Project Study for the Course of MS-100

Assessment of Maintenance Management System in Cement Industries: A Case study on Mugher Cement Enterprise, Ethiopia

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Submitted To:

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Addis Ababa, Ethiopia
April, 2013

CERTIFICATE OF ORIGINALITY

This is to certify that the project title ***" Assessment of Maintenance Management System in Cement Industries: A Case study on Mugher Cement Enterprise, Ethiopia"*** *is an original work of the student and is being submitted in partial fulfillment for the award of the master's degree in Business Administration of Indra Gandhi national Open University, Institution the for the fulfillment of the requirements of a course of study.*

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ACKNOWLEDGEMENTS

I would like to express a sincere and special Thank to my advisor Mr Dereje Gelana for his continuous support, guidance, thorough correction and efforts in doing this thesis.

I would like to acknowledge Mugher CementEnterprises management and workers for their support during data collection.

Finally and most importantly, my heartfelt affection goes to my family for providing the security of a loving home which was a prerequisite for completing this work.

Solomon Ambaye

April, 2013

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ABBREVATION

MCE	Mugher Cement Enterprise
OPC	Ordinary Portland Cement
PPC	Portland Pozzolona Cement
VAT	Value Added Tax
E.C	Ethiopian Calendar
G.C	Gregorian Calendar
PM	Preventive Maintenance
CM	Corrective Maintenance
CBM	Condition Based Maintenance
PDM	Predetermined Maintenance
TPM	Total Productive Maintenance
OEE	Overall Equipment Efficiency
TEEP	Total Equipment Effectiveness Performance
RCM	Reliability Centered Maintenance
CMMS	Computerized Maintenance Management System
CMMIS	Computerized Maintenance Management System

ABSTRACT

This study seeks to provide a greater depth into the exploration of the subject "Assessment Maintenance Management System in cement Industries" (MMS). It is found that improved maintenance helps to increase revenues of a firm by increasing equipment performance and availability. Most importantly, firms must have maintenance policies and strategies so that the whole firm will be directed in the same direction to reduce equipment down time.

The purpose of this study is to improve the existing maintenance management system and maintenance efficiency of the enterprise under consideration.

The establishment of effective and efficient maintenance management system is the mechanism by which controllable costs are reduced and equipment availability is increased. Controllable costs are the costs incurred due to improper decision during purchasing process by selecting incompatible and cheap price items with out considering reliability and maintainability, and costs incurred due to poor maintenance management system practiced during operation. Thus, the main objective of this thesis is to examine the existing maintenance of Mugher Cement Enterprise (MCE) and recommend better maintenance management system that enhances plant availability with reasonable maintenance cost. The researcher believes upon implementation of the recommended maintenance management system model, availability of plant and useful life are expected to increase due to minimizing of down time.

CHAPTER ONE

Introduction

1.1 Background of the study

Business enterprises use complex equipment to deliver products and services. The failure of their equipment can cause serious social and economic consequences. However, maintenance activities on these equipments are often neglected, either for short-term cost savings from lower maintenance activities or due to lack of awareness on importance of maintenance by top management. However, various organization are starting to realize that cost-effective maintenance results in better efficiencies, higher availability of equipment and more profit and savings with regards to their strategic and operational objectives. Equipment failures are rectified through corrective maintenance actions while preventive maintenance actions are used to reduce the recurrence of failure.

All these maintenance actions resulted additional cost. Therefore, maintenance must be done so as to achieve the objectives of the organization, making a rational between corrective and preventive maintenance. The enterprise under consideration MCE (Mugher cement Enterprise) is one of the biggest organizations engaged in production of cement in Ethiopia. The enterprise has more than 25 years of experience in cement production with a capacity of 2.2 million tons of cement per annum and revenue of Br 3.0 Billion(equivalent to approximately USD 150 million). It plays indispensable role in the development of the country and neighbors countries.

But from time to time the enterprise faced with increasing down time of plant and equipment, higher repair costs, too many obsolescence, and financial losses. The cement industry is essentially a chemical

process industry entailing various engineering unit operations. Cement is manufactured by intimately mixing together calcareous and argillaceous and/ or silica, alumina or iron oxide bearing materials, burning them at clinkering temperature and grinding the resultant clinker so as to produce cement.

1.2 Cement industries in Ethiopia

In Ethiopia, a cement factory was established by Italians in 1936 during the five year fascist occupation of the Country. Currently, there are 17 cement plants with a combined production capacity of about 10.61 million metric tons per year. The Dire Dawa Cement Factory is the first factory established in the country.

These cement plants presently manufacture cement mainly for the local market. However, the Messebo Cement plant has started exporting cement to the neighboring country, south Sudan.

Table 1.1: Cement Plants Capacities of the Country.

S.No	Operating plants	Ownership		Location	Annual production Capacity(in 1000 tons)Cement
		Public enterprise	Private Limited		
1	Muger Cement Enterprise (Existing)	✓		Mugher	876
	Muger Cement Enterprise (New)	✓		Mugher	1400
2	Mesebo Cement Factory (Existing)		✓	Mekele	840
	Mesebo Cement Factory (New)		✓	Mekele	1400
3	National Cement S.C		✓	Dire Dawa	150

S.No	Operating plants	Ownership		Location	Annual production Capacity(in 1000 tons)Cement
		Public enterprise	Private Limited		
4	Abyssinia Cement P.L.C		✓	Chancho	90
5	Jema Cement P.L.C		✓	Muketuri	45
6	Red-fox international investment business P.L.C		✓	Nazreth	(Clinker)100
7	Huan Shang P.L.C		✓	Mojo	435
8	Zhong Shan Cement P.L.C		✓	Dukem	250
9	Debresina Bussiness industries P.L.C		✓	Holeta	90
10	Dashen Cement P.L.C		✓	Dejen	90
11	Hua Yu cement Plc		✓	Nazreth	150
12	Inchini Bedroc Cement P.L.C		✓	Inchini	300
13	Pioner Cement Manufacturing P.L.C		✓	Dire Dawa	450
14	Capital Cement grinding and packing P.L.C		✓	Dire Dawa	450
14	East Cement P.L.C		✓	Fiche	750
16	Derba Midroc P.L.C		✓	Derba	2300
17	C.H Clinker manufacturing P.L.C		✓	Gebre guracha	(Clinker)450
	Total				**10,616**

Source: *Compiled by MoI Chemical Industry Development directorate (Quick reference on Existing cement factory designed production capacity, their performance and other information)*

1.3 Background of the MCE

Mugher Cement Enterprise, 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, is one of the biggest cement plants in the country [Ethiopia].

Being a government owned company and now under the privatization and public Enterprises Supervising Agency (PPESA), it started production in 1984 with a single line and later added another production line in 1990. In July, 1999 the government decided to merge it with another small scale cement plant, the Addis Ababa Cement Factory under proclamation and gave it its current name, MCE.

It produced two types of cement-Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC) based on customers' need. It also has a paper bag plant for packing cement which it uses for internal consumption and for sales to other cement factories.

The raw materials for the plant are within the vicinity of the factory and unlike its competitors, the fact that the plant location is near to the major market area has given MCE to enjoy the leading market share and profitability for at least until this time,

The number of permanent employees (management included) working at MCE both in Addis Ababa and Mugher places reach 1,500. The Enterprise provides housing service to all of its employees at Mugher including educational and health facilities such as schools (Kindergarten to High School Grades) and health service center.

MCE's contribution to the country's fast socio economic development can be categorized as significant. Infrastructural development among others is growing from time to time for which cement is a major input. Besides, the witness to the saying is that when we look at the income tax and VAT (value added tax) the company contributed to the national revenue for the last three years alone, it amounts Birr 784,820,675 (equivalent to approximately USD 39,241,034).

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, MCE with a couple of other cement producers in the country could not even meet the supply demand gap. The current capacity of 2,286,600 tons per annum of cement and 40 million pieces of paper bags per annum.

Fig 1.1 Mugher Cement Plant

1.4 Statement of the problem

In MCE, the plant and equipment maintenance record keeping and failure analysis culture is very poor. Maintenance is performed without any manual procedure on breakdown based; this decreases the economic service life of plant and equipment and lacks critical information on the plant and equipment' status, for its replacement or disposal.

MCE follows reactive and less preventive type of maintenance. This causes higher down time, less availability and high maintenance cost. As a result the enterprises maintenance cost reaches 74 million Birr in 2011/12 G.C.

Hence, this study aims at addressing and improving the maintenance system of the Industry to clearly scrutinize the hidden factors, which hinder the capacity of the Industry.

1. What is the state of the current maintenance management system?

2. What are the major causes for equipment breakdown?

3. How should the maintenance management system be improved

1.5 Objective of the study

As a result of effective and efficient maintenance management, it is possible to prolong the physical, technical and economic service time of plant and equipment. Thus the main objective of this study is to analyze the current system of plant and equipment maintenance management system of MCE, to know OEE of the plant and to recommend improved maintenance management system. In this study, the design and implementation of rational maintenance system, work standardization

procedure, and appropriate organizational structure with efficient personnel who can accomplish the task encountered is recommended.

1.6 Methodology

In order to achieve the objectives of the study, the methodologies followed are**:**

(**a**) **Literature survey**:-To be familiar with the concepts of maintenance, maintenance management system and performance improvement, literature review was carried out. Articles and journals are also reviewed to reinforce the current maintenance practices of the enterprise

(**b**) **Data collection**: - review of available data in MCE such as general operating costs and maintenance costs, types of maintenance practices, frequency of break down and resource consumption are collected and examined. Direct observation on maintenance process of the enterprises, Focus Group Discussion on existing maintenance management system and its ways of improvement, questionnaires distributed to collect the opinions of production and maintenance employees and non structured interviews with Executives production, Marketing, supply and maintenance managers assist to identify the problems.

(**c**) **Existing system analysis and system design**: - after identifying the problems in the enterprise, recommendations are presented which enable to improve the maintenance management system.

1.7 Organization of the paper

This study is organized in six chapters, including the first chapter; an introduction part; gives the background of the study and discusses best maintenance practices, contains a brief discussion of research objectives, significance of the study and scope of work. Chapter two a literature review that covers various topics relevant to maintenance management. Chapter three; a detailed overview of the

methodology for the study, to include data collection, Data analysis. Chapter four; contains the case study data analysis and also present results obtained from Questionnaires and discussions. The results are compared with the maintenance best practices. Chapter five; contains discussion of the results, conclusion derived and recommendations, as well as a suggestion for possible future research work. Chapter six explained the suggested model of the maintenance management system.

1.8 Scope and Limitations of the study

The study covers the maintenance management system of the case company, MCE. The performance measurement is aimed to determine the missed practices in order to achieve further productivity improvement in cement industry. Furthermore, the researches push the management to adopt best practices to remove the waste of the overall process

There are a number of limitations that bounded the results of this study. The primary limitation was time. Since variations in maintenance practices can take months or years to generate noticeable effects, the relatively short timeframe of this study did not allow direct comparison between different maintenance practices. Another limitation was the poor quality of existing data.

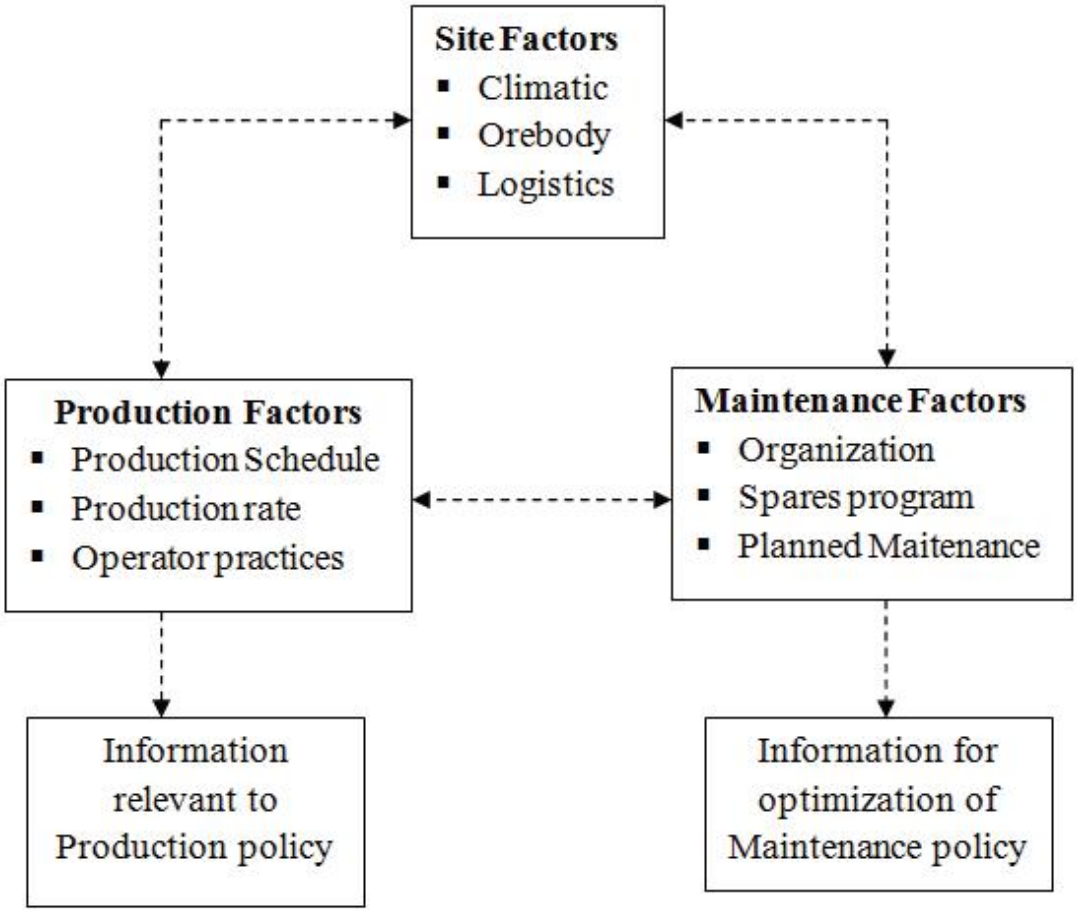
CHAPTER TWO

Literature Review

2.1 Definition of Maintenance

Maintenance is a combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function (EN 13 306, 2001). Proper maintenance and repair are very crucial for any kind of equipment which is subjected to operations. Safety assurance also is an important parameter to be taken care of when dealing with operational business entity, it is even more critical when operations are associated with cement production systems due to its environment and space limitations. To improve safety and production capacity in cement industries, knowledge of maintenance strategies is needed, and this knowledge should have its base in the areas of interacting factors to maintenance. Watson (1968) presents some of the critical interacting factors which influence a cement production system's reliability.

Figure 2:1 Factors affecting Maintenance Strategies (Watson, 1968)



If these interacting factors can be managed properly it is obvious that equipments reliability will be improved readily, reduction of operational cost and profit maximization will be the end results (Watson, 1968).

2.2 Maintenance Management System Objective

Maintenance management is concerned with the good control of the maintenance function and its related areas in order to best assist the objectives and goals of the entire organization. It is a combination of all

technical and administrative actions to retain an item in, or restore it to the state which it can perform its requirements under normal stated operating conditions. In short, maintenance management can simply be defined as managing the maintenance activities to ensure the availability of equipment and facilities and keeping the downtime to a minimum. As such, maintenance management supports the effective operation process by eliminating and reducing the frequency and severity of equipment failures. With the changes in the maintenance and the management techniques, there is a need to provide an integrated approach that pulls together all of the design tools and maintenance tools that exist into an integrated whole. This requirement is in the form of Maintenance Management System, which when properly organized and established, is able to provide personnel at all levels access to real-time information.

2.3 Work Order Records/systems

A Work Order System is the essential tool for keeping track of documents used to record equipment maintenance tasks and provides the most important source of information for the maintenance analysis and the writing of PM procedures. In other words, a good work order system, with management commitment to its use, should produce quantifiable feedback on overall maintenance performance, job and plant cost, and equipment history. These above mentioned documents are called work order forms and there are several types and uses for them, according to the particular needs of each company. The basic purposes of the Work Order System according to Herbaty,1983 are as indicated below:

- To provide a means for screening and authorizing work.
- To provide cost data segregated in a logical manner.
- To provide feedback information on repetitive failures for analysis purposes.
- To provide a tool to facilitate planning and scheduling of maintenance work.

- To facilitate control of productivity and performance of predictive and preventive maintenance.

2.4 Maintenance Planning and Sceduling

In the implementing of a maintenance plan, the terms preventive maintenance and Predictive maintenance are often used by those working in the maintenance engineering department. With the implementation of preventive maintenance and predictive maintenance, planning and scheduling of maintenance work will ensure lower cost and better quality of the maintenance work than when maintenance work is performed on an emergency or unscheduled basis.

2.4.1 Planning

Planning is the determination of all necessary elements required to perform a task in advance of performing the job. It is the heart of good inspection and preventive maintenance. Good planning ensures proactive maintenance strategies to provide effective maintenance to the equipment. All maintenance work should be planned so that the quality and cost effectiveness of the work is assured. To put it simply, planning is to provide an accurate description of what is needed, e.g. manpower, tools, materials, and equipment, at the proper time before the job is started. Good planning of maintenance function should include:

• A general plan on the distribution of labor throughout the various departments under “normal” operating conditions.

• Detailed planning and scheduling of major events taking place during the year such as major overhauls or rebuilds, large construction jobs, major preventive maintenance tasks and vacations of maintenance

workforce. Preventive maintenance tasks should include routine maintenance, preventive maintenance, general repairs and emergency maintenance.

• Required spare parts, tools and other supply from the standpoint of the business organization.

2.4.2 Scheduling

Scheduling is an important tool for ensuring high labor productivity and the orderly accomplishment of maintenance tasks and actions. Scheduling is the action to arrange for the availability of all the planned elements prior to the job execution. Two-way communication between the operation and the maintenance department is critical so as to ensure that any maintenance plans are made known to the operation department in advance. It is equally important to ensure that the planned elements or resources are properly scheduled so as to perform the job adequately. The typical elements required to perform a job are listed below [Herbaty,1983 **]**:

- Labor
- Equipment
- Material
- Safety Lockouts
- Tools
- Instructions

To ensure that all the planning effort is efficiently implemented, all the various maintenance actions and tasks such as general repairs and overhauls, preventive maintenance, lubrications, and routine maintenance must be all scheduled.

2.4.3 Maintenance Cost Control

Preventive maintenance is an operating cost necessary in ensuring that operational targets are met. The benefits of an improved maintenance helps to increase revenues by increasing equipment performance due to high efficiency, improve return of assets by reducing the need for expensive capital upgrades and increasing output due to high availability. In terms of operation, maintenance will to increase enable the

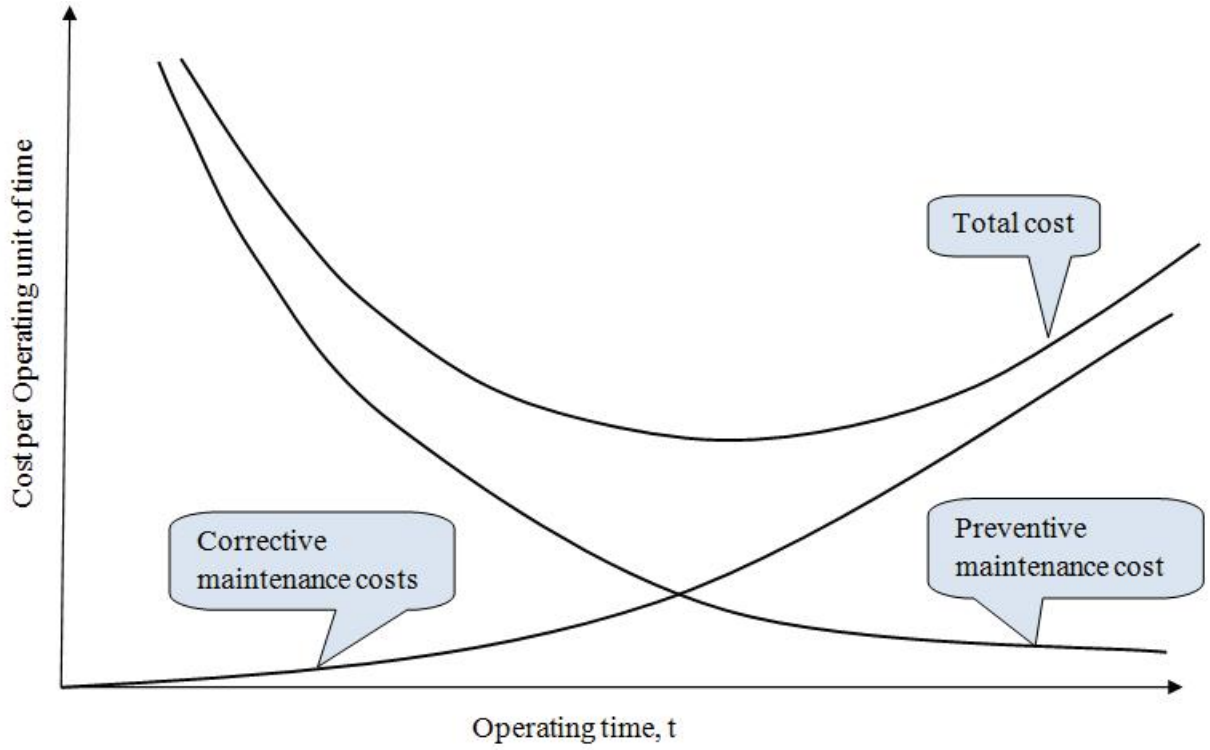
uptime or availability of equipment, to ensure attaining of high productivity and quality level. Budgeting is paramount importance to control the various necessary costs in maintenance. Often is done by comparing man-hours used, labor cost accrued, material cost accumulated, and total cost committed. The output of these costs is equipment, buildings or facilities maintained, activities performed, or jobs completed. In order to control cost, effective use of labor, tools and materials must be adhered to ensure a smooth operation of production equipment. There are some common facts that people should know about maintenance cost control as indicated below according to Tomlingson,1994:

- Most maintenance departments have a relatively stable work force, and total labor cost variations are primarily due to overtime.
- Material costs are determined by volume of equipment that must be maintained and the speed at which the equipment consumes spare parts and materials. Therefore, an increase of emergency repairs will require more spare parts and materials than normal routine and preventive maintenance programs.
- Labor costs in maintenance are incurred by the need to install spare parts and performing the various maintenance tasks. However, a maintenance department doing mostly emergency work usually works less productively as more labor is consumed and the quality of work will tend to be poor as the works are performed in reactive mode.
- Maintenance supervision tends to help in control of costs due to the efficiency with which spare parts and materials are installed. Thus, the control of labor on their quality and performance will become a vital maintenance activity.

- Better control of individual jobs is achieved through planning and scheduling. The result will be completed jobs in less elapsed time, often with a reduction in cost and with less consumption of manpower. Another significant improvement is that downtime will be reduced and uptime is increased.
- With quality supervision, maintenance supervisors are able to control the quality of the job and also maintain the potential benefit of planning. Supervision also tends to result in better productivity and quicker completion of work.
- Successful cost control requires a work order information system that provides information to judge performance and guide corrective actions.

It can be seen that the corrective replacement costs increase as the operating time interval increases (Figure 2:2). In other words, the less often you perform a PM action, the higher your corrective costs will be. Obviously, the longer we let a component operate, its failure rate increases to a point that it is more likely to fail, thus requiring more corrective actions. The opposite is true for the preventive replacement costs. The longer you wait to perform a PM, the less the costs; while if you do PM too often, the higher the costs. If we combine both costs, we can see that there is an optimum point that minimizes the costs. In other words, one must strike a balance between the risk (costs) associated with a failure while maximizing the time between PM actions (Reliasoft Cooperation, 2007).

Figure 2:2 Cost per operating unit time vs. operating time (Reliability Edge,2000)



Overall, it is vital for businesses to administer a system of good maintenance cost control to assist in controlling of the labor and materials resources.

2.4.4 Reducing Maintenance Cost

With good planning and scheduling of the maintenance efforts, the maintenance department should look at ways of reducing the overall maintenance cost without affecting the efficiency of the maintenance function.

With good implementation of procedural maintenance actions, the discovery of problems before failure occurs is possible. The final result will be less costly repair and less downtime. This will indirectly reduce the rate of repairs and lower the use of spare parts.

Furthermore, a good repair history record that highlights the chronic, repetitive problems and leads to their permanent correction can be helpful. It is important for a business to impose a strict adherence to a regular PM Service schedule to help to extend equipment life. Operation can also contribute to reducing the rate of parts consumption by making equipment available for scheduled major repairs, as this is also a sign of confidence in the maintenance program. One direct cost that will affect the maintenance function is labor. In situation of immerse absenteeism, overtime is required for planned jobs. This explains why successful businesses often have good human resource system that curbs absenteeism which will affect the overall productivity and morale of the firm. To summaries, a successful cost reduction program requires the following to be established according to Tomlingson,1994:

- Maintenance work must be approved before it is performed.
- All the maintenance work must be planned according to its scope, criticality, cost,etc.
- Planned work must be prioritized
- Planned and prioritized work must be scheduled
- Schedule of major work should be subjected to labor allocation and deferred if not certain.

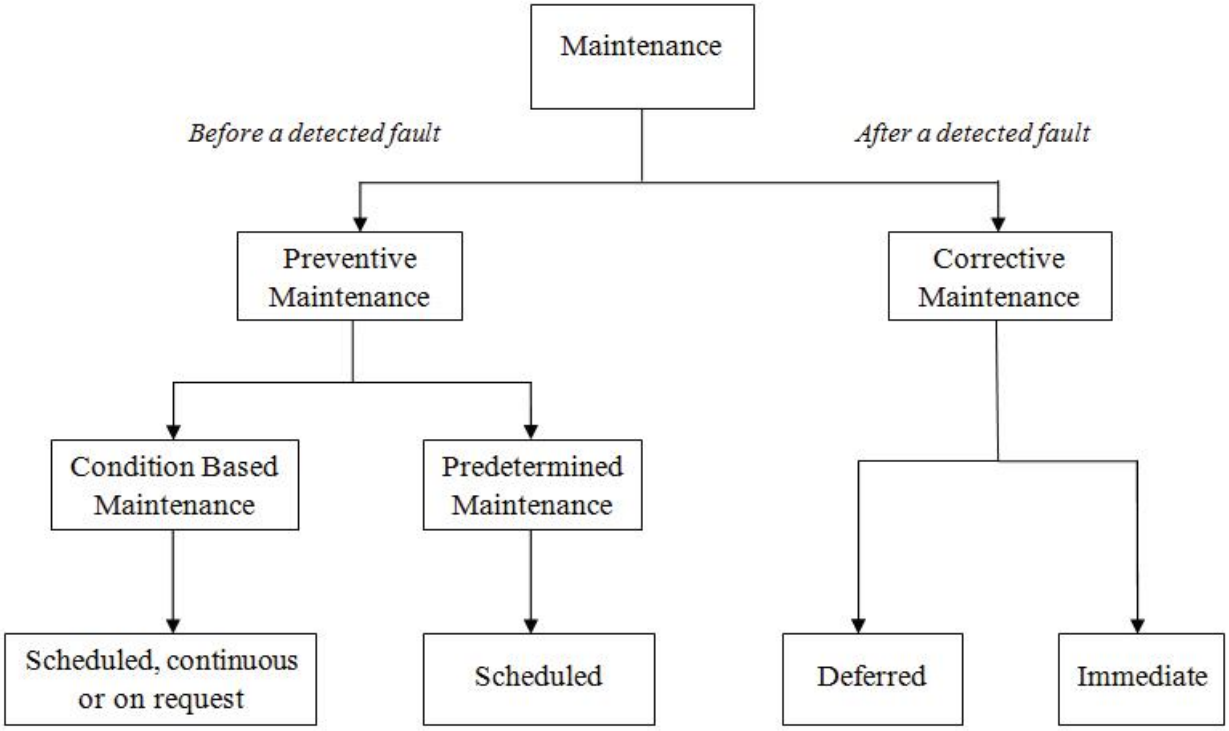
- Use of manpower should be scrutinized; performance to be measured and any questionable use of labor should be justified by maintenance supervision.

From the above, we can see that immense planning efforts are required to contribute to a successful cost reduction.

2.5 Maintenance types and strategies

According to EN 13 306 (2001) standards, maintenance practices approaches can be grouped into two major groups, namely Preventive Maintenance (PM) and Corrective Maintenance (CM) (Figure 3:2). Preventive approach can further be subdivided into condition based maintenance and predetermined maintenance; this implies that PM can be time based or condition based. Corrective maintenance has been subdivided into two subgroups which are deferred and immediate; CM is an approach which is reactive in nature as compared to PM which is a proactive form of maintenance. Timing plays a major role in all these approaches (Smith, 2002). Researcher's view is that if a business entity such as a Cement production equipment maintenance department best fit in maintenance strategy will experience cost saving.

Figure 2:3 Maintenance overview chart according to EN 13 306 (2001)



2.5.1 Corrective Maintenance (CM)

CM is the maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function (EN 13 306, 2001). This is the most expensive form of maintenance especially if the maintenance is going to be done urgently because no planning or coordination can be made. Therefore the start-up cost and the cost of lost production can be large (Kumar et al., 2010). CM does not involve forecasting of failure when an item tends to fail. Depending on the necessity of the failed item(s) on the functioning of the system, maintenance can be done immediately or deferred. CM is the maintenance strategy applied most often when it is difficult to predict when an item will fail.

2.5.2 Preventive Maintenance (PM)

PM is carried out at predetermined intervals or according to prescribed criteria and intend to reduce the probability of failure or the degradation of the functioning of an item (EN 13 306, 2001), all preventive management programs are time driven. The item to be maintained can either be replaced or reconditioned depending on the condition of an item. The failure rate of the item is its probability to fail over a given period of time. PM can be divided into condition based maintenance or predetermined maintenance (Coetzee, 2004).

2.5.2.1 Condition Based Maintenance (CBM)

According to EN 13306, (2001) CBM of an item is PM based on performance and/or parameter monitoring and the subsequent actions. The standard needs to take note that performance and parameter monitoring may be scheduled, on request or continuous. Condition monitoring and inspection are the two main strategically approaches to CBM of an item. In condition monitoring, parameters are measured to ensure that maintenance is done before failure and is performed based on predetermined criteria. Inspection is done at regular intervals by a person involved in maintenance to ensure that maintenance is performed as soon as it is required. Through regular inspections, measurements or tests, or continuous monitoring, one can determine when it is time for replacement, servicing or adjustments. These checks can be performed in three ways:

- Using the subjective senses (sight, hearing, touch, smell and taste)
- Intermittent or continuous use testing methods for detecting wear
- Running the equipment and notice that all functions work (Kumar et al., 2010).

Coetzee, (2004) identified that CBM is normally suitable when failure rate is dependent on operating condition rather than time.

A complete CBM program must include monitoring and diagnostic techniques. These techniques include vibration monitoring, acoustic analysis, motor analysis technique, motor operated valve testing, thermography, tribology, process parameter monitoring, visual inspections and other non-destructive testing techniques. Explanations for some of the commonly used CBM techniques according to Mobley, 2002 is here under.

i. Vibration Monitoring

All mechanical equipments in motion generate a vibration profile, or signature that reflects its operating condition. This is true regardless of speed whether the mode of operation is rotation, reciprocation, or liner motion. Vibration analysis is applicable to all mechanical equipments; its profile analysis is a useful tool for predictive maintenance, diagnostics and many other uses.

ii. Tribology

This is the general term that refers to design and operating dynamics of the bearing lubrication- rotor support structure of machinery. Two primary techniques are being used for predictive maintenance; these techniques are lubricating oil analysis and wear particle analysis

a. Lubricating oil analysis

Lubricating oil analysis is an analysis technique that determines the condition of lubricating oils used in mechanical and electrical equipment.

b. Wear particle analysis

Wear particle analysis is related to oil analysis and the particles to be studied are collected by drawing a sample of lubricating oil. Whereas lubricating analysis determines the actual condition of the oil sample, wear particle analysis provide direct information about the wearing condition of the machine-train.

iii. Thermograph

Thermograph can be used to monitor the condition of the plant machinery, structures and systems. It uses instrumentation design to monitor the emission of infrared energy (i.e., surface temperatures) to determine operating conditions.

iv. Ultrasonic

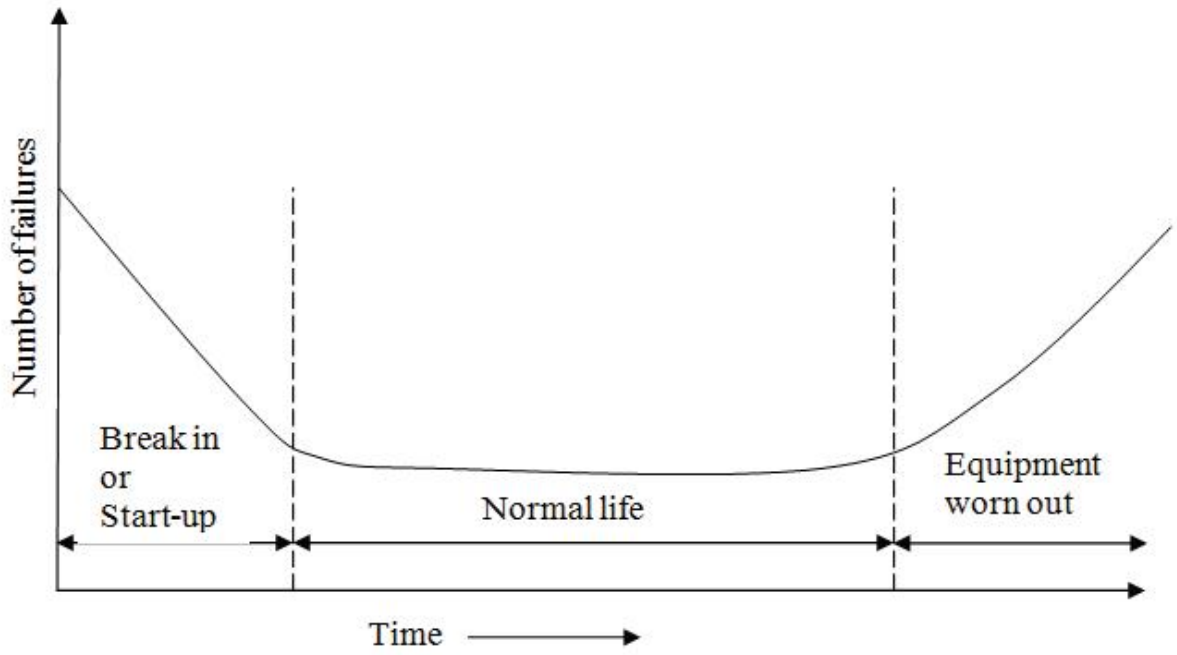
Ultrasonic like vibration analysis is a sub set of noise analysis. The only difference in the two techniques is the frequency band they monitor. In the case of vibration analysis, the monitored range is between 1Hz and 30,000Hz, ultrasonic monitor noise frequencies which are above 30,000Hz.

2.5.2.2 Predetermined maintenance (PDM)

Predetermined maintenance is carried out in accordance with established intervals of time or number of units of use but without previous condition investigation (EN 13 306, 2001). In order for PDM implementation to be successful, failure rate of an item needs to be increasing as the usage time of an item increases. Therefore the decision for the item maintenance interval should be based on machine

hours, age, the frequency of use and the distance travelled (Coetzee, 2004). According to Mobley (2002) most groups of similar machines will display failure rates that can be predicted in some ways if averaged over a long period of time. The Bathtub curve (Figure 2:4) relates failure rate to operating time.

Figure 2:4 Typical bathtub curve (Mobley, 2002).



The mean-time to failure curve/Bathtub curve indicates that a new machine has a high probability of failure because of installation problems during the first few weeks of operation. After this initial period the probability of failure increases sharply with the elapsed time (Mobley, 2002).

2.5.3 Total Productive Maintenance (TPM)

TPM aims to maximize equipment effectiveness. It consists of a range of methods that are known from maintenance management experience to be effective in improving reliability, quality and production.

TPM tries to improve a company through improving personnel and plant, and changing the corporate culture. Cultural change at a plant is a difficult task to perform and it involves working in small groups, a strong role for machine operators in the maintenance program, and support from the maintenance department (Willmott and McCarthy, 2000). In the TPM framework, the goals are to develop a "maintenance-free" design and to involve the participation of all employees to improve maintenance productivity. Original goal of total productive management is to “Continuously improve all operational conditions, within a production system; by stimulating the daily awareness of all employees” (Nakajima, 1988). Normally the company put forwards its main priorities based on its plans, and these priorities performance actions need to be measured, so the issue of the need of key performance indicators arises. The main parameters which usually are important to measure are total system/plant effectiveness as well as system/plant productivity, availability, cost efficiency and quality (Moubray, 1997).

A metric, termed the “Overall equipment effectiveness (OEE)” is the benchmark used for world-class maintenance programs. The OEE is established by measuring equipment performance. Measuring equipment effectiveness must go beyond just availability or machine uptime. It must factor in all issues related to equipment performance. The formula for equipment effectiveness must look at the availability, the rate of performance and quality rate. This allows all departments to be involved in determining equipment effectiveness. The formula could be expressed as:

Availability x Performance Rate x Quality Rate = OEE. (Moubray, 1997)

The OEE calculation is based on the three OEE factors; Availability, Performance and Quality. They are also called Effectiveness Factors.

i. Availability

The availability portion of the OEE Metric represents the percentage of scheduled time that the equipment is available to operate. The Availability Metric is a pure measurement of Uptime that is designed to exclude the effects of quality, Performance, and scheduled Downtime Events.

It is calculated by

$$\text{Availability} = \frac{\text{Operating Time}}{\text{Planned Production Time}}$$

When downtime losses are zero, the availability is 1or 100%, the gross operating time equals the available time for production. i.e. Operating time equals Planned Production time. 100% availability means the process has been running without any recorded stops.

ii. Performance

Performance takes into account Speed loss. Performance is the ratio between Net Operating Time and Operating Time.

$$\text{Performance} = \frac{\text{Net Operating Time}}{\text{Operating Time}}$$

The performance portion of the OEE Metric represents the speed at which the equipment runs as a percentage of its designed speed. The Performance metric is a pure measurement of speed that is designed to exclude the effects of Quality and Availability

iii. Quality

The Quality portion of the OEE metric represents the Good Units produced as a percentage of the total units produced. The Quality metric is a pure measurement of process yield that is designed to exclude the effects of Availability and Performance.

It is calculated as

$$\text{Quality} = \frac{\text{Good Pieces}}{\text{Total Pieces}}$$

100% Quality means there have no reject or rework pieces.

2.5.4 Reliability Centered Maintenance (RCM)

The need for effective and efficient maintenance management methods have resulted into the development of RCM (Nowlan and Heap, 1978). RCM is a process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context (Moubray, 1997), the process was developed within the aircraft industry and later adopted to several other industries and military branches. A high number of standards and guidelines have been issued where the RCM methodology is tailored to different application areas. The major advantage of the RCM analysis process is that, it is a structured and traceable approach to determine the optimal type of PM (Rausand and Vatn, 2006). This is achieved through detailed analysis of failure modes and failure causes. Although the main objective of RCM is to determine the preventive maintenance, the results from the analysis may also be used in relation to corrective maintenance strategies, spare parts optimization and logistic consideration; in addition, RCM has an important role in overall system safety management (Rausand and Vatn, 2006).

2.5.5 Computerised Maintenance Management Systems (CMMS) and its benefits

CMMS is also known as Enterprise Asset Management and Computerized Maintenance Management Information System (CMMIS). A CMMS software package maintains a computer database of information about an organization's maintenance operations, i.e. CMMIS - computerized maintenance management information system. The software has evolved from relatively simple mainframe planning of maintenance activity to window based, multi-user systems that cover a multitude of maintenance functions. The capacity of CMMS to handle vast quantities of data purposefully has rapidly opened new opportunities for maintenance, facilitating a more deliberate and considered approach to managing assets. Among others, the greatest benefit of the CMMS is the elimination of paperwork and manual tracking of activities, thus enabling the staff to become more productive. It should be noted that the functionality of a CMMS lies in its ability to collect and store information in an easily retrievable format (Sullivan et al., 2004). A CMMS does not make decisions; rather it provides the Operational & Management manager with the best information to affect the operational efficiency of a facility.

Benefits with having a CMMS include the following:

- Detection of impending problems before a failure occurs resulting in fewer failures and customer complaints.
- Achieving a higher level of planned maintenance activities that enables a more efficient use of staff resources
- Affecting inventory control enabling better spare parts forecasting to eliminate shortages and minimize existing inventory.

- Maintaining optimal equipment performance that reduces downtime and results in longer equipment life (Sullivan et al., 2004).

CMMS is widely used as a method of controlling group industrial maintenance operations.

2.6 Maintenance Management

Like in any other area of technology, management plays an important role in maintenance activity. Procedures and strategy are normally derived from maintenance management for all maintenance-related activities in addition to exercising required management and technical control of maintenance programs. Management surveys show that the average productivity of maintenance employee is between 25 to 35% (Wireman, 1994). This means that a craftsman has less than 3 hours of productive time per 8hour shift, due to poor maintenance management (Wireman, 1994). It is normally important that the manufacturing or production companies identify, define and communicate the maintenance strategies as business strategies are communicated to other business companies. With connection to the maintenance practices and procedures, Vanneste and Vassenhove, (1995) proposed that, maintenance management process has two parts; the first one is Effectiveness analysis which mainly deals with detecting the most important problems and potential solutions and the second is efficiency analysis which deals with identification of the suitable procedures. Eight phases are defined, namely; determination of existing performance of the plant/machine, downtime and quality problem analysis, effectiveness analysis of the alternative solutions, efficiency analysis of maintenance procedures, plan actions, data collection and implementation actions, data processing and actions monitoring, and the last one is to adapt plans or information procedures in case of undesired deviations.

2.7 World class maintenance practices and benchmarking

Best maintenance practices are defined in two categories: standards and methods. Standards are the measurable performance levels of maintenance execution; methods and strategies must be practiced in order to meet the standards (Smith, 2002).The combination of standards with methods and strategies provides the elements of an integrated planned maintenance system. Achievement of the best maintenance practice standards (maintenance excellence) is accomplished through an interactive and integrated series of links with an array of methods and strategies (Smith, 2002). According to Wireman, (2003), best practices in maintenance are "the maintenance practices that enable a company to achieve a competitive advantage over its competitors in the maintenance process." In other words the maintenance best practices are the world class maintenance practices. Hiatt, (2009) suggested that in order to achieve the world class maintenance, the following steps have to be followed;

- Philosophical and theoretical shifts,
- Understanding change, teamwork and training,
- Asset management and warehouse/inventory control,
- Corrective maintenance (CM),
- Preventive maintenance (PM),
- Predictive maintenance (PdM),
- Purchasing, accountability and reliability centered maintenance (RCM).

The world class maintenance practices also needs continuous improvement in asset care of the ongoing process to make it sustainable. Benchmarking is one of the key tools for continuous improvement. To be able to benchmark successfully it is important to know the current status of the maintenance

program and vision. Of the several types of benchmarking practices, one of the most successful is process benchmarking, which examines specific processes in maintenance, compares the processes to companies that have mastered those processes, and maps changes to improve the specific process (Campbell, 1995). The key to benchmarking is self-evaluation. Benchmarking is a very useful tool when it comes to regulatory compliance. Understanding how other companies achieve compliance can help companies modify their approach to achieve a higher level of compliance or reduce the current cost of compliance. By studying other companies' approaches, implementing improvements, and monitoring the improvements, increased compliance levels can be achieved (Wireman, 2003).

2.8 World Class OEE

World class OEE is a standard which is used to compare the OEE of the firm.

Table 2.1 World Class OEE levels

OEE Factors	**WORLD CLASS**
Availability	90%
Performance	95%
Quality	99%
OEE	85%

These values of OEE factors are generally accepted but the values are different for different industries. For Manufacturing, the value of World Class OEE is 85% but for Paper Industry and Cement Industry, the value is 95% and 80% respectively. The aim of the firm is to achieve this value of OEE by continuous improvement.

CHAPTER THREE

Methodology of the Study

3.1 Study Design

This study is based on case study research method. A case study for this particular research will enable the researcher to collect data on the operations within cement plant and being an employee at the company; the researcher can spend an extended period of time on site and interact regularly with the people and departments that are being studied. The empirical study consists of:

- Surveys (questionnaires) at cement plant.

The survey will enable the researcher to:

Make direct contact with the management team, team leaders, team members and maintenance artisans within the various departments to establish their expectations of maintenance management systems;

- Observe the activities that support the assessment of the maintenance management system.

In this study both primary and secondary data sources are used. Primary data source contain raw, original, non-interpreted and unevaluated data. The secondary data sources are technical documents and annual reports that help to cross check the official information and to get details concerning the study. Discussion, interview and questionnaires are techniques that are used for gathering primary information and relevant data for the study.

3.2 Data collection

Data collection is in both qualitative and quantitative nature. Quantitative means anything that exists in a certain quantity and can be measured. The methodology has a quantitative nature because there are quantifiable measures of variables and hypotheses can be formulated, and conclusions drawn from samples to populations. However some of the data are not inherently quantitative that is they do not necessarily have to be expressed in numbers, and so it has also a qualitative nature.

The data required for the study is identified and collected by communicating maintenance and production staff of MCE. Thus, samples are taken to generalized where the MCE production and maintenance staff as a whole stands, concerning the maintenance activity.

Questionnaire is also prepared and given for all selected to have information, which can express the total maintenance activities within the company. Having the result collected, the culture and the system of maintenance in MCE can be pointed out.

Interviews are held with the respective maintenance and production personnel's.

Yin (1994) presents six data sources for case studies: documents, archival records, interviews, direct observation, participant-observation, and physical artifacts. The empirical data collected in the case studies and presented in this thesis has been collected through documents, interviews, direct observations.

3.2.1 Primary data

Primary data is a data that is collected for usage in a specific study. Gathering primary data is important to in order to create an understanding of a specific research object (Björklund and Paulsen

2003). The primary data for this study has been collected through observations, interviews and questionnaires.

3.2.1.1 Observations

The researcher has worked in MCE for seven years in production department as production division head of clinker production and manager for cement milling process up to now. This enables him to understand the nature, characteristics and problems in maintenance department.

Observations were conducted as a way to establish how the maintenance work was conducted at MCE. The observations were used to get an understanding how maintenance were performed at the company and the behavior of the people involved.

According to the literature, observations can be a very time consuming, but can also give more objective data (Björklund and Paulsen 2003). When conducting an observation, what is observed is what actually is done and not what is said to be done, although time is usually a concern. Through planning the observations became time efficient enough to be considered and observations were therefore used in the study.

3.2.1.2 Interviews

An interview is a good way to gather information that otherwise could be hard to get through other methods, such as questionnaires or observations (Esaiasson, et al. 2009). In the study, six interviews were carried out with executives and managers of maintenance, production, supplies and marketing representatives, The main goal was to gather opinions and ideas from the people working with or close to maintenance or to get an understanding of different processes.

3.2.1.3 Questionnaires

The questionnaires are prepared for data collection from production and maintenance staffs about maintenance organization, planning, Scheduling. About 70 questionnaires were distributed and 61 (87%)were collected and analyzed based on six major groups. The questionnaires are being answered accordingly to the priority of concern by using predetermined sets of questions with predefined ranges of answers so as to avoid any conflicting series of response. The questionnaire is adopted from book of Benchmarking Best Practices in Maintenance Management, Terry Wireman, 2004

3.2.2 Secondary Data

Secondary information is information that has been produced for another purpose than the forthcoming study (Björklund and Paulsen 2003). In this thesis the secondary data consists of information from literature studies and document review.

3.2.2.1 Literature study

An academic literature review regarding maintenance was conducted and worked as a basis for the thesis. The literature was used to find a model for analyzing the maintenance management. The literature study was mainly performed in the beginning of the study work but was followed up and expanded throughout the process.

The literature used was in form of academic articles, handbooks and books. To find the appropriate literature multiple search engines was used such as library, Google scholars. The searches were based on the following key words: Maintenance, OEE, Planning, Preventive, Maintenance management, framework, Criteria, lean and different combinations of these.

3.2.2.2 Documents Review

Yin (1994) finds that documents play an explicit role in any case study. When using documents in research, it is of importance to verify that the documents used are relevant to aspects of revisions, dates, and the like, and that they describe the reality of the intended phenomena. In the research performed, different documents such as maintenance strategies, maintenance organization charts, and others have been studied. Relevant documents provide reliable data on the formal structures and real outcomes of the system Based on the maintenance activities like equipment historical recording system for quantitative data requirement. And then further analysis of maintenance activities including maintenance and equipment unavailability cost is made based on the existing maintenance systems of the company. After analyzing this incorporated cost of maintenance department, the best methods or approach of maintenance will be selected based on background written in literature survey section of the study.

3.3 Sample size and Sampling technique

Sampling may be defined as measuring a small portion of something and then making a general statement about the whole thing. It enables the study of large, heterogeneous population more economic wise, meaning not too costly, and more realistic. The population to be researched upon is quite small; hence scientific sampling is implied to each member of the population since the number of population is attainable for sampling. I decide to use the unstructured random sampling technique since the population is well in the reach of statistical evaluation.

The respondents of the study include the Executives, Process leaders, Team leaders, Supervisors, Maintenance and production employees with a set of carefully prepared and logically ordered questions.

There are 400 production and maintenance personnel directly related with maintenance activities. Among them 70 respondents are randomly selected for this study data collection from different production and maintenance function of MCE.

3.4 Data analysis

The next step after necessary data is collected from different data sources in a research study is to process the data to useful information, i.e. examine, categorize, arrange, and rearrange and recombine the data (Patel and Davidson, 1994). For this study a quantitative approach using statistical methods and a qualitative approach using verbal analysis method will be used.

For the quantitative analysis computer software called Microcal Orgin6, SPSS will be applied. Pie chart, Bar chart and line graphs will be used to describe data collected. For the qualitative data SWOT analysis can be carried out.

3.5 Reliability and validity

When doing research there are some terms used to value the outcome, making sure that it is trustworthy (Eliasson 2010). Reliability and validity are two terms used meaning in what extent the results of the study are reliable and valid (Bryman and Bell 2005).

3.5.1 Reliability

Reliability means to what extent the result of the research is repeatable. In other words, if it were done again would the result be the same (Bryman and Bell 2005). According to Olsson and Sörensen (2007) the reliability of a study is ensured for example through having a high data quality.

The data used in the study came from the maintenance information and MCE annual performance report. The way that the information in the orders was entered had just been standardized at the time of the study and verified by auditors year to year . This was handled in the way that the old data was seen as an indicator of the development and the later data was used when looking at the potential future changes.

Apart from using the most recent data as a base for the analysis also the interviews and observations had been a basis for the analysis and were used to back up the secondary data.

The interviews were conducted in a semi-structured way, which opened up for follow up questions. After each interview the notes were gone through and discussed together and transcribed to make sure that nothing was missed.

The researcher also performed several interviews and together with observations that supported the opinions the results are thought to be reliable.

3.5.2 Validity

Bryman and Bell (2005) divides validity into internal and external validity. External validity is whether the results of the research is generalizable or not and the internal validity is defined as if the measures used really measured what was intended (Bryman and Bell 2005). Since this study was performed as a case study is not to large extent externally valid. Some parts are, however, believed to be generalizable such as the maintenance model discussed in chapter six and the general literature review. According to the discussion with officials the model developed was not only a product of academic papers but also had significance in reality to improve the maintenance system in MCE.

CHAPTER FOUR

Data Collection and Analysis

4.1 MCE Maintenance Department Units and Existing Work Flow

In MCE, the Maintenance department which has the following units:

- Workshop
- Mechanical Maintenance
- Electrical Maintenance
- Instrumentation Maintenance
- Automotive Maintenance
- Civil Works

The responsibilities of these units are in general

- To carry out preventive maintenance and emergency repair of all equipments in the plant including vehicles.
- To prepare schedules and assign manpower and request delivery of supplies for preventive maintenance programs
- To present proposals on the revision of PM program and instruction of the plant.
- Carry-out reconditioning of components and produce parts in a workshop
- To plan and control maintenance

-cost and suggest cost reduction schemes

1.Workshop

The duties of the workshop are:

- To produce spare parts and other items necessary for the plant
- To recondition and repair machine components
- To prepare order of materials necessary for parts fabrication
- To maintain workshop machinery
- To rewind electrical machines (electrical)

2.Mechanical Maintenance

- Conduct, lubrication, inspection, repair and overhaul of mechanical parts of machinery of PM and sudden breakdowns
- Assist installation of machinery incase of replacement

3.Electrical Maintenance

- Conduct inspection, repair and overhaul of electrical machines, and electrical wiring and apparatus of machinery incase of PM and sudden breakdowns.
- Installation and maintenance of power supply unit and line

4.Instrumentation Maintenance

- Maintenance of all instruments and control system

5.Automotive Workshop

- Conduct PM and corrective maintenance of all vehicles

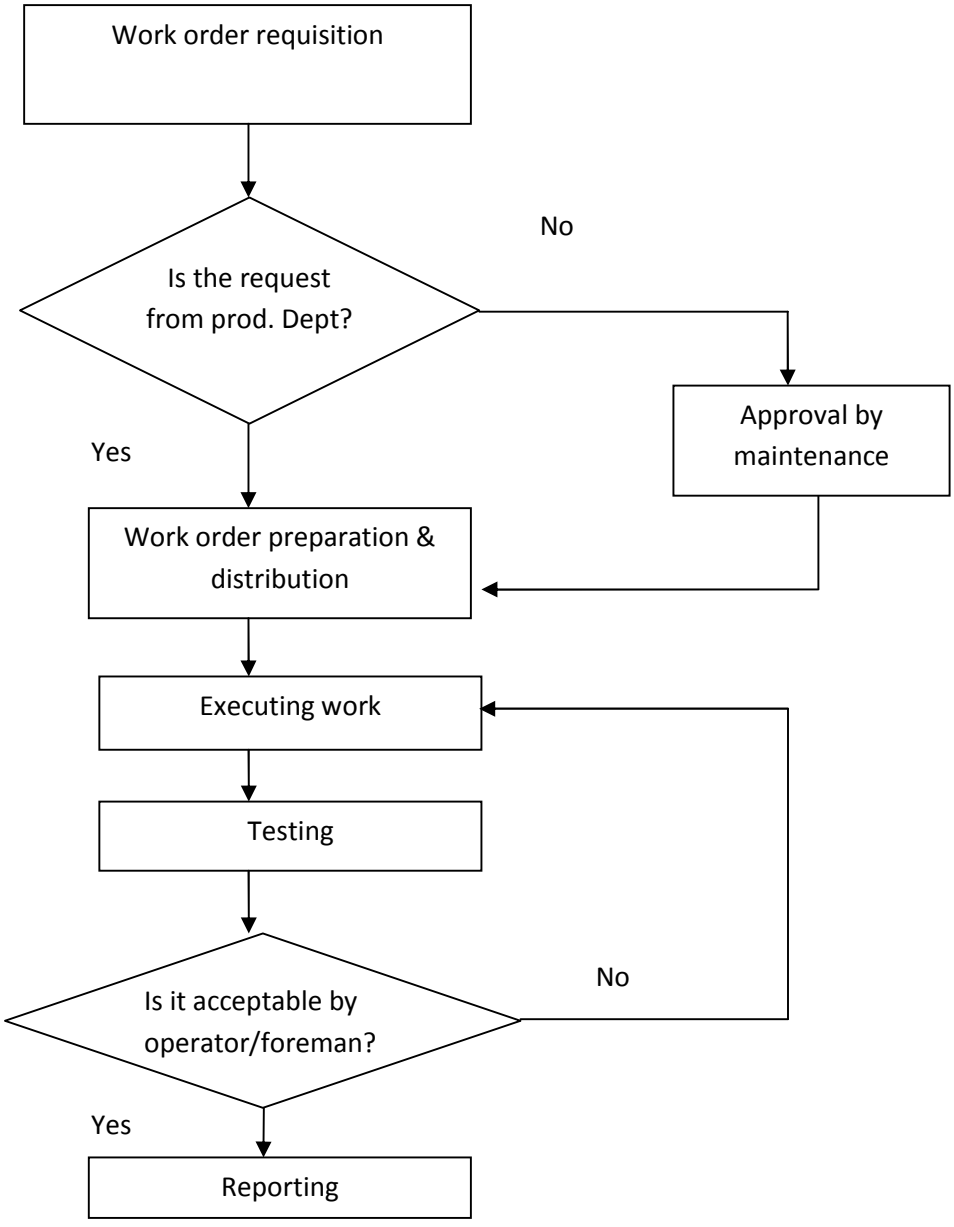
6.Civil Works

- Management of construction and maintenance of buildings and other civil works
- Maintenance of rotary kiln bricks

4.2 Work Flow of existing maintenance

In Mugher Cement Enterprise the maintenance activities are performed in two ways; when machine is breakdown that is corrective maintenance and when the work is generates from the maintenance plan. When breakdown occurs the production department informs the maintenance department by requisition paper. After receiving the request, the maintenance manager passes the work to the concerned division regarded to the compliant, if necessary technicians are assigned to justify the problem. Finally, it reaches to the technicians through supervisor. The accomplished work is approved by supervisors and then reported to managers. There are also maintenance works scheduled as planned maintenance to replace parts and overhaul of equipments.

Fig. 4.1 Existing maintenance workflow for breakdown order



4.2 Presentation and Analysis of Secondary Data

4.2.1. Presentation of Secondary Data

The data, presented below, helps to calculate the amount of the maintenance cost and the loss of production due to unplanned maintenance activities. Thus the selected necessary data are:

i. Total Cost of Production in MCE

To produce one ton of cement from raw materials there are costs associated with it. The common production costs for cement industry are raw material cost, energy, fuel cost, labor cost, overhead cost. And the operating expenses are general & administration cost and selling & distributing costs. The amount of total cost of each type for 2004 E. C. (2011/12G.C) is taken from the annual report of the company and tabulated as follow.

Table 4.1 Total costs of the company for 2004 E.C. (2011/12G.C)

Type of Cost	Cost in Birr
Production cost	1,175,289,832
Administrative expense	89,397,556
Sales and distribution	31,900,738
Maintenance cost	63,460,571
Total cost	1,360,048,697

Source: MCE 2011/12 G.C Annual Report

With this total production cost, the company makes the net profit of 227,569,030 birr in the year. The profit is not only from the net sells of the cement but also from the raw materials and scrap sales.

ii. Maintenance Cost of MCE

Since this study is focused in maintenance, the maintenance cost of the company is selected for the analysis. The maintenance cost of the company is recorded in the annual report as shown below.

Table 4.2 Maintenance cost of the company in 2004E.C. (2011/12G.C)

Maintenance	Cost in Birr
Spare parts cost	44,724,675
Employees wage	16,848,448
Over time cost	6,850,731
Tools	5,643,212
Total	74,067,066

Source: MCE 2011/12 Annual Report

iii. Bottleneck Machines and their Availability in MCE

Table 4.3 : Kilns down time from 2008/09 -2011/12 G.C for two kilns

Kiln Down Time (DAYS)										
Kiln Line	Causes for Down time	Mechanical	Electrical	M.C.T	Power	Bricks Relining	Heating Up	Technological	Fuel Shortage	Total
ONE	2001(2008/09)	35.96	5.38	0.13	58.43	42.91		1.86		144.67
	2002(2009/10)	2.15	0.83	0.04	54.23	21.53	4.98	4.40		88.15
	2003(2010/11)	15.58	2.05	0.27	12.56	72.58	13.55	9.19		125.78
	2004(2011/12)	97.13	0.73	0.02	1.16	58.97	10.54	1.88	5.60	170.43
TWO	2001(2008/09)	13.64	1.64	0.14	60.75	24.17		8.9		109.24
	2002(2009/10)	14.52	1.52	0.46	61.71	35.59	9.91	0.46		124.18
	2003(2010/11)	40.35	2.23	0.03	12.33	38.72	10.32	9.28		113.26
	2004(2011/12)	70.84	5.94	0.17	1.82	63.59	9.79	2.80	17.28	154.95

Source : MCE annual Reports

The bottle neck machine in cement plant is the rotary kiln which is used to the main ingredient of cement and accounting 80% of production cost. The breakdown of these machine stop the quarry and cement grinding plan. So, these machines are critical and analyzing the kiln indicates the performance of the cement plant. The kilns time they spend due to breakdown in the year 2001-2004 E. C.(2008/09-2001/12 G.C) is listed below, which helps to calculate the total amount of money that the company lost due to unavailability of the kilns.

Table 4.4 Clinker Production from 2008/09 -2011/12 G.C for two kilns

CLINKER PRODUCTION(TON)								
	2001(2008/09		2002(2009/10)		2003(2010/11)		2004(2011/12)	
Year	PLAN	ACTUAL	PLAN	ACTUAL	PLAN	ACTUAL	PLAN	ACTUAL
ONE	295,000	210,109	298,000	226,041	295,000	218,506	293,000	182,956
TWO	315,000	256,583	297,0000	192,229	295,000	234,822	292,000	185,839
TOTAL	610,000	466,692	595,000	418,270	590,000	453,328	595,000	368,795

Source : MCE annual Reports

Table 4.5 kilns capacity utilization from 2008/09 -2011/12 G.C

KILN CAPACITY UTILIZATION(TONS/DAY)								
Year	2001(2008/09		2002(2009/10)		2003(2010/11)		2004(2011/12)	
kilns	PLAN	ACTUAL	PLAN	ACTUAL	PLAN	ACTUAL	PLAN	ACTUAL
ONE	1000	953.76.	1000	919.4	1000	911	1000	963
TWO	1000	1002.9	1000	916.2	1000	933	1000	959

Source : MCE annual Reports

4.2.2. Analysis of Secondary Data

The data collected from MCE is analyzed below. Considering the result the next chapter will recommend best maintenance management system model.

4.2.2.1. Maintenance Cost Analysis

The common production costs of cement production are fuel cost, spare part cost, labor cost, paper bag cost and overhead cost. From the table 4.1 the production cost is the lion share of the total cost (about 87%) of the company. And the operating cost, that is the administration, selling and distribution costs are the second larger cost, 9% of the total cost. Maintenance cost is the least of the total cost that is 5% of the total cost. However the hidden cost that comes from lack of proper maintenance is too big. That is, the loss of production due to the unavailability of the machines and the cost associated with this downtime are large. Therefore the maintenance cost is analyzed in detailed in this study. Let's start by considering the maintenance activities done in the company in the year 2004 E. C. (2011/12G.C)

4.2.2.2 Maintenance Activity

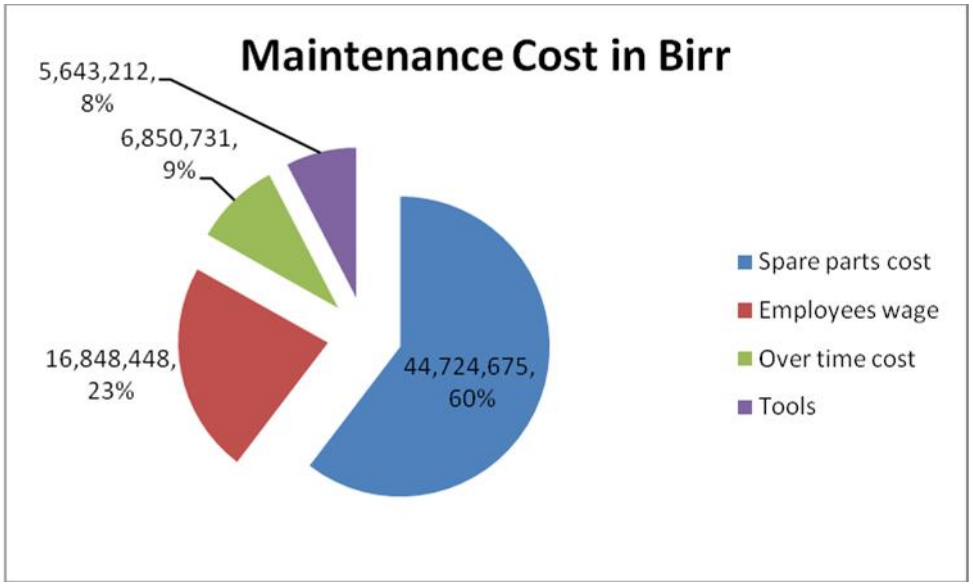
As can be seen from table 4.3, the mechanical, Electrical, Electronics, bricks relining and heat up maintenance activities is 97 % of the total down time. This shows that, the existing maintenance planning system of the company cannot decrease the frequent breakdown of the machinery. The reason should be either the plan does not consider factors for interval of

inspection, or the planned activities are not well practiced. According to the 2011/12 G.C. annual maintenance report, 415 activities are performed with planned and 1120 activities are unplanned activities. Which means around 73% of the unplanned work is done. So the problem is mostly how they plan the maintenance program. It should be the goal of the department to achieve zero breakdowns. But the main duty of the maintenance department in the company is repairing the failed machine not preventing or inspecting machines. Thus, this situation urges an implementation of a maintenance system, which improves this big number of breakdown..

4.2.2.3 Maintenance Cost

Increasing productivity by looking for ways to reduce maintenance cost is one of the objectives of the study. As it is seen from the table 4.2, the main maintenance cost of the company is employee wage, spare part and overtime. The pie diagram below shows these costs in percentage share.

Fig. 4.2 Maintenance cost comparison of the company in 2004 E.C. (2011/12



As it is shown in the diagram, the lion share(60%) of the maintenance cost is the spare part cost. If the proper maintenance system is applied and if operators are aware about their own machine, the cost incorporated with spare parts decreases dramatically. The spare part cost can be decrease if the machine properly lubricated and inspected frequently, and if the loosen parts tighten properly before it causes the breakdown of expensive parts etc. Therefore the spare part cost can be reduced if the preventive activities dominate total work done in the company. Unless the total view of the company changed to preventing the failure before it occurs, it is difficult to make the cost minimum.

When we consider the wage of the employee, it cannot be minimized, unless we changed the way the department staffed or we use other alternatives of maintenance approach like TPM (Total Productive Maintenance). At present condition the workers have job description for each of them and work accordingly.

Overtime cost is also the one that can be minimized or totally avoided. If we take an ideal condition that it can be totally avoided, if no breakdown occurred and if the crafts are staffed based on the need of preventive maintenance action. Thus, as the number of breakdown jobs decrease, the amounts of overtime will decreases. Therefore, if the amount of overtime is directly proportional to the number of breakdown occurred, the effort should be on decreasing the number of breakdown occurred in the company.

4.2.2.4 Maintenance downtime cost

Table 4.6 downtime cost/ loss of profit for two kilns

Year	kiln down time (days)	lost Clinker production(tons)	lost cement (tons)	lost profit(Br)
2008/09	133.91	267,820	2,819,158	61,316,684
2009/10	139.29	278,580	2,932,421	63,780,158
2010/11	98.48	196,960	2,073,263	45,093,474
2011/12	201	402,000	4,231,579	92,036,842

Source: MCE annual Reports

When the kilns are in down time, the lost production is 1000 tons of clinker per day for each. When the clinker ground with 5 % gypsum it gives cement of br 21.75 profit. So the lost profit due to down time ranges from br 45,093,474 lowest in 2010/1 to br 92,036,842 highest in 2011/12.

4.2.2.5 The Maintenance Performance (OEE and TEEP)

As MCE is the biggest and modern cement factories in the country, it equipped with different modern machines. These machines are arranged in product layout to process the raw material to the finished cement. Because of this operationally series arrangement, the breakdown of one machine affects the whole production processes especially for bottleneck machines that is the rotary kiln which produce clinker from raw material and gives as input for finish grinding.

Table 4.7 Calculation of OEE and TEEP for the two kilns from 2008/09-2011/12G.C

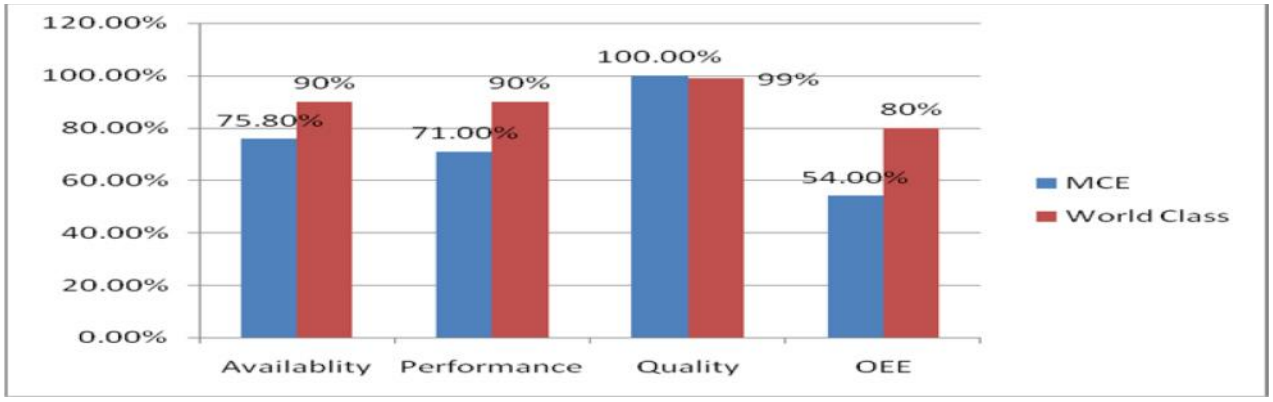
				1			2		3	4		5
Kiln Line	**Operating years**	**Actual Oprating days**	**Planned operating days**	**Availablity**	**Actual production (ton)**	**Planned production (ton)**	**PERFORMANCEF**	**quality goods produced**	**QUALITY index**	**OEE**	**calander days**	**TEEP**
		A	B	B/A*100	C	D	C/D*100	E	E/C*100	1*2*3	F	A/F*2*3
ONE	2008/09	220.29	295	**75%**	210,109	295,000	**71%**	210,109	**100%**	53%	365	**43%**
	2009/10	245.87	298	**83%**	226,041	298,000	**76%**	226,041	**100%**	63%	365	**51%**
	2010/11	239.81	295	**81%**	218,506	295,000	**74%**	218,506	**100%**	60%	365	**49%**
	2011/12	190	293	**65%**	182,956	293,000	**62%**	182,956	**100%**	40%	366	**32%**
TWO	2008/09	255.8	315	**81%**	256,583	315,000	**81%**	256,583	**100%**	66%	365	**57%**
	2009/10	209.84	297	**71%**	192,229	297,000	**65%**	192,229	**100%**	46%	365	**37%**
	2010/11	251.71	295	**85%**	234,822	295,000	**80%**	234,822	**100%**	68%	365	**55%**
	2011/12	194	292	**66%**	185,839	292,000	**64%**	185,839	**100%**	42%	366	**34%**

The Table 4.7 above indicates the availability, performance and quality rate of the two rotary kilns with capacity of 1000 tons per day each analyzed for four years data from 2008/09 up to 2011/12 . The column A is the actual Operating days of the kilns and The column B is the planned of the kilns then column 1 is the Availability of kilns which is A divided by B for each period.

The column C is the actual production of clinker in tons of the kilns and The column B is the planned production of clinker in tons of the kilns then column 2 is the performance of the kilns which is C divided by D for each period. The column E is the quality of clinker produced from the total produced clinker which is 100%. Then column 3 is the ration of column E to Column C and all are 100%. Then column 4 is the Overall equipment Efficiency OEE= Availability * performance * quality rate calculate from column 1,2 and 3 which ranges from 40% to 63% for line one kiln and from 42% to 68% for line two kiln. The OEE of the two kilns are far less than the world standard for cement plant which is 80%.

The column F is the calendar days of the year and column 5 is the Total Equipment Effectiveness performance (TEEP) which is the product of column A divided by column F and multiply by column 2 and 3. The TEEP ranges from 32% to 51% for line one kiln and from 34% to 57% for line two kiln. The TEEP of the two kilns are far less than the world standard for cement plant which is 75%.

Fig 4.3 performance, Availability, Quality and OEE comparison of MCE and World Best



As shown in the figure 4.3 MCE performance on Availability and performance is 14.2 % and 19 % below the world class respectively and it is quality is equal to world class. The OEE is 26 % below the world class plant.

4.3 Presentation and Analysis of Primary Data

The questionnaire is distributed to 70 production and maintenance employees out of these 61 (87%) questionnaires are collected for data analysis as seen below, the questionnaire is attached in the Appendix A.

Table 4.8 Characteristic of production and maintenance employees respond to questionnaire

S/N	Description	Respondents	
		NO	%
1.1	Sex		
	1. Female	7	11%
	2. Male	54	89%
	Total	**61**	**100%**
1.2	Job position		
	1. Management members	26	43%
	2. Non management members	35	57%
	Total	**61**	**100%**
1.3	Employees Department		
	1. Maintenance	35	57%
	2. Production	26	43%
	Total	**61**	**100%**
1.4	Education qualification		
	1.12 grade	13	21%
	2.10+1	8	13%
	3.technical & vocational diploma	14	23%
	3.college diploma	18	30%
	4.First degree	6	10%
	5.post graduate	2	3%
	Total	**61**	**100%**
1.5	Years of Experience at MCE		
	1. Below 5 years	11	18%
	2.5 to 10 years	13	21%
	3.10 to 15 years	21	34%
	2.above 15 years	16	26%
	Total	**61**	**100%**

Source : Questionnaire survey

Most of the employees in production and maintenance department in MCE are males, so 89% of the respondents are males. Regarding the job positions and department 57% are non management and maintenance department employee.43% are management members and production employees. 82% of the respondents have more than 5 years of experience in cement plant.

Table 4.9: **Maintenance Organization**

	ORGANIZATION	**4**	**3**	**2**	**1**	**0**	Total
1	organization chart		46	15			61
			75%	25%			100%
2	Job descriptions are available for maintenance personnel	28	15	12	6		61
		46%	25%	20%	10%	0%	100%
3	Maintenance shop area location	20	15	11	10	5	61
		33%	25%	18%	16%	8%	100%
4	Maintenance shop area layouts		11	15	25	10	61
		0%	18%	25%	41%	16%	100%
5	Maintenance tools/equipment quality and quantity	8	15	28	8	2	61
		13%	25%	46%	13%	3%	100%
	Total of part one	56	56	66	49	17	244
		23%	23%	27%	20%	7%	100%

Source: Questionnaire survey

The organization chart in MCE is more than one years old and incomplete with planning and design out unit. The job description is given to all employees and supervisor even if it does not include detailed activities and responsibilities. The workshop facilities is not complete to carry out

the preventive maintenance and far from the quarry location.

Table 4.10: **Training Programs in Maintenance**

No.	Description	**4**	**3**	**2**	**1**	**0**	Total
	Training program in maintenance						
1	Supervisory training	5	10	18	13	15	61
		8%	16%	30%	21%	25%	100%
2	Planner/scheduler (or a person who plan) training				9	52	61
		0%	0%	0%	15%	85%	100%
3	General quality and productivity training	15	23	16	7		61
		25%	38%	26%	11%	0%	100%
4	Maintenance craftsman training	18	23	12	8		61
		30%	38%	20%	13%	0%	100%
5	Maintenance training intervals	13	23	15	7	3	61
		21%	38%	25%	11%	5%	100%
6	The quality and skill level of the maintenance work force	16	18	19	8		61
		26%	30%	31%	13%	0%	100%
7	The quality and skill level of supervisor group	8	25	22	6		61
		13%	41%	36%	10%	0%	100%
	Total of part one	75	122	102	49	18	366
		20%	33%	28%	13%	5%	100%

Source: Questionnaire survey

Training is carried out both internally and by outsourcing. However, the training is not need based, not planned properly and the impact of the training is not analyzed to fill the gap of human competence. The quality of craftsmen and supervisor is above average.

Table 4.11: **Maintenance Work Orders**

No.	Description	4	3	2	1	0	Total
	3.Maintenance work orders						
1	Maintenance man-hours are reported to a work order	8	10	14	15	14	61
		13%	16%	23%	25%	23%	100%
2	Total jobs performed by maintenance are covered by work orders		3	8	22	28	61
		0%	5%	13%	36%	46%	100%
3	The work orders are available for historical data analysis	5	8	11	15	22	61
		8%	13%	18%	25%	36%	100%
4	The work orders are checked by the supervisor for work quality and	6	7	12	16	20	61
		10%	11%	20%	26%	33%	100%
5	The percentage of the work orders are generated from the preventive maintenance inspection		10	38	11	2	61
		0%	16%	62%	18%	3%	100%
	Total of part three	19	38	83	79	86	305
		6%	12%	27%	26%	28%	100%

Source: Questionnaire survey

The maintenance department of MCE do not use work order properly or sometimes do not use this system.. It is one of the most indicators of the status of a maintenance department. If a maintenance organization does not have a work order system, it is impossible to measure or control maintenance activity.

Table 4.12: **Maintenance Planning and Scheduling**

No.	Description	4	3	2	1	0	Total
	4. MAINTENANCE PLANNING						
1	Planned work orders experiencing no delays due to poor or incomplete plans			5	23	33	61
		0%	0%	8%	38%	54%	100%
2	Maintenance Planners are available				3	58	61
		0%	0%	0%	5%	95%	100%
3	Maintenance job schedules are issued				6	55	61
		0%	0%	0%	10%	90%	100%
4	The job is completed, the actual time, material downtime, and other information is reported by		10	12	10	29	61
		0%	16%	20%	16%	48%	100%
5	The actual time compared with the estimates for monitoring planning effectiveness				8	53	61
		0%	0%	0%	13%	87%	100%
	Total of part four	0	10	17	50	228	309
		0%	3%	6%	16%	74%	100%

Source: Questionnaire survey

No dedicated planner to plan and schedule maintenance activities. Planning is carried out with annual production by maintenance manager. More than 40% of the organization use planned maintenance done by maintenance manager or other staff. Most experts agree that, this is one of the largest potential for cost savings in maintenance area. It is estimated that planned versus breakdown work may have a cost ratio as high as 1:5

Table 4.13: **Preventive Maintenance**

No.	Description	4	3	2	1	0	Total
	5. PREVENTIVE MAINTENANCE						
1	The preventive maintenance (PM) program includes lubrication	45	13	3			61
		74%	21%	5%	0%	0%	100%
2	The PM inspection/task checklist are checked to ensure completeness:	17	19	16	9		61
		28%	31%	26%	15%	0%	100%
3	The plant critical equipment is covered by a PM program	6	5	4	18	28	61
		10%	8%	7%	30%	46%	100%
4	The PM program is checked against an equipment item's history			13	21	27	61
		0%	0%	21%	34%	44%	100%
5	The frequency of a PM inspection or task/service interval is		16	24	18	3	61
		0%	26%	39%	30%	5%	100%
6	The responsible for performing PM tasks	14	23	15	9		61
		23%	38%	25%	15%	0%	100%
	Total of part five	82	76	75	75	58	371
		22%	20%	20%	20%	16%	100%

Source: Questionnaire survey

It is known that preventive maintenance is another major part of any successful maintenance program to be productive. Without successful preventive maintenance program, maintenance can only react to given situation. Preventive maintenance allows the organization to plan better and reduce maintenance cost. The major PM in MCE is lubrication of machineries and equipment in schedule basis. The performance of preventive maintenance is far below with world standard of 90% of maintenance activities

Table 4.14: **Maintenance Inventory and Purchasing**

No.	Description	4	3	2	1	0	Total
	6. MAINTENANCE INVENTORY AND PURCHASING						
1	percent of the time are materials in stores when required by the maintenance organization	12	25	19	5		61
		20%	41%	31%	8%	0%	100%
2	Controlling maintenance inventory items	55	6				61
		90%	10%	0%	0%	0%	100%
3	The maintenance stores catalog is produced by	38	17	4	2		61
		62%	28%	7%	3%	0%	100%
4	Maximum and minimum levels for the maintenance stores items are specified for what percent of the inventory	23	17	16	5		61
		38%	28%	26%	8%	0%	100%
5	Maintenance stores inventory levels are updated daily upon receipt of materials what percent of the time	18	16	15	12		61
		30%	26%	25%	20%	0%	100%
	Total of part six	**109**	**94**	**70**	**32**	**0**	**123**
		89%	76%	57%	26%	0%	100%

Source: Questionnaire survey

The spare part arrangement and control in store is good with easily identifiable. Some spares are not readily available for preventive maintenance activity.

4.2.3 Summary reports from Interview

The findings and discussion in the interview section have revealed that there are strengths, weaknesses, opportunities, and threats associated with MCE .

i. Strength

The strength of MCE among the competitors in cement industries are Availability of skilled and long served manpower, Availability of most Spare parts for critical equipment

ii. Weaknesses

The Weakness of MCE are the unavailability of maintenance planning and control unit and dedicated planner, High rates of unexpected breakdown and maintenance costs, No motivational system for employees and Weak Organizational culture.

iii. Opportunities

The opportunities of MCE are the **i**ncrease domestic demands for cement and construction products, and potential to export the cement for neighboring countries and the availability of technological equipments in condition monitoring

iv. Threatens

The treats of MCE at present are the Unstable and sudden changes in political rules and regulations, the cost of Spare parts increase and high turnover of skilled employees to competitor cement plants.

CHAPTER FIVE

Conclusion and Recommendation

5.1. Conclusion

Based on the findings in the previous sections, equipment maintenance system of most cement industries in Ethiopia needs much improvement. Maintenance department of these industries should be well equipped with resources to assure the cost effective availability of machines to increase productivity. As it is seen in chapter 2, maintenance has a great impact on the productivity improvement; but it has received little notice in most of cement industries in Ethiopia.

In this study MCE is taken as source and reference for the case study. It is seen that most of the work order, in this company, is generated from breakdown of machines. This shows most of the maintenance activities are corrective action rather than preventive. In effect, the downtime of the machines rises. This downtime of the machines costs the company around 92,036,842 birr loss of production in budget year of 2011/12 G.C., that is approximately 40% of the total profit gained in the year which is 227,569,000 birr. Thus, this study finds out the causes of breakdown and ways to minimize them in order to increase the machines availability.

The main causes of breakdowns investigated in the paper for MCE are condition of equipment, operators, and condition of the area around the equipment. Thus, equipment must

be changed so it is clean and will not develop abnormalities so easily, and the workplace must be changed so its overall quality is improved. People themselves must be changed so they understand and treat their work, workshop and continually find a new & better way.

As it is the main objective, this study proposed a model for the workflow system of maintenance management system, considering the existing problem. The model simplifies the whole process and makes the activities to be efficient. So the productivity will be improved. It is developed by coordinating the four major duties of maintenance; inspection management, failure management, work management, and spare part management. Maintenance planning section has a great role in the model developed. It is the responsibility of this section to coordinate the corrective and preventive maintenance with the limited resources, and set the maintenance program considering the factors and the feedback of maintenance report.

5.2. Recommendation

The following recommendations are proposed for MCE and other cement industries in Ethiopia based on the outcome of the study.

1. Maintenance should be an organizational policy as one of the strategy in being productive and competitive. And the department should be given emphasis, as it is one of the main areas for productivity improvement. The developed maintenance workflow system in this study is recommended for them to be effective.

2. Maintenance awareness and commitment should be created in the companies starting from the top management in the organizations up to the lower level through training .

3. Companies should encourage their operator to become familiar with the machines they operate. Training should be provided for them to acquire:
   - The ability to detect equipment abnormalities and make improvement,
   - The ability to understand equipment functions and mechanisms, and the ability to detect causes of abnormality
   - The ability to understand the relationship between equipment and quality- The ability to make repair

4. Equipment operator should be responsible for machine and the workplace by taking every breakdown as a shame. Taking responsibility means taking action. When breakdown occurs, the operator concerned should meet with a maintenance worker to find out exactly what he or she did that caused it or could have done to prevent it.

5. The equipments should be kept so 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.

6. Daily, weekly, and monthly checklist should be available for every machine to be inspected by operators, mechanics and electricians. The frequency of inspection should consider the equipment history as well as factors like status of the equipment.

7. Spare parts should be managed well by classifying them as consumable, standard, and special spare part for every equipment to facilitate the ordering process.

8. Any preventive maintenance activities should be given emphasis, as it is the only solution to increase the availability of equipment. Thus maintenance and production has to be integrated with a common goal of the company to alleviate the conflict created between them. Here, the maintenance plan should consider the production plan whenever planned. The production department staffs also should understand preventive maintenance activities and should provide the equipment whenever needed.

9. The work order system should be available for all activities done in the maintenance department to measure or control the activities. Moreover, if they use the developed computer program, it will be much benefited in data recording system and for ease retrieval of information concerning the maintenance activities.

10. Since the very nature of production in cement is continuous, that is the kiln system continually operated, the situation calls for condition based maintenance system to be efficient and effective. And also condition monitoring instruments and tools, which makes the time taken for failure analysis and repairs short, should be available.

11. All cement industries should work together to support each other concerning the maintenance activities. For example, the maintenance department of MCE should be well equipped and staffed to support other medium and small cement industries in training and consultancy for taking this as one of income generation.

12. Finally, further studies can be made on the productivity improvement in Ethiopian cement industries through capital resource other than maintenance and through human resource. Since cement industries are one of the potential economic sectors, further studies can be carried on the maintenance improvement strategies and model development to enhance the cement production in the country.

CHAPTER SIX

Maintenance Model

In the chapter four, the amount of loss due to unavailability of machines, for the case of MCE, is seen. All of those machines become unavailable due to breakdown, which can be eliminated or minimized through good maintenance system as it is recommended in the chapter five. Thus, the main intention of this chapter is to introduce a general maintenance model for improvement of maintenance management.

This is actually the concept of Total Productivity Maintenance, which takes the operators as a key player in equipment availability. On the contrary, the operators in MCE are not totally aware of these things. It is stated that operating the machine is the only responsibility of operators. This system makes the machines to fail frequently because operators are not responsible for the machines they operate.

In MCE the general thinking among equipment operators is '**I run it, you fix it'**. Operators consider themselves responsible only for operating their equipment to produce cement. Any maintenance activities including light maintenance and lubrication are the responsibility of the maintenance staff. This way of thinking makes the operators not to care about the machine.

The operators can prevent the breakdown simply by getting a feel for abnormalities through physical contact with the equipment. Taking time to tighten loosen bolt, lubricating dry parts and cleaning away dirt, they can increase the life of equipment. Therefore, training the operators of M C E increases the availability of equipments that helps to maximize the productivity.

6.1. Equipment Availability Improvement

Breakdowns should be minimized as much as possible in order to meet the planned production amount. The main target of the maintenance department should be zero breakdowns. In order to achieve this prevention action should be well organized and coordinated with the other activities.

Every production section of the cement industries consists of a particular combination of two components: people (operator) and machine (equipment). No matter how these are combined; one operator per machine or one operator to a number of machines, the workshop system consists of people working closely with machines. Thus, how the machine is operated, how the machine is kept, and how the working condition is comfortable affect the machine availability greatly.

Equipment must be changed so it is clean and will not develop abnormalities so easily, and the workplace must be changed so its overall quality is improved. People themselves must be changed so they understand and treat their work, workshop and continually find a new

and better way. It is seen that MCE lacks this so each will be discussed below.

6.1.1. Improving the Status of Equipment

To improve the condition of equipment, it must be cleaned, lubricated, checked, and inspected in the planned interval. Cleaning is the most important operation to keep the machine working in a good condition. When machines are cleaned, the outlets become open, and flow becomes ease if the system allows circulation and also protects the fluid from contamination. On the other hand cleaning the machine motivates workers and so they become more productive. Thus, cleaning the machine is an ideal operation to increase the lifetime of the equipment as well as to be productive.

Cleaning becomes checking; checking becomes discovery of abnormalities. Cleaning equipment requires touching and moving it, coming into closer contact with it, making it easier to tell when it is acting abnormally. That is why "cleaning becomes checking." In fact, cleaning a machine is one of the best ways to check for abnormalities. For example, while cleaning a machine component, one may notice something loose inside.

When cleaning becomes checking, checking in turn becomes a means of discovering abnormalities and dealing with them at an early stage. Thus, when operators learn how to discover abnormalities and practice it, often with the help of maintenance staff, they eventually learn to see their equipment in a whole new way. They learn to use all their senses to better understand the equipment and its condition.

The next step is to understand the abnormalities better that were discovered and come up with ways of restoring or improving them. Then the defective components can be easily repaired, while others can or must be replaced. Perhaps the loose part needs tightening.

Often this is much easier said than done. It may be difficult especially at first, to figure out just what the problem is or how to solve it. But it is only by struggling with challenges and finding a solution that equipment operators come appreciate the issues with which maintenance workers must deal. This experience also helps operators to learn that they cannot be offhand and allow troublesome problems to happen again.

From the viewpoint of the operator, the process of "improving the status of the equipment" involves cultivating a sharp eye for abnormalities, taking the trouble to fix them, and experiencing the pleasure of making successful improvements and finding ways to maintain them.

6.1.2. Improving the Operator's Attitude through Training

Good maintenance management requires operators to understand their equipment. The job related expertise must not be limited to simply operating the equipment; it must also include a lot of things traditionally regarded as maintenance work. All of the equipment operators need to learn how to detect abnormalities. This means acquiring the ability to look at the quality of the product and the performance of the equipment and notice when something is

strange. This depends on the following three skills.

- A clear understanding of criteria for judging normal and abnormal conditions (the ability to establish equipment condition)
- Strict enforcement of condition management rules (the ability to maintain equipment condition)
- A quick response to abnormalities (the ability to repair and restore equipment condition)

When an operator has mastered all three skills, he or she will understand the equipment well enough to recognize the causes of future problems and realize weather the machine is in good condition or not. The following points explain some of the skills that operators should have.

i. The ability to detect equipment abnormalities and make improvement

- Ability to watch for and discover abnormalities in equipment operation and components.
- Understanding the importance of proper lubrication, including correct lubrication methods and methods for checking lubrication.
- Understanding the importance of cleaning (inspection and proper cleaning methods)
- Understanding the importance of coolant

ii. *The ability to understand equipment functions and mechanisms, and the ability to detect causes of abnormality*

- Understanding what to look for when checking mechanisms.
- Ability to clean and inspect to maintain equipment performance
- Understanding criteria for judging abnormalities.
- Understanding the relations between specific causes and specific abnormalities.
- Ability to confidently judge when the equipment needs to be shut off.
- Some ability to perform breakdown diagnosis

iii. *The ability to understand the relationship between equipment and quality, and the ability to predict problems in quality and detect their causes.*

- Ability to analyze problem related phenomena
- Understanding the relationship between characteristics of quality and the equipment.
- Understanding casual factors behind defect.

iv. The ability to make repair

- Ability to repair parts
- Understanding the life expectancy of parts
- Ability to deduce causes of breakdowns
- Ability to take emergency measures
- Ability to assist in overhauls repairs

6.1.3. Improving the Overall Quality of the Workplace

Once operators have developed a sharp eye for abnormalities, they start to think what must be done to minimize the causes of abnormality. They can, then, focus on everything around it, tools, processing conditions, control systems, and so on. These peripheral aspects of the workplace are also covered with abnormalities, and having seen them, the operators know that timely action must be taken to prevent them from developing into big problems. So the first step to changing the workplace is taken when operators begin to notice and list the countless things that need improvement.

i. Changing the way of seeing and thinking about things

To change the workplace there must be a change in the way of thinking about it and everything in it. With current attitude of MCE, there is no recognition of the abnormalities and defects that exist in the machines and tools that are used. Thus operators need to be concerned about the overall quality of workplace, good or bad, is entirely the result of human behavior. So the most important idea that workers should cultivate is an abnormalities before they develop in to major problems.

ii. *Seeing each breakdown as a humiliation*

It is all too easy to find workshops of the cement industries where the operators to look at breakdowns as someone else's fault: blame is usually put on the maintenance staff. This is a big problem. Availability of machine improvement will not go anywhere until equipment operators and/or other workers take responsibility for their workplace, regarding every breakdown as a sham. Taking responsibility means taking action. When breakdown occurs, the operator concerned should meet with a maintenance worker to find out exactly what he or she did that caused it or could have done to prevent it.

In summary, changing the equipment leads to changing attitudes and behaviors, which in turns leads to improving the overall quality of the workplace. These three changes - in the equipment, the people, and the workplace - are basics for improvement of availability of equipments.

6.2. Developing Effective Maintenance System

Planned maintenance is essential for efficient maintenance activities. In MCE there is a planned maintenance activities but it covers less than 30% of the total work order in the year 2011/12 G.C. The maintenance staff said that they are following condition based maintenance system. That means every planned maintenance activities are programmed and done after the inspection is executed. However their yearly maintenance plan shows that, they are following the fixed time planned maintenance system also. One of the other big problems in performing planned maintenance activity is that the maintenance plan does not consider the production plans. Thus several conflicts between maintenance and production staff are observed. The maintenance plan should be done considering the production plan of the company to avoid such conflict and to perform the planned maintenance activity.

Therefore good managerial actions must be taken to manage the total maintenance activities done in the company. Maintenance managerial activities that help for the construction of maintenance workflow model are listed below.

6.2.1. Inspection Management

Inspection is the examination of certain critical machines or parts of equipment or machines to determine their state or condition. This information is useful for planning and programming actions, which help to maintain accuracy of the machine and the prevention of unwarranted breakdowns of the cement equipment.

A sudden failure rarely takes place, as there are always signs of gradual wear and tear noticeable long before an actual failure occur. Periodic inspection helps to detect extent of deterioration and plan for its repair or rectification, or if need be, even make replacement before an actual breakdown occur. It is therefore, a means of reducing breakdowns and loss of production, and the cost of expensive repairs and many other expenses. In MCE, actually, the inspection is done but it cannot prevent the machine from frequent failure. The problem is either the inspector does not understand the purpose of inspection or he/she may not know what to inspect. Thus, the inspection intervals should consider some factors as follow and the check sheet should be at hand whenever inspection is takes place.

Frequency of Inspection

To determine the frequency of the inspection in MCE, the following engineering analysis should be considered

- the age of the machine, its condition and value
- severity and intensity of service
- hours of utilization, are they prolonged or intermittent
- Susceptibility to wear and tear – is the machine subjected to dirt, friction, fatigue, stress, corrosion?
- Susceptibility to damage – is the machine subjected to severe vibration, overloading, abuse, heat, freezing cold?
- Susceptibility to losing adjustment during use – will the maladjustment or non- alignment affect the accuracy or functioning? Will the lack of proper balancing affect performance?
- safety requirements and considerations

Inspection Checklists

Every machine in the MCE needs daily, weekly and monthly inspection check sheet. Daily inspection are performed to insure that, critical equipments are in a good condition so as to continue to perform satisfactorily, and that no such situation develops, which might cause a failure or breakdown suddenly. In the same procedure weekly, monthly and annual inspection should be done. The inspection routine in MCE would involve carrying out checks for:

- any abnormality vibrations, or any abnormal noise
- the temperature of all bearings to ascertain that they are acceptable levels and that they are not overheating condition
- leakages from the gear box to see whether it is excessive
- oil level in cups
- grease nipples to insure that they are not dry

6.2.2. Spare Parts Management

This means organizing spare parts so the right ones are always in the right place at the right time. The stoking system should be well designed or organized to facilitate the supply of spare parts to decrease the delay in retrieval of the required item. The spare part cost is also the one, which should be considered. It is the main cost of the maintenance department. Most spare part ordering is taken place in an urgent way because the machines are waiting for parts to be available. This is the main reason for the maintenance cost increment in MCE.

In MCE the spare parts for each machine should be categorized and listed as consumable, standard, and special spare parts. This helps the maintenance department to order which type of spare part at what time. It also helps to know which are used in common for different machines.

The spare parts are mainly purchased from the local and foreign market. Few are worked in the metal and wood workshops of the company. The main function of these shops are reconditioning screw blades, shafts and other damaged parts, and some modification work.

6.2.3. Work Management

The work done in maintenance department of cement industry should be well managed to be productive. In MCE the resources are limited and so they should be assigned in a systematic way to do all the maintenance works in the given period of time. It is a practice of the MCE to pass the preventive maintenance if the workers are occupied by corrective maintenance activity. But it is known that the preventive maintenance is very essential and should be performed according to the planned time to avoid or minimize the corrective maintenance. Therefore, since the works are generated from two sources, from the planed and from the breakdown, they should be managed based on the resources available.

To perform these two maintenance activities, the production and maintenance managers should have a common understanding concerning these activities. In MCE production department is don't allow any interruption during the production time to achieve planned production. So maintenance craftsman can not get time for preventive maintenance during the production time. Thus, the production managers should be cooperative and should understand the prevention activity to manage the planned work easily. The maintenance program should also consider the production plan during the plan.

6.2.4. Equipment Failure Management

Whenever equipment breakdown occur in MCE, the time required for repairing it is too long. That affects productivity, because, unless the machines are repaired, no product is

produced. Thus the main activity of failure management is to shorten the repair time.

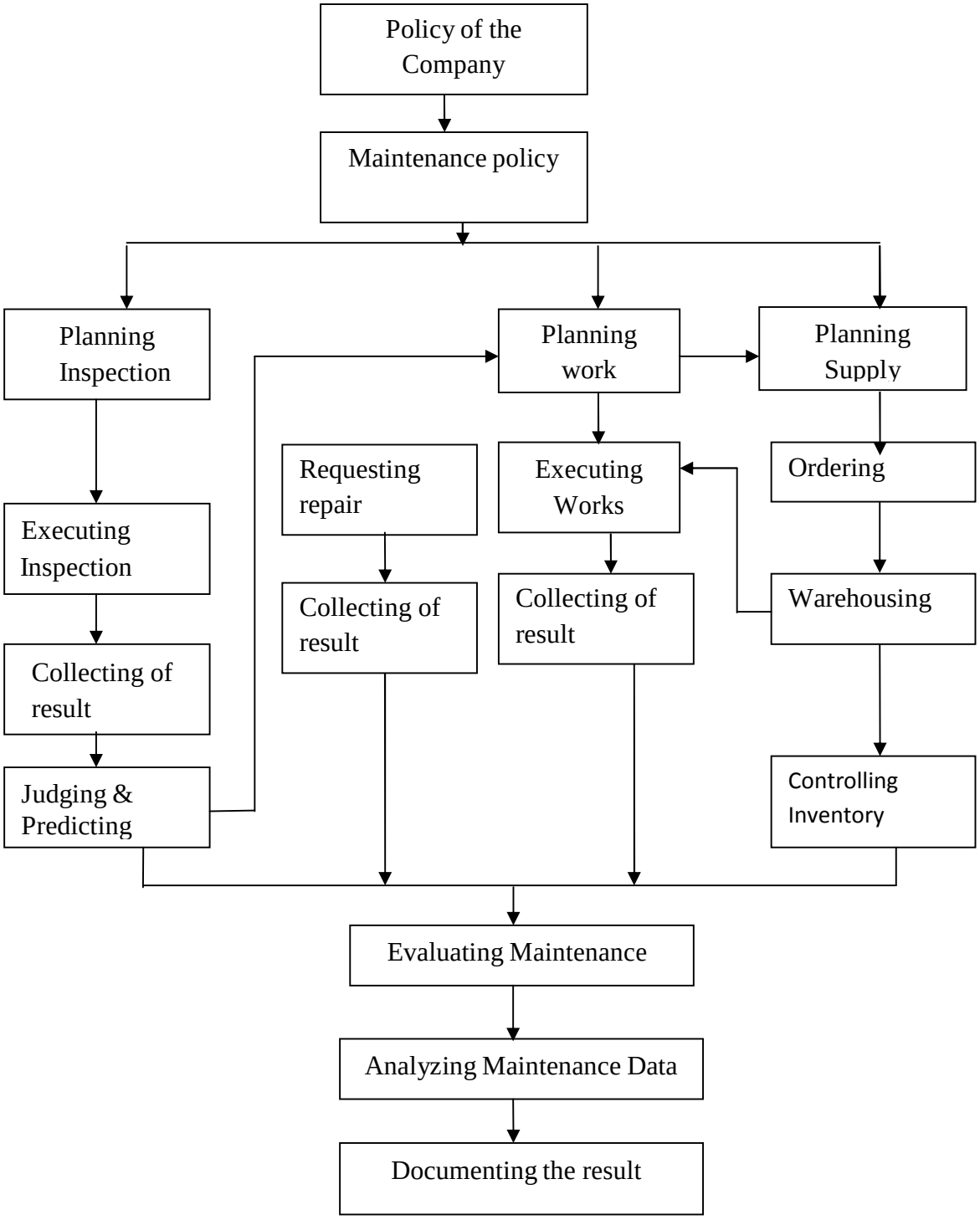
In MCE, usually, much of the time between the occurrence of the breakdown and completion of the repair is spent by diagnosing the causes of failure or by looking for the broken part or parts. Thus maintenance people should be trained on how they diagnose and understand the work. Having the diagnostic device may be expensive for maintenance department, but the maintenance staff should work on inventing themselves to suit their particular situation. On the other hand spare part management is also one factor to shorten the repair time and it is discussed above.

Therefore, these four managerial functions are basic to develop a successful maintenance workflow. The procedures in which all maintenance activities should be clearly identified and known by all concerned bodies of the plant staff. Thus the duty and responsibility of production and maintenance managers, supervisors, planner, operators, and the craftsman should be clearly identified and known by the company's concerned department.

As it is seen from chapter four Fig. 4.1 the workflow of the existing maintenance department of MCE, several problems can be extracted. The work is not planned to consider the corrective action. And also the spare parts are not ordered at the work planning stage, thus the downtime of the machine increases by waiting the spare part.

Therefore, the workflow should be modified to alleviate the above stated problems. Thus, the modified workflow, which considers the above problem, is proposed below.

Fig. 6.1 The proposed maintenance workflow



The model proposed above has many advantages over the existing maintenance workflow of MCE described previously. It is seen that MCE uses fixed time maintenance management system. That means the machines are maintained according to the maintenance program planned once in a year. But the very nature of production in cement is continuous, that is kiln is consuming more energy during heating up after shut down period.

It is most efficient interims of cost and availability. This model uses condition based maintenance type for these reasons. Daily, weekly and monthly inspections are planned for each machines then inspection will be executed accordingly. Having the result the condition of the machine is known and so the need of overhaul, medium or small maintenance or not will be decided. Then after the work will be planned taking this as a feedback with the requisition of failed machine together. Thus when the work is planned it considers both the preventive and corrective activities together. While planning the work the type and amount of spare parts needed will be ordered simultaneously. This decreases the time spent in waiting the spare parts.

The result collected from each step will be evaluated and analyzed to be a feed back for the next year maintenance policy preparation and documented finally.

The model is can be applied for all Cement industries in Ethiopia. Because it consists of basic duties that must be performed to minimize the breakdown of machines as well as the maintenance cost.

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APPENDICES A

QUESTIONNARIES

Indra Gandi National Open University (IGNOU) School of management studies ,Maiden Garhi,New Delhi (To be filled by production and maintenance department employees of Mugher Cement enterprises)

This questionnaire is designed for the purpose of understand a study topic " **Assessment of maintenance management system in Ethiopia Cement Industries: a case study in Mugher Cement Enterprise**". Please tick the appropriate choice. The data that you give me will keep ***confidential*** .I will be used only as an input to my study

Section 1

1. Sex

1. Female ☐ 2. Male ☐

2. Job position

1. Management members ☐ 2. Non management members ☐

3. Department

1. Maintenance ☐ 2. Production ☐

4. Education qualification

S/N	Education qualification	
1	12 grade	
2	10+1	
3	technical & vocational diploma	
4	college diploma	
5	First degree	
6	post graduate	

5. years of Experience in the Enterprise

S/N	Years of Experience at MCE	
1	Below 5 years	
2	5 to 10 years	
3	10 to 15 years	
4	above 15 years	

Section 2

Part 1: Maintenance Organizations

1. Maintenance organizational chart

A. Current and complete B. Not complete or over 1 year old

C. Not current and not complete D. None

2. Job descriptions are available for:

A. All maintenance positions (including supervisors)

B. All maintenance positions (except supervisors)

C. All maintenance supervisors (and no others)

D. Less than 50% of all maintenance positions

E. No job descriptions

3. Maintenance shop/work area locations:

A. Perfect B. Good (some improvement possible)

C. Fair (major improvement possible) D. Poor (major improvement required)

E. Unsuitable or nonexistent

4. Maintenance shop/work area layouts:

A. Perfect B. Good (some improvement possible)

C. Fair (major improvement possible) D. Poor (major improvement required)

E. Unsuitable or nonexistent

5. Maintenance tools/equipment quality and quantity:

A. Perfect B. Good (some improvement possible)

C. Fair (major improvement possible) D. Poor (major improvement required)

E. Unsuitable or nonexistent

Part 2: Training Programs in Maintenance

1. Supervisory training

A. All are trained when salaried and additional training is mandatory on a scheduled basis

B. All are trained when salaried and additional training is offered on an optional basis

C. The majority are trained when salaried

D. The majority are offered and attend training, which is offered on an infrequent or irregular basis

E. Few are given initial training and little or no additional training is provided

2. Planner Training

A. All planners/schedulers have been to one or more public seminars providing instruction on maintenance planning and scheduling

B. All planners/schedulers are provided with a written training program for maintenance planning

C. All planners/schedulers receive 1-on-1 on-the-job training for at least 1 month

D. Planner/scheduler training is on the job

E. There is no planner/scheduler training program

3. General quality and productivity training

A. Includes upper management, line supervision, hourly worker, support personnel

B. Includes upper management, line supervision, hourly workers

C. Includes upper management, line supervision

D. Is for only upper management

E. No training program

4. Maintenance craft training

A. Training is tied to a pay and progression program

B. Formal job experience is required before employment and on-the job training is provided.

C. Formal job experience is required before hire

D. Training is provided by on-the-job experience after hire

E. There are no formal training requirements for hire and no subsequent training is provided

5. Maintenance training intervals. Formal maintenance training is provided to ALL maintenance craft employees at the frequency of:

A. Less than 1 year B. Between 12 to 18 months

C. Between 18 to 24 months

D. Not to all employees, but to some in any of the above frequencies

E. No training is offered

6. Quality and skill level of the maintenance work force

A. Perfect B. Good (some improvement possible)

C. Fair (major improvement possible) D. Poor (major improvement required)

E. Unsuitable

7. Quality and skill level of the supervisory group

A. Perfect B. Good (some improvement possible)

C. Fair (major improvement possible) D. Poor (major improvement required)

E. Unsuitable

Part 3: Maintenance Work Orders

1. What percent of maintenance man-hours are reported to a work order?

A. 100% B. 75% C. 50%

`D. 25% E. Less than 25%

2. What percent of total jobs performed by maintenance are covered by work orders?

A. 100% B. 75% C. 50%

D. 25% E. Less than 25%

3. What percent of the work orders are available for historical data analysis?

A. 100% B. 75% C. 50%

D. 25% E. Less than 25%

4. What percent of the work orders are checked by a qualified individual for work quality and completeness?

A. 100% B. 75% C. 50%

D. 25% E. Less than 25%

5. What percent of the work orders are generated from the preventive maintenance inspections?

A. 80-100% B. 60-79% C. 40-59%

D. 20-39% E. Less than 20%

Part 4: Maintenance Planning and Scheduling

1. Percentage of planned work orders experiencing delays due to poor or Incomplete plans:

A. Less than 10% B. 10 to 20% C. 21 to 40%

D. 41 to 50% E. More than 50%

2. Who is responsible for planning the work orders?

A. A dedicated maintenance planner B. A maintenance supervisor

C. Each craft technician D. Anyone else

3. Maintenance job schedules are issued:

A. Weekly B. Biweekly C. Between 3 and 6 days

D. Daily E. Any other frequency

4. **When the job is completed, the actual time, material, downtime, and other information is reported by:**

A. The craftsmen performing the work B. The supervisor of the group

C. Anyone else D. Information is not recorded

5. What percent of the time are actual measures compared to the estimates for monitoring planning effectiveness?

A. 90% or more B. 75 to 89% C. 60 to 74%

D. 40 to 59% E. Less than 40%

Part 5: Preventive Maintenance

1. The preventive maintenance program includes lubrication:

A. 90% or more B. 75 to 89% C. 60 to 74%

D. 40 to 59% E. Less than 40%

2. What percent of the PM inspection/task checklists are checked to insure completeness:

A. 90% or more B. 75 to 89% C. 60 to 74%

D. 40 to 59% E. Less than 40%

3. What percent of the plant's critical equipment is covered by a preventive maintenance program?

A. 90% or more B. 75 to 89% C. 60 to 74%

D. 40 to 59% E. Less than 40%

4. **What percent of the PM program is checked against an equipment item's history annually to insure good coverage**?

A. 90% or more B. 75 to 89% C. 60 to 74%

D. 40 to 59% E. Less than 40%

5. **What determines the frequency of a PM inspection or task/service interval?**

A. Program is condition-based

B. Program is based on a combination of equipment run time and fixed calendar interval

C. Program is based on equipment run time only

D. Program is based on calendar intervals

E. Program is dynamic and is scheduled based on completion date of previous task

6. **Who is responsible for performing preventive maintenance tasks?**

A. Dedicated preventive maintenance personnel B. Specific individuals on each crew

C. Any individual on a crew D. Entry level technicians

E. Operating personnel

Part 6: Maintenance Inventory and Purchasing

1. What percent of the time are materials in stores when required by the maintenance organization**?**

A. More than 95% B. 80 to 95% C. 70 to 79%

D. 50 to 69% E. Less than 50%

2. Who controls what are stocked as maintenance inventory items?

A. Maintenance B. Anyone else

3. The maintenance stores catalog is produced by:

A. Alphabetic and numeric listings - 4 pts B. Alphabetic only - 2 pts

C. Numeric only - 2 pts D. Catalog is incomplete or non-existent - 0 pts

4. **Maximum and minimum levels for the maintenance stores items are specified for what percent of the inventory?**

A. More than 95% - 4 pts B. 90 to 95% - 3 pts C. 80 to 89% - 2 pts

D. 70 to 79% - 1 pt E. Less than 70% - 0 pts

5. **Maintenance stores inventory levels are updated daily upon receipt of materials what percent of the time?**

A. More than 95% - 4 pts B. 90 to 95% - 3 pts C. 80 to 89% - 2 pts

D. 70 to 79% - 1 pt E. Less than 70% - 0 pts

APPENDICES B

Interview Questions

1. What are the main general problems you encounter in your day to day activities?
2. What can you say about your current equipment breakdown status and trend?
3. Does equipment breakdown affect your maintenance planning budget? How?
4. What are the major causes of equipment breakdown?
5. What have you done and what are your future plans to reduce equipment breakdown problems?
6. What is the current maintenance philosophy at MCE? (Fail and Fix, PM, CBM)
7. What are your Preventive Maintenance improvement plans? Are they specific with timelines?
8. What is the maintenance time interval and/scheduling for major equipment?
9. How do you control the flow of spare parts/Material? How is the supply chain organized, when and how do you order spare parts? Which criteria do you use to order spare part?
10. What kinds of spare part are frequently used for the maintenance works so needs to be stored mostly.
11. What are your key performance indicators? How do you measure the performance?
12. How do you measure equipment effectiveness and reliability?
13. What are the means for improving equipment's effectiveness and reliability?
14. Do you have operators based maintenance?
15. How do you motivate your maintenance team?

APPENDICES C : list of Top management members interview for the study

No	Name	Positions
1	Mr Mekonnen Zergaw	Chief Executive Officer
2	Mr Elias Kifle	Operation Executive Officer
3	Mr Daniel Alemayehu	Maintenance Process Leader
4	Mr Tebabal Wudineh	Clinker Production Process Leader
5	Mr Asrat Kidanu	Supply Team Leader
6	Mr Fikire Bekele	Marketing Process Leader