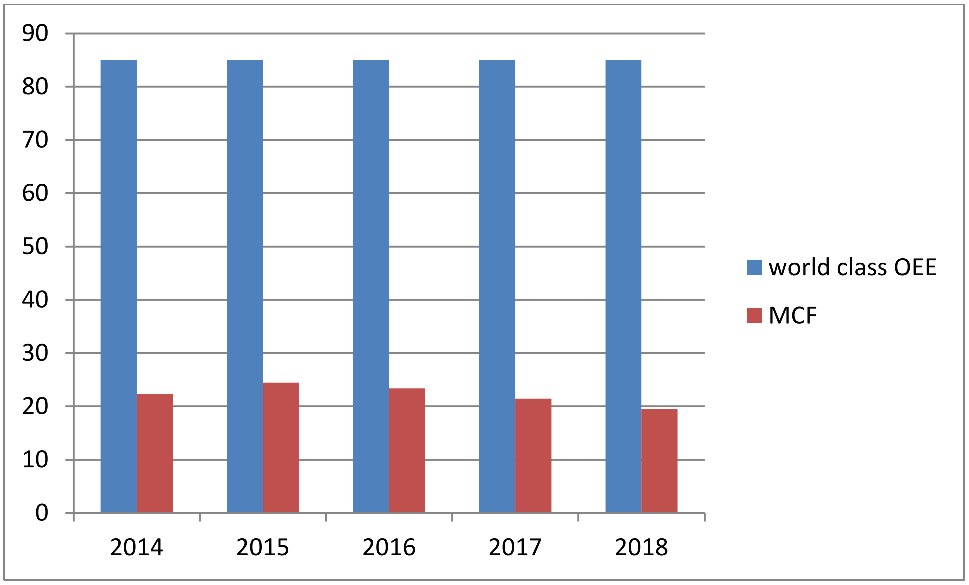

Figure 4.8 Comparison of OEE of MCF kiln with world class target

Therefore, the calculated Overall Equipment Effectiveness of the machine shows that the company needs to work hard to improve the efficiency of the machine, reduce down time, and identify the major causes which highly affect the OEE.

4.5 Root Cause Analysis

In order to bring improvement in the machine availability, it is necessary to identify the root cause of the problem. By conducting a focused group discussion, which consisted of 8 workers from both the production and maintenance departments and by direct observation of the work place, a root cause analysis for the major problems contributing to down time together with the counter measures were brainstormed and categorized into appropriate themes of critical causes using 5M principles for each major causes and constructed into the fish bone diagram to show the root causes of the problems by using Microsoft Office Visio 2007, analyzed and recorded properly so that they can be used for implementation. Figure 4.10 indicates the root cause analysis for the major down time reasons and the counter measures for the critical root causes.

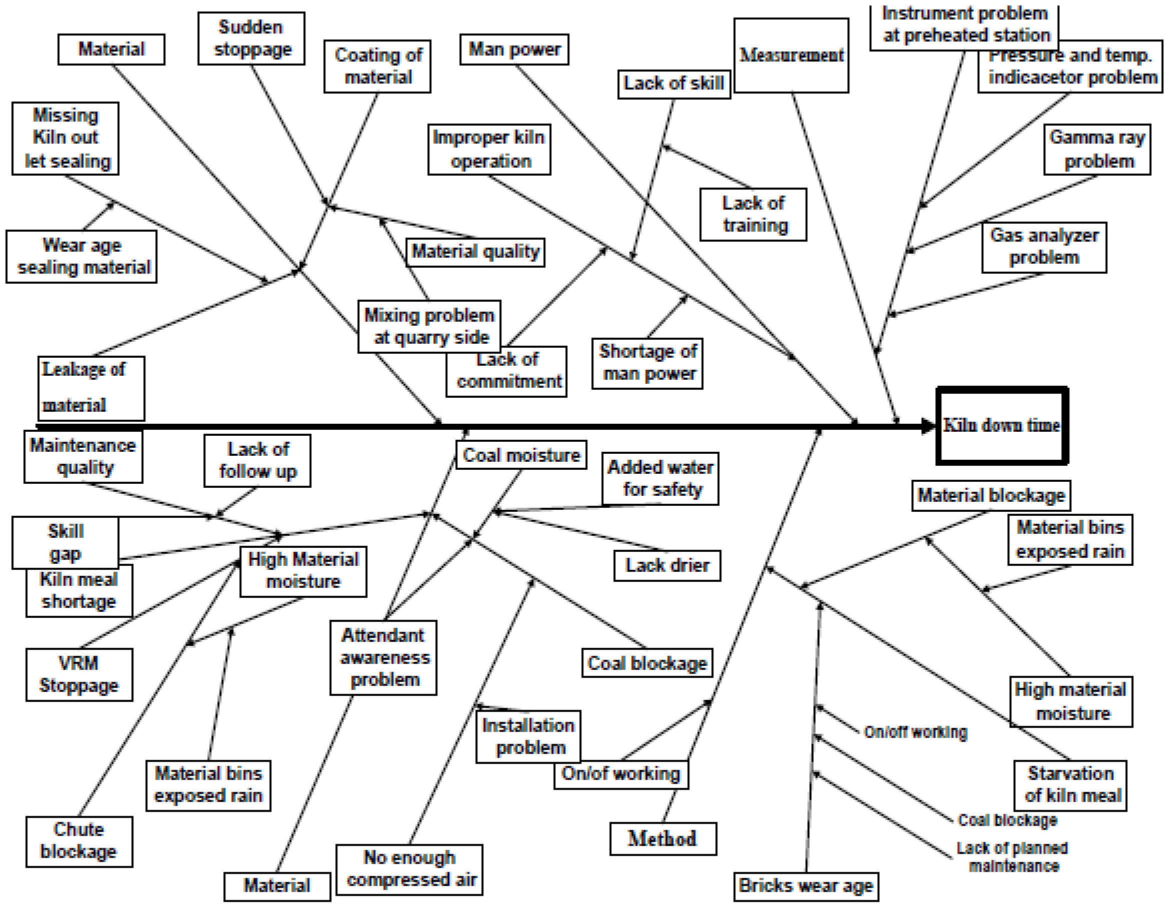

Figure 4.9a fish bone diagram for down time due mechanical, electrical, bricks relining and technological problems in terms of material, man power, method and measurement

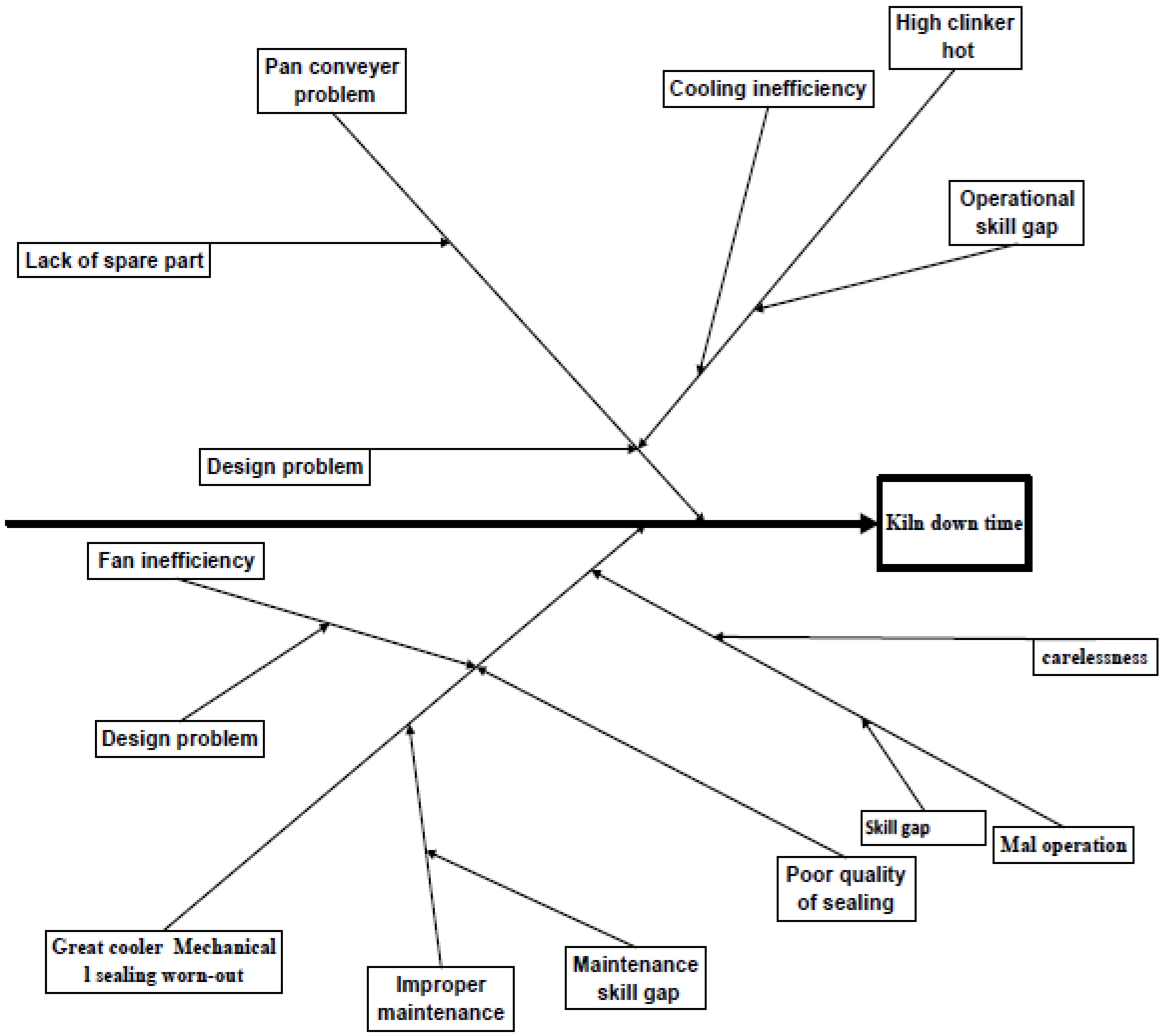

Figure 4.9b fish bone diagram for down time due mechanical, electrical, bricks relining and technological problems in terms of machine

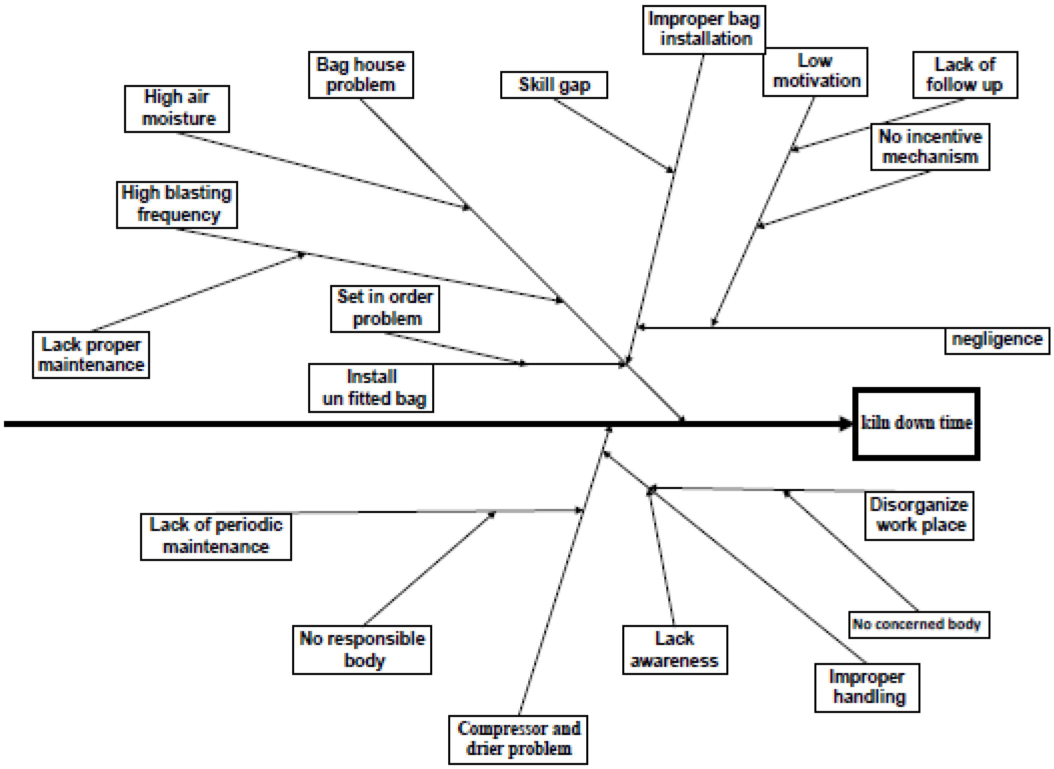

Figure 4.9c fish bone diagram for down time due mechanical, electrical, bricks relining and technological problems in terms of machine

The cause and effect diagram indicates that the company can minimize the downtime problems if it eliminates the identified possible causes. Based on the identified root causes of the major problems in the cause and effect diagram, counter measures to eliminate the root causes were discussed and summarized in table 4.4.

Table 4.4 Major root causes and counter measures to eliminate the root causes

No	Major Root Causes	Proposed counter measures
1	Raw material bins exposed to rain (seasonal)	• Build shelter for material bins at the proportioning station • Improve hot air line/Valve/
2	Cooling inefficiency	• Increase cooling efficiency of great cooler by doing preventive maintenance for machine • Use proper water spray system
3	Lack of spare part for blasting device at kiln inlet and cooler inlet	• Do modification using necessary materials • Purchase new spare parts
4	Improper mixing of raw material at quarry site	• Properly mixing of raw material at quarry site • Use standard operational procedure to mix the raw materials • Improve the communication gap between quality assurance department and quarry site/raw material preparation sub process
5	Operators skill gap	• Provide training for employees on job and class training by doing skill gap
6	Clinker leakage	• Replace mechanical sealing on time • Use quality spare parts
7	Diverting flap to yellow bin failure due to lack of preventive maintenance	• Avail diverting flap for operation • Use preventive maintenance for sensor of flap diverting • Implement autonomous maintenance

4.6 Survey Results and Discussion

The purpose of the survey was to assess maintenance practices of the company and its awareness of TPM concept. 25 questionnaires were distributed to top and middle management and to operators and technicians. Out of the 25 questionnaires distributed, all were returned and the collected data is then processed using SPSS to test the validity and reliability as indicated in chapter three.

Manufacturing performance dimensions

The success of a TPM implementation program does not only depend on a formal implementation of various TPM initiatives in the organization but also requires ensuring the laid out programs are moving in the right direction and the quantifiable benefits and results can be derived as a result of the implementation of TPM (Ahuja and Khamba, 2008). As Shingo (2007) describes, people's attitude and behavior (regarding TPM) will not change until they see the results and benefits of TPM implementation. When people's thinking change, defects and breakdowns starts to be seen as something to be ashamed of and when people's behavior change, they strive to make improvements and manage their work more carefully (Shingo, 2007).

Shamsuddin et al. (2005) states in his paper that the results of TPM implementation towards an organization can be in terms of intangible gains like customer impression and working environment and tangible gains which may cover a host of business functions in an organization. Nakajima (1998) also listed six categories of achievements arising from strategic TPM programs such as productivity, quality, cost, delivery, safety and morale. Suzuki (1994) too cited in his paper the PQCDSM (Productivity, Quality, Cost, Delivery, Safety, and Morale) improvements for early TPM implementers in Japan. A common theme in operational strategy research like TPM for example is describing the manufactures choice of emphasis among key capabilities or in short manufacturing performance (Ward *et al*., 1995). In this paper, the four basic dimensions of plant manufacturing performance that are going to be studied are as follows:

1. Cost (MP1)
2. Quality (MP2)
3. Delivery (MP3)
4. Overall equipment effectiveness (MP4)

In order to evaluate the interrelationship between the manufacturing performance dimensions TPM pillars implementation, a five point Likert scale is used for this study with a rating mechanism: 1 - no correlation at all, 2 - nominal correlation, 3 - some correlation, 4 - reasonable correlation, 5 - extensive correlation).

4.6.1 Evaluating of TPM Element Emphasis and their Contribution towards Manufacturing Performance

Relationship between Factors

Based on the responses from the questionnaires, the relationship between TPM pillars and their contribution towards different manufacturing performance dimension are indicated. To show this relationship, the bivariate correlation procedure is used to compute the Pearson's correlation coefficient between various TPM pillars and manufacturing performance dimension as shown in Table 4.5. It is useful to determine the strength and direction of association between two scale variables. In this case, Pearson correlation is worked out to define significant TPM element contributing towards realization of different manufacturing performance. The Pairs that are considered to have strong association with one another are those statistically significant at 1 percent level of significance.

Table 4.5 Pearson's correlation between TPM pillars and manufacturing performance dimension

	MP1	MP2	MP3	MP4
Pillar1	0.752**	0.419**	0.782**	0.799**
Pillar2	0.950**	0.932**	0.847**	0.822**
Pillar3	0.865**	0.859**	0.754**	0.793**
Pillar4	0.721	0.752	0.784*	0.722
Pillar5	0.218	0.295	0.287	0.395*
Pillar6	0.751**	0.735**	0.752**	0.743**
Pillar7	0.250	0.369*	0.238	0.225
Pillar8	0.401*	0.457*	0.445*	0.397*

Discussion on Relationship between TPM pillars and Manufacturing Performance

The Pearson's correlation results show that there exist significant association between various TPM elements and their contribution towards manufacturing performance. Autonomous maintenance (pillar1) shows significant contribution towards contributing to manufacturing performance of an organization in terms of overall cost saving (MP1), delivery of products (MP3) and increased OEE of the plant (MP4). This indicates the OEE of the equipment increases if minor maintenance is made by operators which reduces the down time of failed machine that waits until a technician come and sorts a problem. The engagement of operators in small maintenance activity also allows them to get experience in doing change over efficiently, which in turn increase productivity which will in turn significantly affect the delivery. Execution of minor maintenances and cleaning and inspection will give a chance to make immediate measures on any abnormalities and helps the machine to be in basic condition, this will minimize cost of maintenance. Autonomous maintenance also brings a higher level of shop floor employee involvement (team activities) in improvement activity, and greater employee empowerment (Ames, 2003). For example, it is hard to access the value of 5S activity (an autonomous maintenance tool) even though it is a valuable and critical part of TPM process. This is because the activities are not centered on results, rather they emphasize on peoples' behaviors, such as the elimination of unnecessary items from the work environment or the cleaning of equipment.

Next, the results also show similar pattern with focused maintenance (pillar2) with improving quality (MP2), strong delivery performance (MP3) and increased OEE (MP4). This is due to the objective of Focused Improvement which is Zero Losses. Increasing equipment effectiveness necessitates the complete elimination of failures, defects, and other negative phenomena which imply the wastes and losses incurred in equipment operation (Nakajima, 1989). Planned Maintenance also shows significant contribution towards improving manufacturing performance by lowering cost (MP1), high levels of quality (MP2) and increased OEE (MP4). The main objective of Planned Maintenance is to create and sustain optimal equipment and process conditions (Suzuki, 1994). As it is described by the JIPM, applying a planned maintenance system means increasing output (no failures, no defects) which in turn results in reduced product cost, as well as improved quality of product and machine. The fourth pillar, quality maintenance also shows strong relation with cost (MP1), quality (MP2) delivery (MP3) and OEE (MP4). This can be justified by the fact that Quality Maintenance (QM) targets customer satisfaction through defect free production of the highest quality products. The focus is on eliminating non-conformances in a systematic manner. According to Meng, (2011) and Induswe, (2013) QM activities control equipment conditions to prevent quality defects, based on the concept of maintaining perfect equipment to maintain perfect quality of products. These conditions are measured and checked in time series to verify that measured values are within standard values to prevent defects.

Education and training (pillar6) also shows significant impact on all four manufacturing performance dimension in terms of cost (MP1), quality (MP2), delivery (MP3) and OEE (MP4). The main objective of Training and Education is to create and sustain skilled operators that are able to effectively execute the practices and methodologies established within the other TPM pillars (Leflar, 2003). It also enables the upgrading and expanding of employees' technical, problem solving and team working skills (Tsang and Chang, 2003). Only by improving the workforce in the organization, would we see improvement in manufacturing performance of the organization. Training and Education can be seen as the most critical of all TPM pillars for sustaining the TPM program in the long-term since its main focus areas are on setting up proper and effective training methods, providing the required infrastructure for training, and expanding the learning and knowledge of the other TPM pillars.. A test of TPM success is to look at organizational learning since TPM is based on the principle of continual learning (Leflar, 2003).

Thus, TPM pillars have to be emphasized on and not neglected in order to reap the benefits of a successful TPM implementation program. Since implementing TPM is a strategic decision and mistakes cannot afford to be made by managers, these TPM pillars can act as a guideline for organization wanting to implement TPM in their organization. This will ensure that all important areas are covered and there is a standard structured implementation process during the TPM implementation phase. At the same time, the improvement of manufacturing performance or the benefits of TPM implementation must be recognized by the organization (Robinson and Ginder, 1995; Cooke, 2000). According to Robinson and Ginder (1995), for TPM to be successful, “the improvement process must be recognized as benefiting both the company and the worker” It is important to identify the critical elements of TPM and their impact on manufacturing performance because many companies fail to invest in maintenance programs because they manage maintenance by a budget and fail to see the strategic implication of a strong maintenance program (Kathleen et al., 1999). Thus, this study could act as evidence to convince management the importance of TPM implementation towards the organization performance.

Present situation in MCF

The qualitative results from interview and direct observation of work place indicate that the maintenance activity in the company is mainly performed by maintenance department, and this means there is less to no contribution of operators and other persons on the maintenance work.

There “exists” I run it you fix it” culture between the production machine operators and the maintenance staffs/ engineering. Overall equipment effectiveness considerations do not exist so far. The machinery that fails due to the absence of well-organized maintenance management system is not given due attention in terms of procuring the necessary spare parts on time (Lack of on time quality spare part delivery).

Moreover, there is lack of using inspection schedule, lack of spare parts and lack of cleaning of machines.

The maintenance crew does not apply different problem-solving techniques such as failure mode analysis, cause and effect analysis, and 5why to detect the root cause of the problem. Moreover, there is no proper maintenance action recording system (maintenance action database), except for reporting purpose. Production machine operators are not empowered to carry out autonomous maintenance of minor stoppages, simple inspection, and machine cleaning.

Generally, the type of maintenance systems currently used in the company is the breakdown and preventive maintenance systems. The breakdown maintenance is predominantly used because the company prioritizes production with less focus on preventive maintenance.

4.6.3 Proposed TPM Framework and Implementation Plan

The introduction of TPM implementation was necessary to increase the sense of ownership of equipment among the operators and developing their interest in work. The objective of maximizing production can be achieved by active participation of operators. Figure 4.11 indicates the proposed methodology for TPM implementation which is developed by intensive literature review and results from the survey.

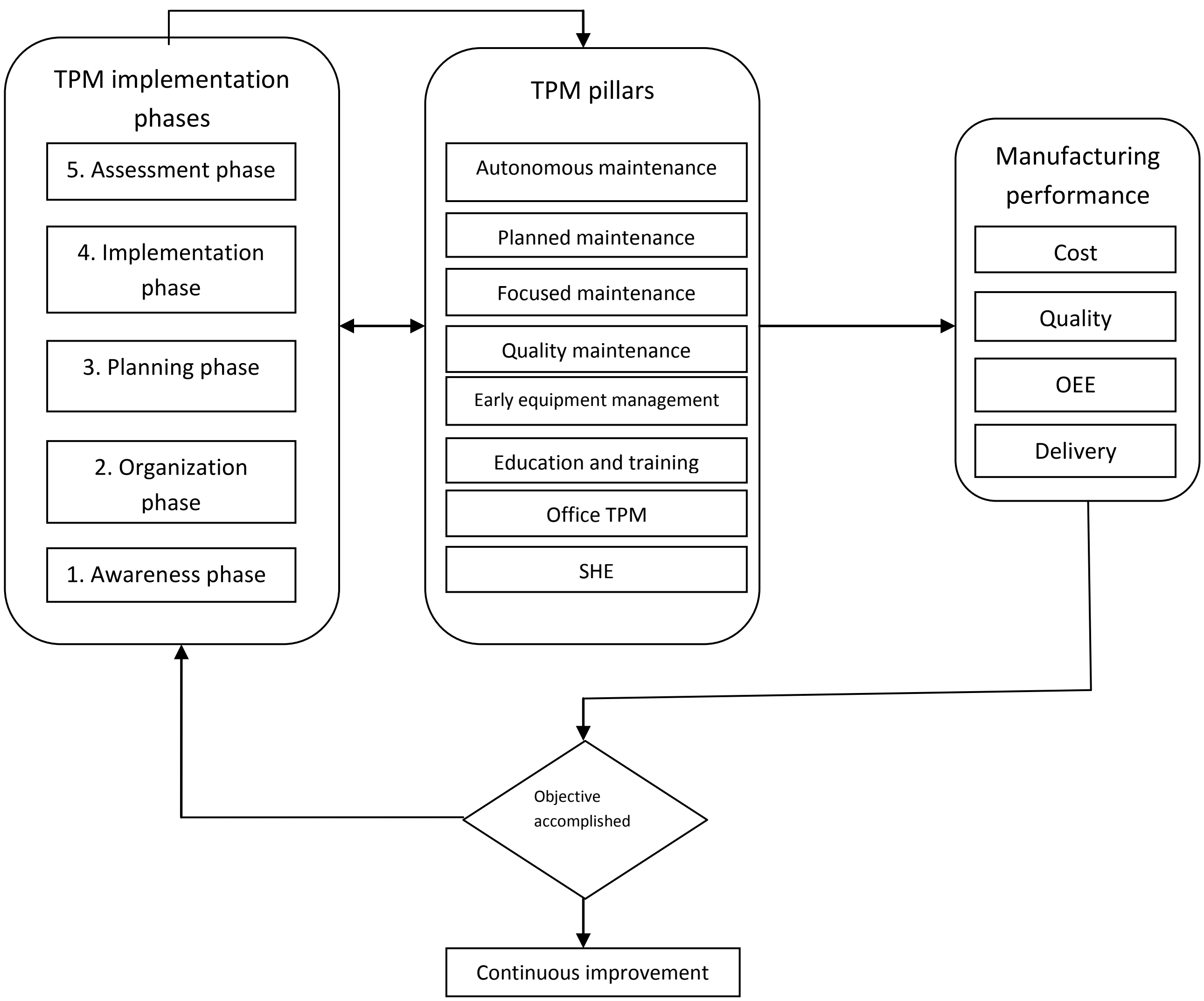

Figure 4.11 proposed TPM framework

The ten step TPM implementation plan:-

Step 1: Announcement of TPM and Top management commitment

The management must aware all employees on the change of shifting towards the new culture of TPM. Top management commitment is the key to start TPM implementation. The management must be ready to prepare employees for training and meetings when required. This is ready to invest in buying necessary equipment and accessories for the team if required.

According to Wang, (2008), change can be bottom-up and top-down. “It must be top-down to provide vision and create structure and it must be bottom-up to encourage participation and generate support.” To bring in changes, the managers have to prepare themselves to the changes before them asking their employees to adopt the changes. Top management must be able to create an environment that effectively reduces or eliminate the confusion for change. In addition to this, the management must provide their employees with proper tools, techniques and other facilities to allow people to synthesize the new concepts, and align them to the new way of the working environment. The company must have top management support, understanding and commitment to engage on the TPM program as it involves a cultural change that cannot happen overnight.

The study conducted by Hoffman and Mehra (1999), described that scholars like Deming, Juran, Crosby, and Garvin, relate top management involvement and commitment to improvement in productivity and quality. Top managements’ major responsibility is to actively promote motivation, ability and favorable work environment (Nakajima, 1989). Among these three keys factors, motivation and ability are mainly the responsibility of the workers and that the creation of favorable work environment will be the responsibility of the management. It would be the good sign of commitment and involvement from top management.

Step 2: Pilot Team building and meeting plan

This step needs a lot of care from management who build (form) teams, as the team is a group of people who are jointly responsible for achieving shared goals. If one member fails then it can delay the achievement of the shared goal of the team. Even if the members fulfill their individual roles but they don't work in a cooperative manner, then they may not fulfill their potential and the results will not be noticeable. Moreover, the pilot team will be used as a model for the rest of the teams. So the members selected should be highly motivated to learn and implement new ideas and ready to adopt changes in working practices and should be made clear about the goal. Also tell them that TPM will allow them to make their work easier, safer and more efficient. In the new system, the most important thing is their opinions, points of view and active participation, and that those who decide to participate will receive training that will allow them to have a higher decision making role. After sharing this information with them, ask them if it would interest them to have the opportunity to participate in this work. Only if their response is positive, consider inviting them to the pilot group training. So the pilot team can consist of small persons for the line, one team leader of their shift, few operators/attendants, the production manager and maintenance manager also has to be included in this team.

This group will promote and sustain TPM activities. In the beginning, weekly one-hour meeting of the group should be organized for one month, after a successful start, the meeting can be held continuously, to assess the progress as the scheduled.

Step 3: Launch a formal training program for selected teams

According to Jeffrey K. Liker (2004) "Teams do not do value added work, the teams coordinate the work, motivate and learn from each other. The teams suggest innovative ideas. Nevertheless, for the most part, it is more efficient for the individuals to do the actual detailed work necessary to produce a product". So the individual excellence and the team effectiveness must be balanced. In order to achieve individual excellence, a training program should be held for in depth understanding of technical knowledge and a broad range of skills.

Nakajima (1989) stated that, to carry out the TPM activities, a company needs persons with strong maintenance skills and knowledge and equipment related skills by using on jobs training. This is because one of the important goals of TPM is to advance workers" skill levels and this only can be done if there is continuous training in company.

The training program should include basic knowledge of the following:

What is TPM?

A brief description about TPM, its advantages and challenges to adopt it, implementation plan and how to measure TPM, TPM 8 pillars should be given.

- Knowledge about OEE

As being the true measure of TPM, operators should understand what overall equipment effectiveness is and how it is calculated.

- Knowledge about 5S activities

What are different 5S and how they are implemented systematically to improve productivity, quality, cost reduction, waste reduction and safety?

- Categorization of losses into six big losses of OEE and sixteen manufacturing loses

It is important that the operators should know the losses categorically, like break down loss, set ups and adjustment loss, idling and minor stoppage loss, speed loss, startup loss, rework and defect loss, so that they can take care of each one of them.

The operators must identify the manufacturing loses according to their foundation/cause like management loses, energy losses, production loses and human factor loses.

- Knowledge about Value stream map (tact time and bottle neck operation)

The current state value stream map should be shown to tell operators about the bottleneck and cycle times at each station so that they can work accordingly. The importance to know the exact tact time should be delivered to the operators.

- Knowledge about optimization of work in process
- Basic training for preventive maintenance

Cleaning is maintaining. Cleaning equipment everyday ensures monitoring of equipment. It works like condition monitoring of the equipment. Whenever there is need for an equipment to be maintained it is very easy to find before breakdown.

Step 4: Establish basic TPM policies and goals for the company

During the meetings, the group should analyze the existing conditions and set goals which are (SMART) specific, measurable, realistic accurate and time-based. In early weeks the improvements should be assessed on the basis of true data. Ideas from the team members should be taken on further improvements and discussed to come up with some goals for the next meeting.

Step 5: Outline a detailed master deployment plan

After three months of the start of a pilot team, the team should develop a detailed master plan through companywide. The plan should take care of following things:

1. Training requirements for operators/attendants.

2. A preventive maintenance plan and preliminary preventive maintenance plans for the rest of lines.

3. Include need for new technology or equipment.

Step 6: TPM training and Kick-off

According to the selected pilot team, new teams should be formed for each production line and their training should be started. The training should include; basic knowledge about equipment for operators, it can be an internal training held by maintenance persons (engineering) or external experts. After a month of training the official kick off for TPM implementation for every employee of production line should take place with a small ceremony to emphasize its importance. This ceremony must involve people from top management, production manager, maintenance department and all employees in the company.

Step 7: Improvement of effectiveness of each piece of equipment

The teams should have the weekly meeting, in the beginning, to analyze each piece of equipment, separately on the basis of collected data and make recommendations for necessary improvements to be analyzed again at next meeting. The meeting should work according to PDCA cycle: which is Plan, Do, Check and Act cycle.

Step 8: Development of an autonomous maintenance program for operators

After one month of kick-off, the teams should be able to make an autonomous maintenance plan for their lines which includes routine cleaning and inspection that will help stabilize machine conditions.

Step 9: Develop a preventive maintenance plan

After three months of kick-off, review the preventive maintenance plan for all equipment and change it accordingly.

Step 10: Follow ups and Continuous improvement

Improve measurement process, carry out scoping study, gap analysis, and accountabilities, periodically. Align short, medium and long term goals under a single change agenda.

4.6.4 Autonomous Maintenance Implementation Framework

Even though All TPM pillars are needed for MCF, this paper suggests AM pillar. TPM helps companies to create clean and productive workplace by changing the way people think about equipment throughout the company.

In Melesse and Ananth's research (2014), the Assela Malt Factory gained a significant achievement by applying autonomous maintenance to the company's boiler plant. This factory is a supplier of malt to local breweries in Ethiopia. As it is indicated in the research, between January 2011 and June 2012, the breakdown time decreased by 46.38% (from 186.39 hours to 99.94hoursmonthly) after the application of AM, the average capacity increased by 8.75% (from 2185.12 to 2394.57 tons monthly), machine idle time only increased by 8.01% (from 54 hours per month to 58.7 hours per month), maintenance cost was reduced by 64.42% (from $520 to $185 every month). Plant OEE increased by 13.79% (from 66.44% to 80.23%). The plant achieved these improvements through the implementation of AM in one and half years (Melesse & Ananth, 2016).

In another study, Amir (2015) indicated that a glazing line of one company reduced defect rates by 8.49% from 14.61% to 6.12% and reduced the breakdown time from 2,502 to 1,161 minutes. The company's OEE improved from 22.12% to 28.61% from April to September 2014. Even though the OEE didn't show noticeable improvement, the AM activities played a positive role in this company's improvement (Amir, 2015).

The study conducted on semiconductor material manufacturing company integrated the Root Cause Analysis and Failure Mode Effects Analysis to reduce the company's manufacturing costs and improve employee and equipment productivity through the application of autonomous maintenance and planned maintenance. The breakdown frequency of this company reduced by 23 occurrences monthly (from 96 times to 68 times). The OEE increased from 48.24% to 61.40%, and the availability rate rose substantially from 69% to 82%. These improvements clearly indicate that AM contributed to the improvement of reduction of the breakdown time with preventive maintenance (Chen, 2013).

As the above literatures indicate, the steps of autonomous maintenance are associated with the pillars of TPM, which are an integral part of the system. The key points that should be considered by the management when carrying out an autonomous maintenance program are operator training, future planned maintenance, and focused improvement. An autonomous maintenance program is a first step in the TPM process. Basic equipment conditions and operator training are the two priorities of this pillar. Based on the above literature findings, the following framework for autonomous maintenance implementation in Mugher cement factory is suggested.

If the company implements the developed autonomous maintenance frame work, it can reduce the problems identified by the researcher. Autonomous maintenance is an important TPM Pillar which emphasizes the importance of the machine operator, that's why this study introduces TPM and develops the AM guideline.

The proposed AM guideline is designed by involving the production operators, and maintenance crew using the discussion and interview on the implementation of AM in the company on the maintenance of their own equipment. The framework focuses on three improvement areas, technical skills of the operators and maintenance persons, attitude and working culture. Thus, this framework is developed as a part of a skill-improvement program that provides step-by-step guidelines on how to train operators to maintain their own equipment. The AM framework is structured with four stages and ten sub-steps as shown in table 4.6.

Table 4.6 Stages and sub-steps of the AM framework (Source adapted from Min et al. 2011)

Stage of the AM framework		Sub-step of the stage
Stage 1	AM initial preparation	AM team formation
		AM activities time frame
		Machine selection
Stage 2	AM preparation (training and motivation) phase	AM-5 activities by using Plan-Do-Act-Check (PDAC) cycle
Stage 3	AM 5-steps execution phase	Initial cleaning
		Countermeasure to sources of problem
		Inspection, Visual Display and Control
		Cleaning and lubrication standards
		Autonomous maintenance standards
Stage 4	AM audit phase	AM audit

Stage 1:- AM initial preparation:

The first stage of the AM framework has three sub-steps: AM team formation, AM activity time frame, and machine selection, the details of each sub-step are as shows above table.

1. AM team formation

The most vital step of the AM practice begins with the formation of AM teams. According to (Min et al., 2011) the aim of the AM team is to coordinate the activities from the preparation to the execution stages. The body of the AM team is categorized into two levels; the management level and the execution level. The management level involves engineers and production supervisors/shift leaders who monitor the progress of AM activities. The execution level is made up of operators/attendants and maintenance technicians/ master technician.

To achieve the best AM practice, both execution and management levels have to focus on individual tasks.

2. AM activity time frame

The arrangement of the time frame of AM activities is performed under the responsibility of the AM team leader (i.e. clinker sub process head/ team leader) and is supported by the management level (i.e. Engineers and supervisors in maintenance department). One of the techniques that can be applied in the organization of the AM activities time frame is the development of a Gantt chart. By using the Gantt chart, the team leader will be able to monitor the progress of the AM implementation if it is within the target period or not. Proper time estimation ensures that the AM program runs smoothly; as a result, the goals can be achieved. The team leader must update the schedule from time to time to monitor the progress and make necessary changes on programs.

3. Machine selection

Selection of machine or equipment is carried out in order to appropriately implement AM activities that have been planned. At this stage, implementing the AM program in all the shop floor machines or equipment at once requires much workforce and equipment change.

Therefore, starting the AM program with one or two critical machines or equipment, the main machine or equipment selection is based on the criticality level of the machine or equipment depending on the breakdown time and its frequency.

Therefore, using appropriate simple statistical techniques, such as a histogram or a Pareto diagram or matrix diagram, the critical machine or equipment can be identified. Selection of the right machine/equipment during the initial stages of implementation of AM can produce excellent results; thus, sufficient momentum to the entire AM program is provided. This is also accomplished to ensure that the AM program is able to achieve the established goals before being implemented to another machine or equipment, and consequently to the entire shop floor.

Stage 2: AM training and motivation

The second stage of the AM framework focuses on AM training and motivation. At this stage, a series of the skill improvement training program is conducted in the company for the employees. The objective of the training program is to introduce AM to train the execution level personnel i.e. operators and technicians in the AM-5 activities as listed below.

The AM-5 activities are as follows:

- ❖ Initial cleaning
- ❖ Elimination of sources of problems
- ❖ Establishment of inspection, visual display, and control
- ❖ Establishment of cleaning, tightening and lubricating standards
- ❖ Establishment of AM standards

The training programs are divided into two phases. The first phase is the introduction of AM in terms of the general idea, concepts, elements, and benefits to all the employees within the department. The second phase is the development of the training program based on plan-do-act-check (PDAC) cycle to improve skills and knowledge using simple analysis techniques of AM-5 activities (Sharma et al. (2006). The process of development of the AM training program is presented.

Table 4.7 AM-5 activity training guide (Source adapted from Min et al. 2011)

PDAC cycle	Cycle action	Remark
Plan	Determine training scope Determine training techniques Determine training materials	On job training for operators, attendants and technicians, class lectures and one point lessons
Do	Determine training schedule Determine trainer schedule	Time and place Trainer turn and responsibility
Act	Initial cleaning method Elimination to the sources of problems techniques and analysis Establish inspection, visual display and control methods	Definition and explanation What are the importance of it What to do? When to do? How to do?

	Establish cleaning, lubricating and tightening standards Establish AM standards	
Check	Evaluation of the above works	Pilot test

1. Plan cycle:-

This cycle involves the preparation of training techniques, scope, and materials. Training techniques, such as on-the-job training, class lecture and one-point lesson are decided by the manager and the management-level personnel to ensure that the training is effective and practical. With regard to the training scope for the operators, attendants, and technicians, the operators and attendants only have to learn where, how and when to clean, inspect the equipment's, whereas the technicians are required to learn simple analytic techniques for cleaning and inspection process improvement.

2. Do cycle:-

This cycle involves the arrangement of training schedules and the selection of a trainer from among the engineers or experts. The training schedule includes the time and place of the training. The training personnel is determined from among the management-level personnel (i.e. engineers), for instance, who and how many engineers or experts should cover a certain lesson for the operators, attendants, and technicians.

3. Act cycle:-

This cycle is an important training process that introduces the AM-5 step activities to the operators, attendants, and technicians. In this cycle, the general process and critical parts of the selected machine (obtained during the previous stage) are evaluated. The trainer plays a vital role during the training session, ensuring that the trainees (i.e. operators, attendants, and technicians) understand their job scope and responsibilities. For example, technicians learn some simple analysis and solving techniques, such as root cause analysis, fishbone diagram, why–why analysis and brainstorming, etc. Meanwhile, operators and attendants learn how to support the technicians by providing data or machine/equipment symptoms for conducting the analysis. To attain the objectives of the training program, trainers should conduct the training based on the questions what, when, how, where to do and who should do.

4. Check cycle:-

Finally, the check cycle is the evaluation process of the training program. It measures the level of knowledge and skill improvement among operators, attendants, and technicians by conducting a pilot test or a simple exam.

Stage 3: Autonomous maintenance execution:

The development of AM practice through the proposed framework is based on five core AM activities. At this stage, an emphasis is given on how these AM-5 activities are carried out. The AM-5 activities are as follows:

1. Initial cleaning
2. Elimination of sources of problems
3. Establishment of inspection, visual display, and control
4. Establishment of cleaning, tightening and lubricating standards
5. Establishment of AM standards.

The activities and processes involved are discussed in detail in the following sections.

1. Initial cleaning

Initial cleaning is the first AM activity. Its main goal is to maintain equipment cleanliness. Another goal is to detect hidden problems and restore the problem areas of the equipment.

Min et al., (2011) stated that "the cleaning activity is not just to clean for the sake of cleaning, but to clean to inspect by practicing „cleaning is the inspection."

The initial cleaning activity is carried out by the operator and attendants. However, at the beginning, support from the other team members (i.e. technicians, engineers, and supervisors) is also required. With the skills and knowledge gained from the training stage, the operators are able to carry out the cleaning activity appropriately. They can conduct the cleaning activity based on the questions where to clean, how to clean and when to clean. At the early period, the cleaning activity is monitored by technicians or engineers to ensure that the operators perform the tasks correctly, In this case, the engineering department must prepare the standard check list for themselves to evaluate the cleaning activities.

2. Elimination of sources of problems

The goal of this activity is to maintain the state of cleanliness achieved in the previous activity (initial cleaning) by eliminating the sources of problems. There are two objectives that need to be achieved, the first one is to identify the sources of problems or break downs and the second objective is to provide solutions to manage or eliminate the sources and to identify the hard to access areas and improve the cleaning method. Countermeasures should be put in place to eliminate these sources permanently and to improve the work method in difficult to clean places. The operators and attendants are able to identify and document the sources or the root cause of the problem, whereas the technicians perform a simple analysis to determine the solution.

3. Inspection, visual display, and control

Inspection is part of the maintenance routine carried out by operators and attendants in parallel with the cleaning activity. The goal of inspection is to monitor and check the current condition of certain parts of the machine/equipment. The visual display and control approach is used to simplify the inspection tasks. Visual display and control are applied by the engineers or technicians by placing appropriate signs, tags, labels and color coding in suitable locations of the selected machines. Color coding can be used to match parts together or group parts with the same functions. Tagging is used to sort out the problems. Labeling is used to provide the instructions for a task. Sign uses symbols to represent conditions. Visual control should be applied in a proper location so that it will not disrupt the equipment function.

4. Cleaning, tightening and lubricating standards

Cleaning, tightening and lubricating tasks are under the inspection activity, where the aim is to prevent any malfunction by monitoring the lubrication system and tightening the points of the machine/equipment. The tasks of cleaning, tightening and lubricating are carried out based on the obtained standard. In addition, the cleaning, tightening and lubricating (C-T-L) standards are established with the aid of the visual display and control approach. The development of this standard is carried out by engineers and technicians.

5. AM standards

The final AM activity is to develop the AM standard, which is the combination of AM activities (i.e. inspection, visual display, and control) and (i.e. cleaning, tightening and lubricating standard). The combination of these activities is the total standard called AM standards, which prescribe the necessary routine tasks of cleaning, lubricating and inspecting. Following this standard, operators and attendants are able to clean, lubricate and inspect all equipment installed in a systematic process.

Stage 4: AM audit and continuous improvement:

The final stage of the AM framework is AM audit and continuous improvement. The main objective of this stage is to enhance the AM practice. Auditors are divided into two groups. The first group consists of the personnel from the AM team itself, and the second group/team consists of the members outside the AM group. The best person to be appointed as an auditor from the AM group is the AM team leader (i.e. operators or plant manager), whereas the second type of auditors can be the engineers from others‟ production lines or departments. Top management should consider any comment and recommendation given by the auditors once they have completed the auditing process to initiate the continuous improvement of tasks.

The results of the AM audit are used for further improvement to achieve the objectives of the AM program before it is widely implemented in the other machine departments of the case study.

4.6.5 Threats to TPM implementation in MCF

Cost of TPM Implementation

Financial incapacity is one of the major hindrances to adoption and implementation of successful TPM within a company. The fear of applying TPM, like any other productivity improvement initiative within a company, could require large sums of money to pay for a consultant, as well as the implementation of these ideas. The training given to the people to utilize these techniques also requires money. In some instances, production of the company may be halted like if machine layout or plant layout need to be changed for smooth flow of material, then the production needs to stop. In the case of providing knowledge and training to the workforce production need to stop. A fact is that the company views it as an unnecessary loss of resources and time, more specifically if they are not getting the immediate returns.

Misapplication

As the current manufacturing market is very competitive, the company is postponing TPM with unpredictable future certainties, as a result declining manufacturing performance. In order to survive, managers have opted to adopt the TPM concept in rush. To achieve a successful implementation an early understanding of the TPM principles and its operational activities must be facilitated concurrently.

Cost Drivers

To increase the profitability, it is very essential to identifying and ranking the factors that generate costs within the company. After finding these factors, both the cost saving exercises and

TPM application that insist on waste elimination and performance improvement can be performed. The size of a plant is an important factor that determines whether a company can achieve a successful TPM application. This is because implementing TPM takes into consideration a number of issues like new plant layout, workplace layout, etc. This could retard the transformation of current production strategy depending on the company's capacity.

Employee Involvement/ Human Factors

The implementation and successful adoption of TPM can only be sustained in structured manner if and only when employees concerned are involved. In the case of Mugher Cement factory only the senior management knows about the TPM methodology. Since the knowledge would have remained within the boundary of mostly the seniors, it results in no proper implementation.

Summary of the Chapter and Contribution of the Study

The first section of this chapter describes the overview of the cement production process which is followed by the analysis of productive and non productive time and reasons for downtime. The results from the analysis indicate that the major failures are due to mechanical and electrical failures. The capacity and actual production data were also analyzed and it is found that the company was performing under both the capacity and target production. The next section analyzed the OEE by calculating the availability, performance and quality rate and the results indicate that the company's OEE for the specific time of the study ranges between 19-24% which is much below the world class target of 85%. Based on this results cause and effect analysis for machine down time was performed and remedial actions are suggested.

Additionally, this chapter has covered the analysis performed on the survey results. First, the reliability and validity of the survey was performed which confirmed that it is both reliable and valid. Next, correlation was performed to indicate the relation between TPM pillars and manufacturing performance of the company and the results showed strong relationship. Based on the results from the survey analysis and literature reviews, a TPM implementation framework was developed which is proposed together with the implementation plan.

Finally, based on the evidences found from literatures, an autonomous maintenance implementation plan was proposed since its implementation can lay a basic foundation for TPM implementation.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research has been conducted and written in relation to enhancing the overall equipment effectiveness through total productive maintenance in the case company Mugher Cement Factory. The problems in these study include high machine break down, no practical inspection, lack of cleaning, lack of quality spare part and lack of skill, and knowledge on jobs and theoretical training for maintenance persons and machine operator were the major problems in this case company. To overcome the above problems, TPM is a key competitive strategy for business organization in the global market place.

In order to conduct the study Primary data were collected through questionnaires, interviews, observations, and discussion with target company groups and secondary data was also collected from the company's annual reports.

The collected data were analyzed through SPSS and SQC tools. As it is observed from the analysis, the OEE was found in the range of 19 to 24% which shows that the OEE of the company was much lower than the world class OEE. From this, the researcher concludes that the company uses the breakdown maintenance system this means there is no preventive maintenance system in the company. The major reason of this decrement was point out by cause and effect diagram and result from questionnaires are collected. Therefore lack of periodic maintenance, lack of autonomous maintenance in the company, like inspection, tightening, cleaning, and low quality of the spare part are the main reasons for the decrement of OEE.

The study has also indicated the relation between TPM pillars and selected manufacturing performance indicators. For this purpose, eight TPM pillars and four manufacturing performance dimensions have been categories after exhaustive literature review in this research. The empirical evidence has also been presented to support relationship between various TPM pillars and manufacturing performance. Findings show that these TPM pillars are quite important to manufacturing organization in terms of lowering cost, better quality products, strong delivery and increased productivity levels.

Eventually, this paper proposed solutions for the company that can eliminate the problems identified and increase machine availability and improves productivity of the company. The proposed solutions are providing adequate training and education for all employees in the factory including maintenance workers and shop floor machine operators depends on skill matrix, empowering the operators to carry out small maintenance activities, standardized maintenance actions and use developed autonomous maintenance implementation frame work for the factory and developed ways to improve the productivity of the company.

5.2 Recommendation

Based on the findings from the study the following recommendations are made.

- The management should take responsibility on the maintenance issue, especially for Preventive maintenance. Because when the management has awareness on maintenance issues the employees also take their responsibility.
- The company has to put in place a system to measure OEE of all machine with respect to availability losses, performance loss and quality loss.
- The company has to focus on series implementation of 5S so that equipments should be kept clean because most of the abnormality develops from dirty machines and also cleaning is one of the best ways to check for abnormalities and dealing with them at the early stage.
- The company has to give emphasis for training and education to create learning organization in the company, because skill gap was one factor for machine breakdown.
- Maintenance activity shouldn't be considered anymore as a separate and isolated function that makes repairs and that leads to high expense. Rather, it should be considered as the main potential area to use as a competitive advantage. Otherwise, higher cost will be incurred for the equipment's deteriorate which directly affects the competitiveness of a company.
- The company has to develop team work between the maintenance and production departments.

- The company has to establish evaluation mechanism and recognition mechanism for the employee who achieves the given goal.
- The company should involve achieving the company goal through the implementation of operator initiated daily maintenance consisting of cleaning, lubrication, and regular inspections, as well as improvement activities minor restoration of equipment.
- Empowering the operators and maintenance men through training, due attention and conducted in sustainable manner to maximize the efficiency of the equipment in eliminating the operators' mistake and improper repair. Especially, the operator should be trained to pinpoint small signs of troubles whenever anything out of the ordinary occurs and to be able to operate in the proper way.
- Implement all TPM pillars for the long term for productivity improvement and to improve the machine failures.

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Appendix 1

Addis Ababa University

Addis Ababa Institute of Technology

School of Mechanical and industrial Engineering

Industrial Engineering Stream

Questionnaire

Questionnaire on Overall Equipment Effectiveness Enhancement through Total Productive Maintenance

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Dear Respondent,

This questionnaire is designed based on the Topic: **Overall Equipment effectiveness Enhancement through Total Productive Maintenance**. The main purpose of this questionnaire is to obtain information about Mugher Cement Factory's experience with Total productive maintenance concepts and pillars.

Any information you give will be kept confidential as the data are needed for academic purpose only.

Your kind cooperation is very much appreciated.

Part I: General Information

1-Position: ______________________________

2-Qualification: MA/MSc & Above ☐ BA/BSc ☐ College diploma ☐

3-Work experience in this company: __________________________________

Part II: TPM pillars

1	Autonomous maintenance	1-strongly agree	2-agree	3-neither	4-disagree	5-strongly disagree
1.	Production operator accept that autonomous maintenance is their responsibility					
2.	Both production and maintenance					

	personnel work together					
3.	Production operator perform a daily maintenance task on their machines					
4.	Production operators have demonstrated the ownership of their machines					
5.	Cleaning, lubricating and tightening standards are developed and implemented in the organization					
2	**Focused improvement**					
1.	Maintenance aims to reduce even minor defects of equipment					
2.	Employees take reasonable risks by continuously experimenting with the new ways of doing work					
3.	TPM is used as a tool to boost manufacturing performance					
4.	Information on productivity is readily available to employees on a regular basis					
5.	Scientific tools like pareto charts, 5why's, fishbone diagram, etc. are used to analyze and eliminate productivity losses					
3	**Planned maintenance**					
1.	Spare parts required for maintenance are available when needed					
2.	The organization prepares schedule in advance for various types of maintenance activity					
3.	There is monitoring and analysis of machine failure and taking action to prevent reoccurrence					
4.	Measuring and control devices and equipment are inspected regularly and to schedule					
5.	Equipment and machinery are cleaned regularly					
4	**Quality maintenance**					
1.	Performance metrics such as OEE, MTTR and MTBF are recorded					
2.	Maintenance program includes training of maintenance personnel in the appropriate field					
3.	Maintenance practices of the company focuses on customer delight and customer satisfaction					
4.	There are scraps and quality defects as a result of poor maintenance handling					
5.	Root causes of all the losses are tracked					
6.	Working on minimizing and eliminating defect is the company's concern in day to day activity					

5	**Early equipment management**					
1.	A new product easily gets to the standard quality and has less development lead time					
2.	During inclusion of new machines the level of scrap is low					
3.	during startup of new machine the ability of the firm to deliver in volume at the right quality is good enough					
4.	You believe new installations and new product development are not main issues in the production performance					
6	**Education, training, and knowledge management**					
1.	There is staff development program that focus on upgrading employees technical, problem solving, team working skills, etc.					
2.	Production operators are trained to perform routine PM task					
3.	Top management is committed to evaluate employees skill to improve it time to time					
4.	Top management takes part in making their employees multi skilling					
7	**Office TPM**					
1.	Administrative and office departments of the company play a vital role in the manufacturing as well as in other departments in reducing waste and losses					
2.	5S initiatives are implemented in office area					
3.	Role of administration is limited to ruling and controlling					
4.	Office decisions and process are executed on the basis of priority					
8	**Safety, health and environment**					
1.	Top management focuses on health, safety and environmental issues					
2.	Top management is committed to create a safe working environment					
3.	Maintenance activities of the company include activities for safety, health and environment					
4.	The incidents of injuries and identification of accidents and its countermeasures are implemented effectively on a regular basis					
5.	There are caution signs and procedures to be followed everywhere on unsafe conditions in working areas					

III: Manufacturing performance

	Cost					
1	Reduction of operating cost through these TPM strategies implementation					
2	Reduction in energy consumption (e.g. electricity bill) and overhead expenditure					
3	Reduction in additional investment in purchasing new machine/parts					
	Quality					
1	Reduction of percentage of internal scrap and rework in operations					
2	Improved customer order compliance and conformance to specification					
3	Reduction of customer’s returns due to defects					
4	Improve overall manufacturing quality and less variation in processes					
	Delivery					
1	Achieving dependable deliveries by having high percentage of products delivered on time					
2	Achieving faster deliveries by averaging low lead times between receipt of order till shipment					
3	Reduction in cycle time to develop new product					
	OEE					
1	Improvement in equipment availability and reliability					
2	Reduction in setup times and unplanned downtime					
3	Improve control over production schedule					
4	Improvement in overall equipment effectiveness (OEE					