Improving Maintenance Perception in Developing Countries

- A Case Study

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Sammanfattning/Abstract

Despite the continuous evolving world of technology, maintenance has responded tremendously in meeting this rapid technological change. Nevertheless, inadequate maintenance has become one of the most issues faced by organizations in developing countries. Maintenance is seen as an unimportant activity in most developing countries thus, it is not given high priority due to insufficient/ minimal knowledge about the concept. Hence, the purpose of this thesis (submitted for Total Quality Maintenance at the Department of Terotechnology) is to enhance the perception and maintenance in developing countries.

A case study was performed at Power Holding Company of Nigeria (National Electric Power Authority). The company is responsible for the production, transmission and distribution of electricity in Nigeria. The analysis shows that proper education and training can facilitate or increase the perception of maintenance in developing countries. However, for the case company, the study shows that not having appropriate maintenance in place is the major problem behind the company’s inability to achieve its objectives. Thus maintenance practice can be improved significantly with proper maintenance education and training. The result from the study shows the concept of maintenance education and training program and who it should address.

One major conclusion that can be drawn from the analysis is that major developments in developing countries are associated with modern technology from developed countries. Thus, maintenance should be given a top priority because keeping the proper functioning of the technologies depends greatly on DCs proficiency, in order to ensure viability of the development policies so as to obtain the benefit from modern technologies.

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Obamwonyi Martyn Enofe

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Växjö University,
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Explanation of some terms

Condition-based Maintenance
The kind of maintenance carried out according to the need indicated by condition monitoring. (BS 3811:1993)

Cost-effective maintenance
The measure of how much of the considered maintenance policy is economically beneficial in the long run whereby two situations (before and after maintenance improvement) is compared with the use of a dimension less ratio. (Al-Najjar 1997)

Maintenance
Maintenance is the 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 13306: 2001)

Maintenance concept
The set of various maintenance interventions (e.g. corrective, preventive, condition-based, etc) and the general structure with which these interventions are govern. (Alsyouf 2004)

Overall Equipment Effectiveness (OEE)
A tool to manage and improve the production/ manufacturing process. (Robbins 2008)

Terotechnology
A combination of management, financial, engineering, building and other practices applied to physical assets in pursuit of economic life cycle costs. (BS 3811:1993)
Abstract

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Lists of abbreviation

BDM: Breakdown Maintenance
Ce: Cost-effectiveness
CM: Corrective Maintenance
DCs: Developing Countries
JIT: Just-in-Time
NEPA: National Electric Power Authority
OEE: Overall Equipment Effectiveness
PHCN: Power Holding Company of Nigeria
PM: Preventive Maintenance
UNIDO: United Nation Industrial Development Organization
1. Introduction

This chapter aims to introduce the reader to the scope of this thesis work, with respect to the issue discussed in this paper. The problem is discussed and formulated, thus the essentiality is elucidated through the purpose, relevance as well as limitations encountered during the study. Furthermore the structure of the thesis is presented, in a view to facilitating continuous reading.

1.1. Background

“Another flaw in the human character is that everybody wants to build and nobody wants to do maintenance”

(Kurt Vonnegut, Jr.).

The environment that companies operates today is changing rapidly and continuously, competition are fierce and the means to gain and keep market shares is a major concern (Miles & Snow 1992). Company’s capability together with stakeholders and customers expectation has resulted in continuous increased pressure for both variety of production and swift delivery (Coyle et al. 2003). The change from a labor intensive industry to a technology-intensive industry and the increasing competition in the market place has set a platform for companies to continue to maintain the exploration of new ways that can keep them competitive so as to distinguish themselves and be profitable (Alsyouf, 2004; Al-Najjar, 2007).

Maintenance as a support function is to guarantee machine availability and reliability, employee’s safety and cost effective production, which attest to the above mentioned objective. Maintenance as a business function serves and supports the primary process in any organization, its process adds to customer value in terms of quality, time and profit (Alsyouf, 2004). One feasible way to ensuring machine availability and reliability with respect to complex machine and equipment used in today’s industries is maintaining the condition of such complex machines (Wireman, 1990).

In addition to ensuring or maintaining the availability and reliability of machine/equipment, downtime is also becoming aggravated in many industries worldwide due to the increasing
adoption of just-in-time (JIT) process, total quality-management (TQM) etc. Reduced stocks or inventory allied with JIT for example, mean that minor breakdowns are much more likely to impede or slow down production. Thus JIT requires high equipment availability, which means equipment must be ready to operate or perform when production demand is made and not break down during operation cycle (Wireman, 1990). Furthermore, the growth of mechanization and automation indicate that reliability and availability have become key issues in industries as well as other sectors as diverse as healthcare, electric-power generation stations, etc. requires preventive maintenance because the more automated the equipment, the more component that could fail and cause the entire piece of equipment to be taken out of service (Eti et al. 2006).

Maintenance perception and practice has also been significantly affected by culture in DCs, which according to the world of maintenance embraces culture (i.e. symbiosis of inherited ideas, skills and knowledge etc.), some appears quite simple and others complicated. For modern day technologies, learning maintenance takes more time than putting them into practice. Thus, their implementation in most DCs entails a certain level of literacy, a general skill of the personnel or workforce. In most DCs, it is a reality of life that maintenance education and training is hardly ever appreciated. The author further stressed that the cultural values of many DCs are often at peculiar with the values required to establish, operate and sustain maintenance organization and practices. Cultural values need to be addressed on a broad front because developing a successful maintenance system entail considerably more than providing instruction in suitable practice.

While cultural values are extensively fundamental for maintenance culture development, the valuable power of economic stimulus should also not be undervalue. The issue of cultural values tends to be very subtle, and thus, building an approach or attitude that support better maintenance practice cannot suddenly be accomplished (Gasskov, 1992).

1.2. Problem discussion
Effective maintenance ensures proper functioning of equipment so as to continue fulfilling the purpose or been capable of doing what it was designed for when required (Eti et al. 2004). Its performance characteristics and functionality do not only take account of output, unit cost and
effective use of energy, but also factors such as quality of end product, process control, employee comfort and protection, as well as compliance with environmental protection regulations (Eti et al. 2006). Business profitability is nevertheless extensively affected by the quality of maintenance practice, thus safety and customer service are factors involves, not just machine availability and cost. However, with the availability of machine becoming critical, issues such as reducing operating cost as well as strategic importance of employing better and, if practicable, optimal maintenance schedules need to be more recognized and implemented across the world (Moubray, 1995).

A developing world needs to adapt to change and advance inventiveness in order to be able to exploit the benefit of change and resourcefulness, consequently in the pursuit of continuous improvement (i.e. energy reduction, greater availability and improved reliability, and higher service performance), adopting and employing maintenance culture is indispensable for contemporary organizations (Eti et al. 2006). Unfortunately for industries or firms in developing countries (DCs), effective maintenance is usually not a high priority and the consequent cost of failure as a percentage of total cost is on the rise. The lack of proper maintenance has become one of the most difficult issues that DCs have been facing over the years and the result is seen on the face of most DCs (such as housing, industries, public infrastructure etc.) all wear off or become a public hazard (Gasskov, 1992).

Today businesses need innovation so as to sustain its competitive advantage, break the inherent moulds of perception and redundant patterns of behavior, thus, organization should be changing from a repair-focused to a reliability-focused culture. According to Eti et al. (2006) several studies of a wide range of industries in developing countries like Nigeria, shows that indigenous low availability and low productivity are prevalent due of lack of proper maintenance culture whereby many organizations see maintenance as cost centre rather than a business centre. The resulting closure of some of these industries has triggered off a realization of the strategic challenge in maintenance strategy and management. More also, the contemporary increasingly competitive business environment in Nigeria has raised the strategic importance of maintenance functions, particularly in organization with significant investment in physical assets.
The need for proper maintenance is not just a matter of concern in DCs; maintenance significance was revived during the 60s in industrialized countries due to the increase in capital intensity. Ever since, maintenance has received a lot of attention and new techniques and practice/ application have been developed. As a result, the opinion that “Maintenance only cost money when it is not performed” is shared by managers and maintenance personnel (UNIDO, 1986). But even with growing impact of maintenance in company’s productivity and profitability, most managers in developing countries still see maintenance from a myopic view, because it is considered as a costly practice and has no impact on business or product. In addition most senior managers have fail to attain the proper maintenance culture, thus do not have relevant knowledge and maintenance experience and lack foresight with regards to long-term planning.

1.3. Problem presentation
The consequences of industries paying little or no attention to maintenance in developing countries has made plants to be often underutilized and run at high costs. Statistics have shown that many industries in developing countries (e.g. Nigeria, where the focus of this paper is based upon) operate productively for less than 50% of the even supposedly functioning hour per year, which part of this is mainly caused by excessive downtime, supply failure for input resources and low spare capacity to cope with unexpected high demands.

1.4. Problem formulation
- How can the perception of maintenance in developing countries be enhanced?

1.5. Purpose
The objective of this thesis is to theoretically show how maintenance perception in developing countries can be enhanced. Thus, this study focuses on training policy as a method aimed at enhancing maintenance perception and culture in developing countries. This will facilitate the change in/ needed maintenance culture which has been adopted in most developing countries.
1.6. Relevance

Though many companies are now beginning to be aware of maintenance and the significant role it plays in achieving organizational objectives, but even with this awareness, accurate perception about the concept is still needed to fully exploit the advantages associated with it. Maintenance capabilities is been regard as an important development factors particularly in developing countries (DCs), thus, lack of maintenance is one of the reasons (if not the main reason) why most companies in DCs has failed to attain its prospective capability. In today’s business, it is obvious that customers are the centre of any business; therefore, availability and reliability of plant is one of the fundamental solutions to sustain production capacity, product quality, prompt service and other factors threatening the security of companies to stay in business.

1.7. Limitations

Certain restriction which could influence the result of the study is outlined, hence readers should be informed. This thesis objective is to primarily outline the significance of maintenance knowledge and the setback of maintenance insufficiency in DCs. Nevertheless, this study could be even broader and more comprehensive but due to the limited time frame (which I can say is the main limitation when carrying out this research) this study will therefore be limited to the maintenance issues of the case company, Power Holding Company of Nigeria (PHCN). The economic importance of maintenance will not be discussed in this study due to lack of economic data from the case company, thus, it will focus on maintenance culture and practice adopted by the case company.

1.8. Time frame

Table 1.1 shows the time frame of this thesis work has been developed with regards to the limited time assigned to this work so as to be able to meet up with the submission dates.
1.9. Structure of the thesis

This section gives the reader a concise insight about the entire thesis work. It starts with the introduction chapter (Chapter I) which introduces the reader to the paper and what to expect in the study. It also highlights the reason why this study has been embarked upon. A main constituent of the section cites the problem formulation/ research question so as to facilitate the writer’s perspective and the reader’s comprehension.

Furthermore, introduction to the other chapters are described at the top of each chapters, so as to inform the readers of what to expect in the chapter.
2. Methodology

This chapter emphasizes on the research methodology that influences the research work. It specifically addresses the scientific approach, data collection method and the writer’s perspective on the thesis. Furthermore the methods chosen for conducting this study and why it was chosen is presented.

2.1. Scientific approach

There exist different scientific perspectives or approaches that can influence a researcher work, yet no comprehensible consensus on their precise scope and application. Patel et al. (2003) mentioned for example Positivism and hermeneutics approaches.

2.2. Positivism

Positivism is said to have originated from natural science and aims to create a uniform branch of science of which has a goal to formulating laws on physical phenomenon. (Patel et al. 2003) argues that positivists attempt to find conventionality to law not just for physical phenomenon but also for social phenomenon. Hartman (2004), then states that positivistic way of gaining knowledge about reality is observing reality through experiment. Another introductory thought is that positivists’ perspective endeavors to absolute knowledge, i.e. the researcher remain entirely objective and that his/her religious or political view should not be an influence when conducting observation (Patel et al. 2003).

2.3. Hermeneutics

Hermeneutics originated from Greece, meaning more or less general doctrine of interpretation. According to (Patel et al. 2003) the perspective rejects the science ideal of research; instead the hermeneutics perspective is about interpretation of meanings. (Patel et al. 2003) further stress that memories, experience and comprehension are used for interpreting a text in addition to an event and this perspective pursues interpretations that are of comprehensive kind. Hermeneutics researchers desire to get a holistic view of the research problem and thus he is allowed to be subjective, concerned and devoted. Pre-understanding, knowledge and thoughts within the research are seen as valuable assets that help him in interpreting and understanding conditions (Patel et al. 2003).
Pre-understanding

This is a necessary provision for an individual to understand something, individual pre-understanding gives direction to a research. Every individual have a pre-conditioned perception of reality. Hence, in my opinion, I believe that knowledge and pre-understanding cannot be disregarded, thus it is not possible to remain severely unbiased. The theory of hermeneutics shows that interpretation and understanding of situations can be formed by simply studying human nature, language, and actions (Patel et al. 2003).

2.4. Research approach

There are different approaches a researcher can utilize in relating theories to empirical data. A study can start from an already existing theory, from which assumptions are made. The hypothesis is therefore tested against the empirics, thus the empirical data or findings depend on the already existing theory. Such research approach is known as “The deductive approach”. Quantitative research methods often originate from the deduction approach (Patel et al. 2003).

Another approach to drawing general conclusions is to start from the research object without any theoretical anchorage. The empirical data are gathered and then used in structuring the theories. This approach is known as “The inductive approach” (Patel et al. 2003). Furthermore, (Patel et al. 2003) explains that when a researcher works inductively, he or she can study the research entity without first connecting it to an identified theory. The theory can however be formulated from the collected data or information.

*Abductive approach* is another method of drawing conclusion, which combines both the induction and deduction approaches. According to Sauder et al. (2007) the first step to this approach is to prepare the theoretical background inductively, which then clarifies and explain the case. The next step is to test the new theory on other case, however this method cannot be used schematically, but demands experience about the area of apprehension as well as experience on similar cases.
2.5. Data collection

Data Collection is the first step when planning and implementing a study. This is due to the fact that when data collection is incomplete or superficial, there is bound to be difficulties in analyzing the data thereby leading to bad or poor quality of the intended research Yin (2002). Hence, more emphasis should be laid on all possible effort in developing appropriate data collecting tools and/or techniques. Mainly, there are two methods for collecting data (Qualitative and Quantitative) depending on the type of study or nature of study.

**Qualitative method** is used in collecting data that are not numerical, such as interview, observation etc. and could be expressed in words or action as the case may be.

**Quantitative method** is a systematic research approach that aims to find quantitative properties and their relationship. It is used in collecting or analyzing numeric data, for example statistic and graphs.

Yin (2002) expressed that the preparation for data collection can be very complex and difficult if it is not properly done, and thus jeopardizing the entire case study investigation, as well as the early work done with respect to defining research question definition and case study design. According to Wallen (1996) data collection can be seen as a means whereby different characteristics are identified, and the number of object of study with a certain characteristics are counted.

Data collection technique allows information about the object of study (e.g. people object etc) and their way of occurrence to be collected or gathered systematically. When collecting data, a systematic approach has to be adopted in other to be able to perform the required analysis. Hence it will be difficult to answer the research question in a comprehensive and conclusive way if the data are collected in a disapproving manner. Yin (2002) proposes six techniques for collecting data in a case study; they are direct observation, interview, documentation, participant observation and archival records.

2.6. Result evaluation

Validity, reliability and generalization are set of logical test that can be used in judging the quality of research result, which makes sure that a research is well balanced regarding to how
it is structured, how the data is collected, interpreted, as well as how generalization is derived. Some criteria, such as data dependability, consistency, and sincerity are used for making this judgment. Victor, (2006) states that researches are evaluated against these mentioned parameters so that the intended audience for the study can be addressed, and thus result achieved.

2.6.1. Validity

Validity measures the extent to which result can be generalized. According to Victor, (2006), this is the extent to which a variable accurately measures the theoretical concept it really puts to measure or what it was intended to measure. Henrichsen et al. (1997) argues that the validity of both the methods and design of a research should be checked as an indication of how well a research is prearranged. Hence, securing research legitimacy, all possible factors that might hinder the research validity should be taken be put into consideration. Research validity can be divided into internal and external validity.

**Internal validity** - this shows whether the result of the study is in accordance with reality, it is the aspect of the research that can be affected by error within the study itself. Yin (2002) establishes a fundamental connection between the conditions where certain conditions are shown to lead to other conditions. This test however, is mainly applicable for the explanatory (a study that indicates the way certain event is explained) or casual studies and not descriptive or exploratory (study conducted as a result of a problem not clearly defined) studies. Ghauri et al. (2005) argues that internal validity may well measure the extent where researchers can presume that there are casual relationships existing between two or more conditions.

**External validity** - according to Collins & Hussey (2003), it refers to whether the research result is generalized beyond the immediate case study. It measures the extent to which a research from a particular study can be generalized to other studies or context (Yin, 2002).

2.6.2. Reliability

Reliability, according to Grinnell et al. (1990) refers to the consistency or authenticity in result of measuring or analyzing tools, as well as the propensity of a measurement to produce the same result when same entity is measured twice. The aim of this test is to reduce or
preferably eliminate error and partiality in a study, and reliability can be improved by keeping procedures as simple as possible while keeping notes on procedures (Yin, 1994).

2.6.3. Generalization of results

According to Bloor et al. (2006) generalization is the extent to which the finding of research study is applicable to other settings, and making more widely applicable proposition. A research that can be regarded as generalize is one whose result and implications is capable of being brought into general use. Saunders et al. (2007) further states that generalization is sometimes interconnected to external validity where hypothesis and outcome can be generalized. The difference between them is that external validity is associated with the analysis and explanation of theory application to similar event, whereas generalization is associated with the theory usefulness outside its limitations and boundaries.

2.7. Thesis research method

The research method used in this thesis is presented in this section, and shows clearly how this thesis has been constructed. This thesis work started by literature survey within textbooks, scientific journals and articles that are relevant to the study. A qualitative method has been adopted in accomplishing this study because the research was conducted based on case company to understand problem and requirement, thus it covers a quite small study area. And also a qualitative method was used in collecting required empirical data from the case company in form of interview and questionnaire via email and telephone.

Fundamentally, a positivistic approach will be adopted, thus I endeavor to be objective because of the nature of the thesis. However, hermeneutic perspective will also be an influence because it cannot be avoided that this research is going to be affected by personal values and interpretations.

Abductive approach will also be used; abductive research combines both inductive and deductive approaches. Firstly, the deduction approach will be used with regard the literature study and the generalization of the theoretical framework, thereafter the induction approach will be used for the framework verification at the case company.
With regards to this thesis work, my pre-understanding is based on experience and observation while studying in the department of Terotechnology (Systemekonomi) and study visits to various companies during my study of maintenance and maintenance related courses. More also, the society, environment and the five senses thus referring to Nyström (2001) which states that pre-understanding affects how researchers collects and analyze the data, as well as generating the conclusions.

To test the validity and reliability of this study a set of questionnaire was handed to the maintenance personnel at the case company, the same set of questionnaire used on study tour to company during maintenance related courses. This will be used to evaluate the quality of this study.

### 2.8. Classification of study

The nature of this study is primarily qualitative nature, because qualitative research is known to focus on soft data (i.e. interview) while quantitative research entails measurement and statistical process (Patel et al. 2003). This study can be considered as qualitative, because referring yet again to (Patel et al. 2003)’s statement that the concept of qualitative and quantitative researches refers to the way in which data is been generated, processed and analyzed. Consequently, it is not just about how data is actually collected but how it is been interpreted also.

### 2.9. Starting point of this thesis

Having taken some courses on maintenance and maintenance related issues, and some study visit to manufacturing companies during these courses, it gave me an insight on the concept of maintenance and the effect it has on organizational performance. In addition, in Nigeria, most industries or companies operate productivity for less than 50% of even the supposedly functioning hour (Eti et al. 2004). This according to studies is mainly caused by excessive downtime, supply failure for input resources and low spare capacity to cope with unexpected high demand, because maintenance is given a very low priority (Eti et al. 2004). Hence maintenance knowledge is often questionable.
Based on this issue, a preliminary idea of maintenance knowledge was drawn, which I have attempted in the course of this thesis to build upon. Furthermore informal conversation was carried out with personnel in the area of maintenance to ascertain if I am on the precise path to constructing the theoretical framework as well as framing the research question. Thus, this dissertation starts in the empirics and was an increasing process of gathering empirics and explaining theories in correspondence. As a result of this, I reflect on this study to be neither strictly inductive nor deductive, but adduction which is the combination of both inductive and deductive approach because it all started from the empirics.

2.10. Summary

The summary of the methods and techniques that has been used in the design of this thesis is presented below

<table>
<thead>
<tr>
<th>Scientific approach</th>
<th>Research approach</th>
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<tr>
<td>*Positivistic</td>
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<th>Case study design</th>
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*Fig. 2.1 - Summary of research methods used*
3. Theoretical framework

This chapter shows the theoretical framework which highlights the theories used in structuring the research in maintenance perception that is pertinent to this study. It discusses several definition of maintenance, maintenance types, various approaches to maintenance etc.

3.1. Fundamentals of maintenance

Through the last decades, there has been considerably development of techniques for assessing plant reliability or dependability and life circle costs, which more or less can influence the choice of plant. Nevertheless, there is another factor that affects life cycle profitability which is of growing importance; this is known as maintenance (Kelly, 1984). Consequently, to fully comprehend the concept, it is necessary to have clear definitions of this holistic discipline.

“Maintenance is the 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 13306: 2001)

Duffuaa et al. (1999) describe maintenance as the combination of activities by which equipment or a system is kept in, or restored to, a state in which it can perform its designated functions. An important factor in product quality and can be used as strategy for successful competition. Hence, in producing high level quality, production plant/equipment must operate within specifications that are attainable by timely maintenance actions.

The importance of proper maintenance has changed significantly in recent time, as a result of large increase in the number and variety of plant and equipment which in one way or the other needs to maintain throughout the life span. New maintenance technique/approach and modern view on maintenance organization has evolved (Moubray, 2002). The development of expensive, complex and highly-developed equipment, and machinery which led to the need to achieve higher product quality, longer machine life, higher machinery effectiveness and operational safety, has motivated the effort to improve maintenance concepts (Al-Najjar et al. 2001).
Maintenance is thus vital support functions in business, particularly as increasingly large investment are being required in physical assets Tsang et al. (2000). Maintenance in industries according to Komonen (2002) has two essential objectives, i.e. **High availability of production equipment and Low maintenance costs**.

These above stated objectives and other indirect impact of maintenance on the economic performance of organizations have been clearly established (Mobley 2004).

### 3.2. Maintenance concepts

There are different types of maintenance approach depending on the condition and application. Alsyouf (2004) describes maintenance concept as the general structure that governs the types maintenance actions (corrective, preventive, condition based etc) to be performed. For example, maintenance operations are basically divided in two main groups; Corrective maintenance and Preventive maintenance (which includes condition-based and scheduled maintenance).

![Maintenance classification](EN13306: 2001)
3.2.1. Corrective Maintenance (CM)/ Breakdown Maintenance (BDM)

Corrective maintenance or breakdown maintenance is the kind of maintenance carried out after a failure has occurred, and it is intended to restore an item to a state in which it can perform its required function (EN 13306: 2001). According to Chiang et al (2001), corrective maintenance may consist of maintenance activity which includes repair, restoration or replacement of component that has undergone failure or that has totally broken down. The challenge as explained by Mobley (2002) is to detect problems that are beginning to develop, before they lead to total failure and to correct the faults at the lowest possible cost. One of the advantages of adopting corrective maintenance is that the machines are not over maintained and machine condition is not monitored. However, its disadvantages lies in the increase of production down time, overtime labor, high cost of spare parts as well as risk of secondary failures.

3.2.2. Preventive Maintenance (PM)

The European Standard (EN 13306: 2001) defined preventive maintenance as the maintenance carried out at predetermined intervals or according to the prescribed criteria and intended to reduce the probability of failure or degradation of the functioning of an item. According to Wireman (1990) preventive maintenance is any planned maintenance activity designed to improve equipment life and avoid any unplanned/ unscheduled maintenance activities. It is a systematic approach to a regular inspection carried out at a pre-determined interval or in accordance to prescribed criterion, intended to reduce of preferably eliminate probability of failure or performance of degradation of an item/equipment.

The aim of preventive maintenance is to reduce the number of failures and their financial expenditure by performing maintenance at a predetermined point of times without considering the component/ equipment condition. PM involves inspection, testing, repairing and replacement of equipment before failure occurs, and is in most cases applied to complex system in order to avoid operational failure especially when the failures consequences are critical, with regards to environment, economy or safety (Alsyouf, 2004; Isermann, 1997).
3.2.3. Condition-based Maintenance (CBM)
Condition-based maintenance according to *BS 3811:1993* is the kind of maintenance that is carried out according to the need which is been indicated by the condition monitoring.

CBM strategy is one which is based on deterministic and probabilistic models. It takes predictive maintenance one step further by performing the inspection in a “real-time” mode. Data about the failure behavior of the system are obtainable through suitable condition monitoring (CM) parameters which provides information concerning the real state of the systems. Vibration monitoring, shock pulse measurement (SPM), oil and debris monitoring and electrical current are few of several existing condition monitoring techniques that may well be used in a user-friendly way to select the most cost-effective maintenance policy (Alsyouf, 2004; Wireman, 1990).

3.3. Performance measurement
*Komonen (2002)* stress the need for the measurement of maintenance performance in order to show the impact of maintenance as a function on company’s overall goals. Performance measurement of machine/equipment performance would enable top management to visualize maintenance function impact on company’s business (*Sherwin 2000*).

Performance of machine/equipment is measured with regards to clearly defined company’s objective. The generally classified maintenance indicator measures equipment performance, as such it availability, reliability and overall equipment effectiveness (OEE) (*Eti et al 2006, cited in Campbell 1995*). Overall Equipment Effectiveness is a benchmark used in world-class maintenance programs, and measures equipment performance which goes beyond just availability or machine uptime (*Morbley 2002*). OEE formula looks at equipment availability, performance rate and quality rate which permit all departments to be involved in determining equipment effectiveness. It is expressed as;

\[
(OEE = \text{Availability} \times \text{Performance rate} \times \text{Quality rate})
\]
3.4. Maintenance management

In general, the goal of any organization is to increase profitability by providing quality products, prompt or complete service as well as swift delivery. In today’s competitive business, been successful often entail how well a company is able to make change and adapt to those changes swiftly. This can be seen as a way/technique of dealing with out-fashioned or out-of-date managerial approach and other forms of managerial practices.

According to (Wireman 1990) Maintenance as a support function together with asset management can be a driving force in this regards in two major ways, i.e. by decreasing the cost of running plant and machine while also increasing capability. Hence, with the growth of mechanization and automation, which mean that component could fail at any given time leading to interrupted operations, availability and reliability becomes a keyword. Al-Najjar (2007) expressed that company should be able to utilize its valuable and rare resources efficiently and effectively to attain the long-term high profitability, regardless of which prospective, outside-in (i.e. external factors, such as emerging of companies, partnership and market structure) and inside-out (i.e. internal factors, such as company’s resources, competence and differentiation) that is adopted or implemented by the company’s management. In addition, the negligence of maintenance and its role in production processes allows swift degradation of machine and its resultant product quality.

3.5. Culture

Culture is said to be the way a group of people live their lives. The dictionary defined culture as total inherited thoughts, values, knowledge and beliefs, which represent the communal foundation for social action. It is an integrated pattern of human deeds (thought, speech, action etc.) and communication. Thus a successful business, organization or developing environment should reflect the way people live.

3.5.1. Organizational culture

Organizational culture is a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration that has worked well enough to be considered valid and therefore, to be taught to new members as a correct way to perceive, think and feel in relation to those problems. The significance of cultural approach to maintenance activities is that it allows a general view of the social dynamics in a complex and
diverse domain Schein (1985). An organization can influence by positive or negative reward the behavioral actions and values of its members individually, while also the organization itself is constrained by those same individuals (Krell 2000).

3.5.2. Maintenance culture

According to Eti et al (2006) culture tends to mature (occasionally in unwanted way) as the external environment evolves. Such desirable environmental changes have included the information technology revolution, rapid technological breakthrough, lowering cultural barrier or difficulty to communication as well as rising communal values. In addition, organization should be devoted to building a supportive cultural environment (in addition to growth, responsibility, and undeniably vision) also taking into account employees as individuals (rather than just general workers) are essential requirements for achieving optimistic organizational culture and of course high quality maintenance.

From a maintenance perspective, the most significant influence on the culture of maintenance is the top management, and thus should be able to create and maintain an internal environment in which the employees can become completely involved in achieving organizational objectives. For a successful and sustainable maintenance program, development and proficiency building of top managers are decisive. It is coherent to provide an environment and a culture that add to employee’s well being, rather than exhausting their satisfaction Eti et al (2006).

3.6. Maintenance organization

Maintenance organization according to Kelly (1984) may take an immeasurable number of forms, the best for a particular situation being determined by systematic consideration of factors as maintenance work load and its pattern, cost of unavailability, location of plant, amount of emergency work, production organization and maintenance resources. Kelly (1984) further stated that in many cases the problem is one of achieving the optimum balance between plant availability and maintenance resource utilization. The dominant factor in the design of a maintenance organization is unavailability cost. Maintenance organization can be considered as being made up of three essential and interconnected components i.e.
• **Resources** - personnel, spare parts and tools, of a particular size, composition, location
  and movement.

• **Administration** - a hierarchy of authority and responsibility for deciding what, when,
  and how work should be carried out.

• **Work planning and control system** - a mechanism for planning and scheduling the
  work and feeding back information which is needed if the maintenance effort is to be
  correctly directed towards its defined objective.

### 3.6.1. Maintenance organization goals

Maintenance/ production system as a whole according to *Kelly (1984)* is a continuously
evolving organism in which the maintenance organization will need continuous modification
in response to changing requirement. *Wireman (1990)* further states that properly determining
the type of maintenance organization is influenced by the goals and objectives of the
maintenance organization. The main task of a maintenance organization is to match
maintenance resources to the maintenance workload with the mission to achieve and sustain
optimum availability. The typical goal and objectives for a maintenance organization
includes;

• Maximum production or availability of the facilities at the lowest cost, highest
  quality, safety standards (by maintaining existing equipment and facility) and the
  inspection, servicing of equipment and facilities as well as installation and alteration
  of equipment.

• Identification and implementation of cost reduction in the form of finding ways to
decrease expenses associated with maintenance and operation. For example, examining
maintenance practices, certain adjustment can be made in tools, training, repair procedure
and work planning, can reduce the amount of labor or material that may be required to perform a specific job.

• Collecting necessary maintenance cost information. For example, cost that are
  associated with labor, material, tool/ equipment, contractor as well as miscellaneous
  cost.

• Optimization of maintenance resources, i.e. making the most with the resources at
  hand, which is important in maintenance because only few maintenance organizations
  has many personnel, material, or tool at their disposal. In addition, minimizing
inventory on hand is also important since maintenance spare parts account for 40% of the total maintenance budget.

3.7. Maintenance resources

Maintenance resources includes personnel (manpower), spare parts, technical data/information, test equipment/tools, funding etc. that are available or provided for the purpose of maintenance operations.

**Manpower** – according to Kelly (2006), this can possibly classified according to the technical area in which it is employed (mechanical, electrical, instrumentation, etc.), it can however be further divided according to craft (welder, electrician, etc.). Since maintenance work mostly tends to require more than one craft, the above categorization is done on the basis of the main craft content to each job.

**Spare parts** – achieving optimum balance between the cost of ordering and holding (depreciation, interest charges, rental etc.) and cost of stock out (loss of sales due to unavailability, temporary hire charges etc.) is the objectives spare parts organization should address. The main difficulty according to Kelly (2006) arises from the variety and complexity of thousands of different items (of widely varying cost, lead times and usage rate) required sustaining a typical operation.

**Testing equipment/tools** – though it is similar to the objective of spare parts organization, but the problem of control differs because tools are not in the same sense consumable. The main task however with returnable tools is the development of a system for monitoring their loan and maintaining or replacing them if necessary when returned.

**Technical data/information** – this include all document, catalogs, manuals or drawing that might facilitate maintenance work or operation. This can be categorized into training, reference, instruction, scheduling and control.
3.8. Cost-effective maintenance

According to Al-Najjar (1997) is the measure of how much of the considered maintenance policy is economically beneficial in the long run whereby two situations (before and after maintenance improvement) is compared with the use of a dimension less ratio. Generally, the improvement of a maintenance policy performance aim to reduce production cost while increasing profitability and competitiveness of the company through enhancing process availability, performance efficiency and quality rate (Al-Najjar 2007).

The author further expressed that in order to give a good account of maintenance investment, the cost-effectiveness (Ce) of the invested money and the generated improvement (as a result of the investment) can be accessed via the proportion of the difference between \( C_b \) before and that after the improvement \( (C_a) \) to the \( (C_b) \) i.e.

\[
\text{Cost-effective maintenance (Ce)} = 1 - \frac{C_a}{C_b}
\]

Where \( (C_a) \) = after improvement

\( (C_b) \) = before improvement

It can be that at the beginning, \( Ce \geq 0 \), i.e. \( (C_b \geq C_a) \) due to extra expenses incurred during or because of the learning period. However, outside this period, \( Ce \) should greater than zero, (i.e. \( C_b > C_a \)) so as to consider the improvement as cost-effective action.

3.9. Maintenance in Developing Countries

Maintenance work depends on the ability to solve problem, the core element of maintenance skills therefore is knowledge of the equipment and its mode of failure (Gasskov 1992). In most developing countries, take Nigeria for example, breakdown maintenance has continued to triumph in almost every enterprise both private and public. And effort to introduce or implement preventive maintenance has been hindered by the negative thought of the cost involved.

According to Eti et al. (2004), the misguided opinion about maintenance in Nigeria is that traditionally, management of companies regards maintenance as an expense that can easily be reduced in relation to overall business cost. It is however assumed that machine shouldn’t be
checked or inspects for future breakdown why it is still working, instead remain inactive until emergency occurs.

Theoretically, preventive maintenance has the proficient of minimizing downtime or preferably eliminating unwanted stoppages due to machine/equipment failure as well as enhancing machine availability and reliability. However, achieving these benefits entail a high level of skills commitment. Although some multinational companies in DCs (e.g. Cadbury, Guinness, Nestle etc) have a good maintenance policy and do provide vocational training program on maintenance at their own designated centers, which is often too constricted, thus not addressing the most important components of maintenance (maintenance organization and spare parts management). In addition, because of the constriction of the said vocational training, there is less significant effect on the long run, since maintenance has become an element of the economy growth in most DCs (Gasskov 1992).
4. Empirical findings

This chapter shows the empirical findings, it describe and explain the empirical data/information of the case company (Power Holding Company of Nigeria).

4.1. Presentation of Power Holding Company of Nigeria (PHCN)

National Electric Power Authority (NEPA) as it was formally called is an organization that is responsible for electricity production, transmission and distribution in Nigeria, (West Africa). NEPA was renamed Power Holding Company of Nigeria (PHCN) as part of the privatization process of electricity generation and distribution in the country in April, 2005.

The history of Nigeria power sector dated back to the early 60s, Niger Dam Authorities (NDA) and Electric Corporation (EC) merged to form the Electricity Corporation of Nigeria (ECN). Immediately after the Nigerian civil war in 1968, the management of ECN changed its nomenclature to National Electric Power Authority (NEPA) in1972 which is now currently called the Power Holding Company of Nigeria (PHCN).

4.2. PHCN Installations and Operations overview

PHCN as it is now called has approximately 6000 Mega Watts (MW) of installed generation capacity, its national infrastructure consists of nine generating power station (3 hydro-based stations and 6 thermal power plants) located in different part of the country. The transmission network consist or made up of 5000km of 330KV and 6000km of 132KV lines, 23 of 330/132KV sub-stations and 91 of 132/33KV substations. The distribution sector comprises of 23,753km of 33kv lines, 19,226km of 11kv lines, 679 of 33/11kv sub-station. In addition, there are also 1790 distribution transformer and 680 injection substations. However, the maximum available capacity is limited to 3300MW.

The transmission system is unable to deliver electric power to a major part of the country (as a result of insufficient maintenance practice) and thus it is undependable because it does not have an adequate capacity and backup lines. Nigeria’s power sector has high energy losses of (30-35 %) a low collection rate of (75 – 80%) and a low access to electricity by Nigerian population of 36%. Currently, only 10 percent of the rural household and approximately 40
percent of Nigeria’s total population have access to electricity. PHCN however hopes to increase access to electricity throughout the country to 85% by the year 2010, thus it has been estimated that this development would require 16 new power plants, approximately 15000km of transmission lines, as well as distribution facilities. Though there is approximately 6000 MW of installed generating capacity in the existing power stations, the maximum load or capacity that has ever been attained was between 3300MW to 4000MW back in 1992. This has since depreciated to less than 3000 MW thus reflecting the maintenance culture that has been practiced by the country right from independence back in 1960, and the inefficiency and corruption of the public function provider.

Presently, most of the company generating units in the country has broken down due to limited available resources to carry out the needed level of maintenance. The transmission line are radial and overloaded, switchgears are obsolete while power transformers have not been maintained for a long time. The maintenance policy that has been adopted by PHCN is the corrective or breakdown maintenance but it is often not performed in the right manner or carried out according to the accepted standard and sometimes not carried out at the stipulated time.

<table>
<thead>
<tr>
<th>Population</th>
<th>Approximately 150 Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Mass</td>
<td>Approximately 923,770 km²</td>
</tr>
<tr>
<td>Installed Electricity generation capacity</td>
<td>6000 Mega Watts</td>
</tr>
<tr>
<td>Peak National Demand</td>
<td>Approximately 30,000 Mega Watts</td>
</tr>
<tr>
<td>Maximum available capacity</td>
<td>Btw. 3300MW to 4000MW Mega Watts</td>
</tr>
<tr>
<td>Short Fall</td>
<td>Approximately 25,000 Mega Watts</td>
</tr>
</tbody>
</table>

*Table 4.1 - Statistics of electricity distribution in Nigeria*

4.3. Cultural belief

According to most Nigerians, NEPA or PHCN is synonymous to darkness. Thus it is common for Nigerians to shout “N-E-P-A” whenever the power goes off or comes back, this is because of the unstable power condition in the country. It is a saying in Nigeria that NEPA stands for
“Never Expect Power Always” in lieu of its proper title (National Electric Power Authority). Shortly after the name was changed to Power Holding Company of Nigeria (PHCN) a new slogan for the company (PHCN) was made up; which is “Please Hold Candles in Nigeria” as evidence of its inability to supply stable electricity in the country. Despite the consistent perceived money that has been invested by the federal Government for several years, power outages have been the standard for the populace due to existing belief and perception about maintenance, and have excessively limit the impact.

4.4. Maintenance culture
The maintenance culture that has been adopted by the country (Nigeria) since her independence in 1960s has effectively influences the way PHCN perceived its maintenance activities. Breakdown maintenance or repair has continued to prevail at the company whereby machine/ equipment are used until it can no longer perform its intended functions. In addition, PHCN pays minimal attention to its maintenance plan, and the low social status of technical knowledge about maintenance among the top management has resulted in power deterioration in most of its generating and distribution plant.

4.5. Maintenance organizational structure
PHCN maintenance organization has the responsibility of ensuring that adequate power supply is achieved in the country. Thus, achieving sufficient power supply, equipment needs to be given the appropriate maintenance needed for the equipment to function properly.

The maintenance organization structure comprises of the maintenance manger ( overseer of all maintenance functions) and maintenance engineers as well as supervisors of the respective fields. The supervisors report to the maintenance personnel responsible in their respective field. The maintenance engineers and the maintenance planner all reports to the maintenance manager, who then ensure that maintenance work are carried out accordingly and ensure proper coordination between the groups. The maintenance manager establishes maintenance goals (i.e. ensuring the reliability and availability of machines/equipments to ensure uninterrupted power supply, minimize breakdowns and prolong the operational life of the machines) safety of personnel, and hold engineers and maintenance personnel responsible for performance in their areas of responsibility (see structure below in figure 4.1).
4.6. Maintenance planning

Maintenance works at the PHCN are high during the raining season due to the weather conditions. There are two seasons in Africa (i.e. raining and dry seasons). Distribution transformers, fuse, electric pole etc are often affected during the raining season due to storm and strong wind which frequently prompts extra maintenance/repair works. The organization do not performed any scheduled/planned maintenance, rather maintenance/repair work are carried out whenever a fault/failure or breakdown of some units or systems in generating station, distribution transformers or electric poles and cables has been reported. As every other organization, PHCN maintenance goals are aligned with the organization goals to minimize outages by the year end 2010.

When a fault or a repetitive breakdown failure occurs in the generating plants, the supervisors are the first to notice this or be informed by the technicians. Test is carried out to ascertain the cause and extent of the failure and what needs to be done. If the maintenance/repair work is an emergency (i.e. which can directly result to loss of significant unit’s capacity, injury or life threatening incident) or not. In the case of outages, the engineers goes directly to the site/location to investigate the problem, the cause and possible effect it might have with other sub-systems, the general public or the environment. When the extent and cause of the failure is known, the maintenance planner is informed so as to prepare the work order for the repair with respect time and date, and also the amount of resources available for the job.
Before any maintenance work is carried out, the maintenance manager oversees the whole operations of the maintenance process by ensuring high standards for performing maintenance activities and also ensuring consistent adherence to the set standards. While the maintenance planner have completed the necessary planning and schedule on when the maintenance work should commence the extent of the work to be carried out together with the resources available, the maintenance organization then provides the resources required to carry out the maintenance work.

4.7. Maintenance resources

Manpower, electrical and mechanical facilities (as well as funding) are the most notable resources that PHCN currently have at their disposal. Before the beginning of democracy in May 1999, the organization has been financially backed (with about 20 billion naira per annum) by the government. In addition, its internal revenue generated annually, has been estimated to be about 25 billion naira. It also boasts staff strength of about 38,000 employees in all its stations throughout the country. Nonetheless, it has been unable to convert its resources and the benefit of its huge investment to establish and maintain a reliable electricity supply to its customers/ the country at large.

When there is major repair to be carried out, often there is production downtime and electricity transmission is shut down (before the spare parts are ordered from overseas in most cases) due to lack of the required spare parts to carry out the repair. This is the inability of the spare parts organization to attain optimum balance between the cost of ordering and holding and cost of stock out. And because most machines/ equipments are likely to be used past their projected life span, it often becomes difficult to obtain spare parts. More also, majority of the production and maintenance personnel have little knowledge about modern machine, as such often have difficulty reading maintenance guides, manuals etc. to facilitate effective maintenance work/ operations.

4.8. Employee competence

Employees at PHCN have little knowledge about modern day technology/ equipments used in complex industry as power industry. As the technological environment continues to observe changes, machines/ equipments are becoming complex and complicated, better diagnostic
skills is required of engineers and craftsmen in order to carry out analytic studies on equipments and perform the required maintenance activities when the need arises. The use of expatriates is often employed when there is massive maintenance work at the organization (due to the employees not having the required proficiency to carry out visibility studies and data analysis) because maintenance activities electric power plant is a very complex activity which is characterized by many subsystems or sub-component and uncertainty in data that are available to the workers/employees.

4.9. Performance measurement

Maintenance performance measurement and the impact on production at the organization/company are presently not given a high priority just as maintenance work itself. The effect of insufficient maintenance practice has result to successive downtime, prompting the company to operate productively below 50% annually of the supposed operating hours. Shown below in Table 4.2 is a data for a normal day shift.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td>length of Shift</td>
<td>8 Hours (480 Minutes)</td>
</tr>
<tr>
<td>Stoppages</td>
<td>60 Minutes</td>
</tr>
<tr>
<td>Downtime</td>
<td>60 Minutes</td>
</tr>
<tr>
<td>Performance rate</td>
<td>0.68</td>
</tr>
<tr>
<td>Quality rate</td>
<td>0.89</td>
</tr>
</tbody>
</table>

*Table 4.2 - Shift data*

*Table 4.2 above is a typical figure of work shift in the organization. There are mainly two shifts, usually 8 working hour in each shift except on peak season (i.e. raining season). During this shift, there is about 1 hour of normal stoppages during normal working hours, as a result of managerial action or coordination, break, and minor stoppages due to change of parts, lubrication of parts needed to be lubricated etc. There is also about 1 hour when machine are stopped (downtime) to enable the machine to cool down because it has been working for a long period. The performance rate and the quality rate of electricity production and generation are 68% and 89 percent respectively.*
5. Analysis

The analysis based on the theoretical framework and the empirical findings from the case company is presented in this chapter. The present situation of the case company is used as a setting to analyze the area of focus of the study.

5.1. Maintenance culture

The significance of cultural approach to maintenance activities is allowing a broad view of the social dynamics in a complex and diverse area (see section 3.5). PHCN has over the years been unable to provide stable and efficient electricity to its customers not so because of uncertainties about the resources it currently has, but because of the maintenance culture that has been adopted. Thus, the organization has suffered ingloriously from maintenance setback. Nearly two decades since NEPA (now PHCN) first possess a peak electricity generation capacity in its history; the organization is still struggling to return its power generation capacity to the generation capacity that was earlier obtained (see section 4.2). Despite the resources it controls, the sector is unable to follow it maintenance programs and as such most of the equipment or plant units in the stations constantly not working or left unproductive for years, resulting to low power supply and sometimes shortage of power in some part of the country, which has lead to end-consumers to switch to generating equipment (power generator) as an alternative means of generating electricity.

The maintenance culture that has been adopted by the organization since its establishment has been deeply influenced by the company’s policy and work culture (which explains how maintenance and its practices have been perceived at the organization) whereby managers have an influence on the maintenance activities, thus, should be capable of creating and maintaining an environment that allows complete involvement of employees in attaining organizational objectives. At PHCN, maintenance are planned but not always implemented or carried out until it affects other components or sub-systems (thereby attracting additional or unwanted cost) or becomes public hazards. This coincides with the maintenance culture that the organization has adopted since its beginning (which hardly visualizes that a power industry should follow its maintenance program that has been designed for improved performance) with regards to availability and reliability (see section 4.4).
Even with these resurgent questions of insufficient power generation and distribution, there seems to be no sign of the management to improve the present situation at the organization. Several efforts made by the public function provider to improve availability and reliability of electric power supply are often faced with the difficulty of corporate and maintenance culture in the sector. Improving maintenance practices and attaining availability and reliability at the PHCN entails a total transformation of the culture within the organization, thus developing a dependability maintenance culture is an innovative journey.

5.2. Maintenance organization

The effectiveness of a maintenance organization can be measured by its ability to attain optimum balance between plant availability and maintenance resource utilization (Kelly 1984). Fig. 3 shows the company’s organizational structure with the relationship between them. The company’s maintenance organization has the responsibility of ensuring adequate power supply with the available resources. Kelly (1984) considers a maintenance organization to be made up of three vital and inter-related components (see section 3.6).

There is no doubt about the resources at the company’s helm and funding to finance its maintenance program as the company has received financial support on numerous occasion by the authority responsible for its finances. The supposed failure of coordination, complacency, disorderliness, lack of effective management has stalled the organization in performing its functions (see section 3.4). Resources like human, electrical and mechanical facilities have been one area of competence for the company, however, the organization inability to utilize this proficiency; together with the huge investment into establishing and maintaining dependable electricity supply has been a major concern.

The maintenance activities of the company breakdown maintenance/ repair works are mostly field work/ on-site maintenance performed on electric transformers, injection substations, connecting cables etc.) However, the company’s maintenance organization has been unable to optimize the available maintenance resources to the maintenance workload; hence the reason behind the unavailability and the inability to deliver adequate electric supply to its customers (see section 3.4). The absence of effective and efficient maintenance policy in place to guide operation and maintenance (O & M) personnel accounts for the maintenance organization
inefficiency to attain optimum balance between plant availability and maintenance resource utilization. In addition, the issue of diverse interest rather than national interest has stalled the workers from working together in achieving the organization’s maintenance goals and effective operation.

The top management of the organization whose main function is to provide leadership has done little or less to take maintenance of the plants seriously, and create an effective maintenance policy for the training of maintenance personnel. Properly determining maintenance organization is influenced by the goals and objectives of the company, and should be able to contribute to the company’s business strategy (see section 3.6.1). In the case of PHCN, it lacks essential managerial proficiency especially in the area of policy making. Top managers and engineers should have the competence to carry out feasibility studies on maintenance plan and choice of technology in order to propel the maintenance organization in performing its function to ensure availability and maintain existing equipment. Thus, with required availability and reliability, maintenance organization contribution to the overall company’s business goal will be visible. The issue of incompetence in the area of management can be resolved if top managers and engineers are properly trained in the field maintenance management and policy making.

5.3. Maintenance planning

The problem facing PHCN maintenance planning process is that maintenance supervisors and planners lack the desired skills required to plan, prioritize and perform the necessary supervision of maintenance work, as well as maintenance scheduling (with respect to maintenance activities) which includes time and project management (see section 3.4). This often led to maintenance work in the organization not carried out according to the order in which maintenance activities has been prioritize. Also most of its maintenance activities are either ignored or not carried out until other substations; components are affected as a result of the organization not following its maintenance plan thereby leading to complete failure of the whole unit (see section 4.6). This is one of the reasons behind the company’s insufficient maintenance practice.
Furthermore, the organizational ignorance of the dynamic approach to maintenance (in terms of management and coordination) that is required to operate such complex and dynamic industry has lead to the organization’s ineffective and inefficient operation regardless of its huge resources and funding. Managerial training in maintenance can address the mentioned managerial issue and provide the necessary skills and technique to manage such industry (see section 3.4).

5.4. Cultural problem affecting maintenance effectiveness in the company

The world of maintenance embraces culture, and culture has had a major effect on maintenance awareness and practice (see section 3.9). The issue of cultural differences in the company has been a major concern but little or no attention has been shown to this unrest. Humans are fundamental to safe and effective maintenance operation in any electric power plant; effective communication and improved involvement on the work are some of the prerequisite in achieving effective maintenance. The thought and belief of some employees at the company (as a result of diversity) has made it difficult working as team to ensure reliability and availability at the power plant.

The diagram above shows how culture or cultural issues has slow down the company’s effort in achieving its maintenance goals and objectives. Cultural issues like thought, belief, values etc., have been one of the main issues that has neutralize several efforts by the government and the organization to achieve maintenance excellence regardless of the huge resources at its disposal.
Cultural issues have unquestionably been a major concern in PHCN. The existing beliefs, assumption and awareness about maintenance in the organization have excessively restrained the achievement of high quality maintenance or overall effectiveness of maintenance. Managers, workers and personnel of different discipline coming together to perform certain task are often faced with the familiar problems of having to do with the establishment of acceptable but demanding intent, workforce coordination and motivation nurturing in the characters of individuals

Organizational culture is one area of managerial ignorance of maintenance operations in Nigeria electric power stations, where maintenance management still appreciate individualistic (eccentricity belief) and dictating leadership/management that has recurrently fall short to distinguish between strength, weakness, opportunities and threats. Though cultures tend to grow as the outside environment advances, such enviable environmental changes have lower cultural barriers to communication and the growing societal ethics. Corporate managers at PHCN are part of the issues affecting maintenance effectiveness, rather than catalysts for achieving solution to the problem because they are unable to comprehend the effect of change in the environment and take basic preventative actions. Achieving overall maintenance effectiveness requires more effective management and learning; these would prove to be fundamental in organizing maintenance personnel to identify and be fully involved in the prospects in attaining maintenance goals.

5.5. Maintenance impact on organizational process
One of the significant decisive factors for any investment in a company is the financial return on its fixed assets. Asset management therefore focuses on attaining the lowest total life-cycle cost to produce the required product or render the most sought-after service. Maintenance as a support function affects production cost effectiveness, and resources used in the company processes or operations (see section 3.8).

The aim of efficient maintenance in an organization is to ensure reliability safety, and cost effective operation and thus its approach has change in recent times. As illustrated in figure 5.2, by selecting and implementing a cost effective maintenance approach, optimum number
of planned stoppages and minimum numbers of failures are achieved thereby resulting to higher machine availability and performance efficiency.

![Diagram showing maintenance impact on organizational performance](image)

**Fig. 5.2 – Conceptual model showing maintenance impact on organizational performance**

Total maintenance costs depend largely on equipment quality, its usability, and maintenance and business strategy. For example, Maintenance in Nigerian electric power industry can account for about 40% of the total cost of generating or producing electric power, thus maintenance personnel in the power industry are seeking innovative response so as to maximize equipment reliability while optimizing cost effectiveness.

### 5.6. Measuring maintenance performance

To determine maintenance performance at the company, the data presented in *figure 4.2* will be analyzed with respect to the Overall Equipment Effectiveness (OEE). OEE takes into account three factors (i.e. availability, performance rate and quality rate). With performance and quality rate already known; to calculate for OEE, the availability will be calculated. Thus,

\[
\text{Availability} = \frac{\text{Operating time}}{\text{Planned production time}}
\]

To get the value for **planned production time** and **operating time**,

- Planned production time = shift length – stoppages (i.e. 480 – 60 = 420)
- Operating time = planned prod. Time – Downtime (i.e. 420 – 60 = 360)
Therefore: Availability = \( \frac{Operating \ time}{Planned \ prod. \ Time} \) (i.e. \( \frac{360}{420} = 0.86 \)) = 86%

<table>
<thead>
<tr>
<th>Availability</th>
<th>0.86</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance rate</td>
<td>0.60</td>
</tr>
<tr>
<td>Quality rate</td>
<td>0.89</td>
</tr>
</tbody>
</table>

*Table 5.1 – OEE calculation*

OEE = Availability × Performance rate × Quality rate = 0.86 × 0.60 × 0.89 = 45.9 (**45.9%**)

The result of the overall equipment effectiveness (OEE), as a product of availability, performance and quality from the data analysis above is **45.95%**. OEE calculation as the product of \((Availability*Performance \ rate*Quality \ rate)\) is a difficult assessment for organization’s in a competitive economy because of new trend in customers’ demands. The evaluation of effectiveness and efficiency, and how well it assists in achieving its assigned task should be addressed by the company. In reality, the generally acceptable world class goals for each factor of the OEE are different from each other (i.e. Availability = 90%, Performance = 95%, Quality = 99%) the product which is 85%. See (Mobley 2002).

Considering the equipment effectiveness of the company, it shows that over half of the company is not contributing to the company’s goals, which means that the equipments are not run to their full capacity (due to insufficient maintenance practice) and are equally not maintained at that same level.

The data presented in *figure 4.2* (empirical chapter) shows that downtime is presently approximately 21hrs/ week, same for other related stoppages during operations. This is evident in the company’s performance and inability to address its maintenance plans and guarantee optimum availability and reliability over the years. The number of downtime stoppages and other maintenance related stoppages can be reduced in the future to 10hrs/ week or less if maintenance awareness is perceived and is carried out effectively. For example, with effective maintenance practice, a better value for availability, performance rate and quality rate can be obtained. Thus, reflecting on the company’s performance output and attempt for continuous improvement.
6. Results

The main result from the analysis made of the empirical findings is presented in this chapter.

Based on the analysis, it is apparent that the reason behind maintenance insufficiency at that company is mainly due to lack of maintenance perception. Thus, maintenance education / training is required in order to improve maintenance perception (that will lead to better maintenance practice) at PHCN thus enhancing maintenance efficiency. The concept of the proposed maintenance training program should include policy makers and investors (although not discussed in the analysis) because the organization is a governmental own organization with different investors as part of the privatization process. The inclusion of policy makers and investors in the training program is to ensure that the culture of maintenance is perceived in both corporate and organizational level of the organization. Figure 6.1 shows a concept that has been developed for maintenance training program and the groups/ personnel it should address.

![Fig. 6.1 – Concept of maintenance training program](image-url)
An innovative concept of maintenance training that will address different personnel involved in company’s policy, maintenance decision, organization and practice is what the company should implement in order to attain its maintenance goals and objectives. The proposed maintenance training concept should concentrate on the following group or personnel at the company. This includes:

- Policy makers and investors
- Maintenance engineers and managers
- Maintenance planners and supervisors
- Technicians and crafts workers.

**Policy makers and Investors** – Power Holding Company of Nigeria is a governmental organization, and it is govern and controlled by governmental official at the top level that influences the company’s policy. In addition to this, some of the company’s investor also influences the company’s policy in one way or the other. It is often very difficult for maintenance culture to be embedded in an organization when the policy makers and investors knows little or less about the significance of maintenance, what it means to have a proper maintenance practice, costs and budgets of maintenance and spare parts standardization planning. Maintenance training on this aspect should focus on maintenance policies development at the company.

**Maintenance Managers and Engineers** – Maintenance managers and maintenance engineers are considered as the cornerstone of effective maintenance practice, therefore maintenance engineers and managers at the company should be equipped with the competence to carry out feasibility or practicability studies, maintenance plan and choice of technology, putting into consideration the continual evolvement of the world of technology. In addition, the proficiency to analyze maintenance approaches of different kind and consequently, to be able to identify the most appropriate approach to the on hand situation. For example should it be appropriate to apply corrective or preventive maintenance (or should both be suitable)? Maintenance training program in this aspect should include a wide range of standardization methods and spare parts requirement evaluation. Furthermore, familiarity with the technical documentation (as a reference material) that is required to operate and maintain modern day technology or equipment.
**Maintenance Planners and Supervisors** – It is always difficult to achieve the level of proficiency necessary for a successful maintenance planning and scheduling when the necessary training is not in place. Unfortunately maintenance planners at the company have contributed less to the company in terms of project and time management. Maintenance supervisors on the other hand need to be familiar with the job or project they are assigned to supervise. Maintenance training program here should include maintenance prioritization and reporting, technique for maintenance scheduling, maintenance and project management as well as time management should be the main focus. Having these knowledge can help in determine the success of maintenance work being performed at the company.

**Technicians and Craft workers** – Maintenance training for technician and craft workers involves apprentice/ learner’s training (i.e. giving an ordinary person the necessary training to become a skilled worker). Less knowledge about maintenance theory maybe required from technicians and craft workers but specialized knowledge in the area of machine control, repairs, lubrication techniques and vibration monitoring etc. should be guaranteed. The need for training in spare parts and technical documentation management (e.g. coding, inventory or stock control, etc.) is also a necessity.
7. Conclusion & Recommendations

The final conclusion which is the answer to the problem formulation, and recommendation are presented in this chapter.

7.1. Conclusion

The final conclusion to this study is the answering of the problem formulation.

- How can the perception of maintenance in developing countries be enhanced?

The maintenance training concept proposed in the previous chapter can help enhance maintenance perception and better maintenance practice. From the analysis, it can be concluded that lack of proper maintenance training is the reason behind poor maintenance perception in DCs. Thus, the improper practice in DCs can be seen as the level of maintenance education and training attained by maintenance personnel whose responsibility is to make decisions that will have a positive effect on the maintenance actions of their organization, set acceptable standard and also ensure that maintenance personnel adhere to those standards. Hence, with the development of maintenance training concept, the issue of improper maintenance activities can be addressed. Thus, maintenance personnel can attain the required maintenance knowledge/skills to carry out better maintenance practices.

Improving maintenance perception and practice in developing countries requires different measures; maintenance education and training is one basic measure in addressing the main question of lack of maintenance perception. The analysis shows that major developments in developing countries are associated with modern technology from developed countries and with the anticipation that these technologies will bring new innovation, production capabilities, modern proficiency and management to create better investments, employment and economic development. However, the aforementioned benefits depend on the country’s (developing countries) capabilities to maintain and ensure availability and reliability of the machines/technology.

With respect to ensuring availability and reliability of modern equipment, maintenance awareness and skills need to be spread broadly across every sector of the developing economy.
through seminar and symposium, and making sure that the benefit of maintenance is grasped as this is one way to ensure improvement in maintenance practice. The swiftness of improving the awareness of maintenance practice in developing countries depends extensively on maintenance education and training. Introducing maintenance and operation (O&M) and training programs can help address the despair of maintenance awareness in DCs. Conflict with cultural values and inappropriate attitude toward maintenance in developing countries is a delicate issue because attending to cultural unrest and creating an attitude that will be favorable to maintenance would not come easy.

7.2. Recommendations

It is recommended that the need for proper maintenance education and training program should be encouraged and taken seriously because a higher level of skills required for a complete maintenance practice can be achieved comparatively fast through appropriate training. And this can help improve maintenance awareness and the prospect of building a capability needed to meet maintenance and long term improvement goals.

In addition, to maintenance training program, it is obligatory for companies in DCs to continually take notice of changes in the internal and external environment so as to achieve a competitive advantage. In doing so, maintenance performance should also be measured with regard to clearly defined objectives. The question of how well the equipment has achieved its task and the level of effectiveness and efficiency it has attained.

It is also important that the culture of maintenance is embedded in both corporate and organizational level, and a more proactive rather than a reactive approach to maintenance task should be encouraged so as to build a maintenance culture that will increase cohesion and commitment, teamwork, knowledge and sharing etc.
8. Reference

Literatures and articles that was utilized in accomplishing this work are listed below

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